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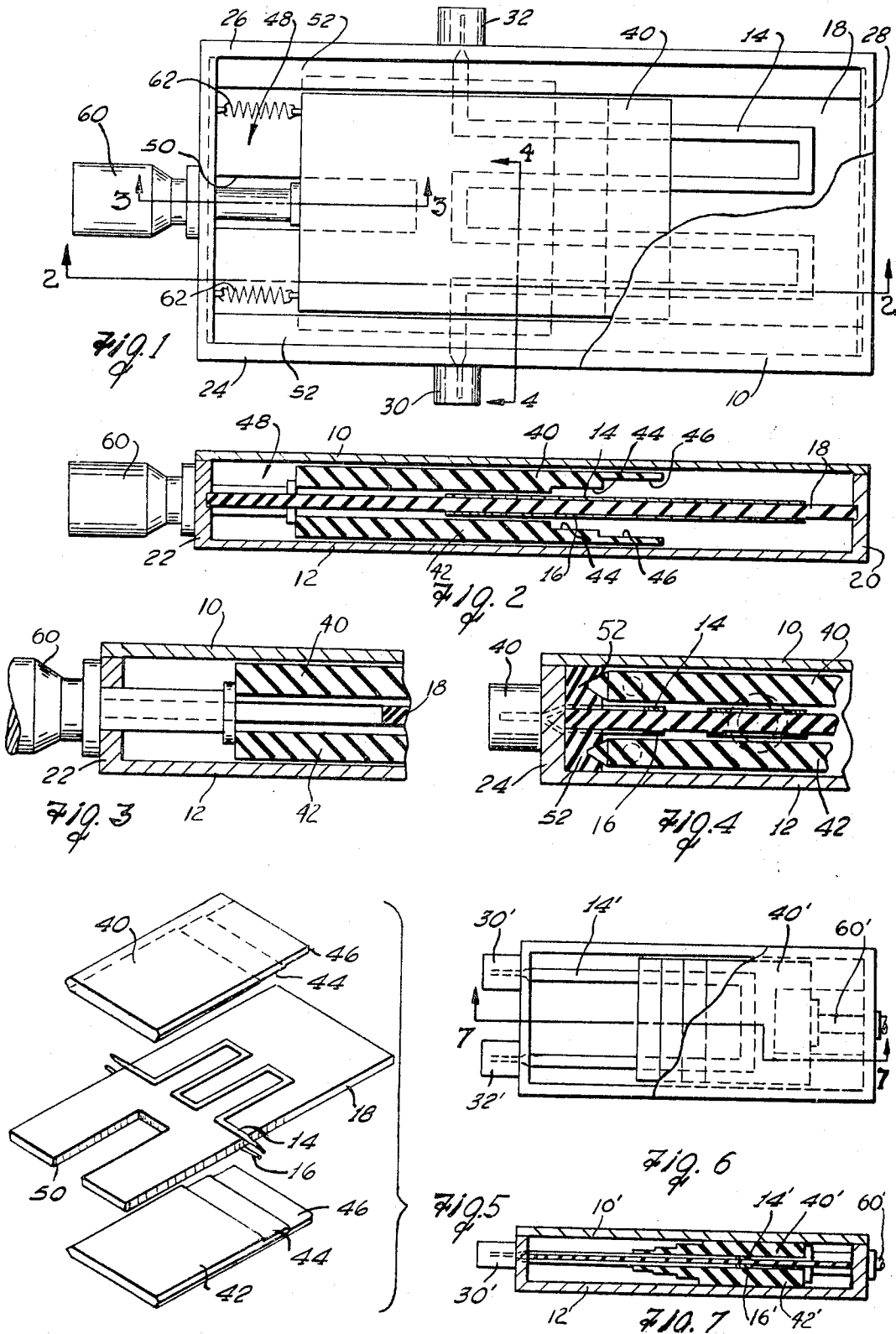
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ELECTRICAL TRANSMISSION LINE COMPONENTS

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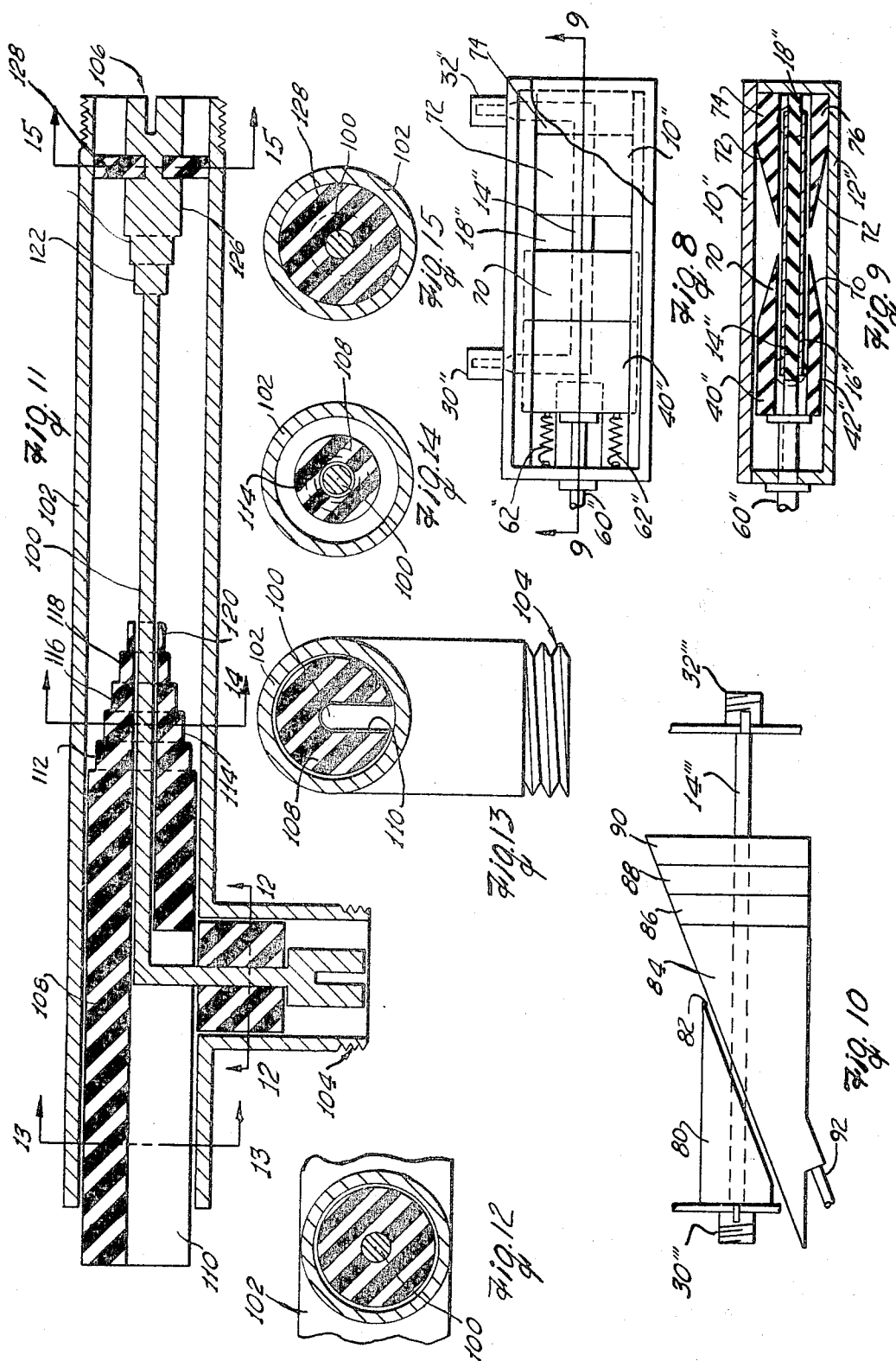
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ELECTRICAL TRANSMISSION LINE COMPONENTS

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14 Claims

ABSTRACT OF THE DISCLOSURE

A stripline phase shifter includes two ground planes and two one mil copper center conductors laminated to a dielectric support sheet. The center conductors are formed to provide four parallel sections of equal length. Two dielectric slabs, one on each side of the support sheet, each has an impedance transformer section of two stepped levels. The two dielectric slabs are slid along the center conductors by a micrometer screw to shift phase.

This invention relates to electrical transmission line components and more particularly to adjustable apparatus for varying a signal applied to an electrical transmission line.

It is frequently necessary to shift the phase of an electrical signal that is to be applied to an electrical transmission line. In electrical transmission systems which operate at microwave frequencies, such phase shifts have been accomplished generally by the use of a "trombone line stretcher" in which transmission line conductors are coupled together with sliding connections so that the actual mechanical length of the line can be varied; or by a phase shifter which utilizes a block of dielectric material supported for movement in a transverse direction relative to the transmission line between a region of relatively weak field strength and a region of relatively strong field strength, e.g., from one side of the transmission line inwardly towards the center of the transmission line. This inward motion effects a reduction in the wave length of the transmission line and, thus, a corresponding change in its electrical length, which produces a phase shift. Transverse motion of the dielectric member, however, produces a non-linear change in the electrical length of the transmission line unless the dielectric volume of the member is varied in a non-linear manner to compensate for this effect. Also, the impedance of the transmission line changes as the dielectric member is moved closer to the center of the transmission line.

Accordingly, it is an object of this invention to provide a novel and improved high-frequency electrical apparatus for varying the characteristics of an electrical signal.

Another object of the invention is to provide a novel and improved transmission line phase shifter.

A further object of the invention is to provide a novel and improved microwave phase shifter which employs fixed conductor components.

Another object of the invention is to provide a novel and improved electrical signal adjusting component operable at microwave frequencies in which the electrical signal varies linearly as a function of the mechanical adjustment motion.

Still another object of the invention is to provide a simplified phase shifter construction operable at microwave frequencies that is relatively inexpensive to manufacture.

In accordance with the invention there is provided an electrical signal adjusting apparatus which includes an

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input terminal and an output terminal. A transmission line section is connected between the two terminals, that transmission line section having a dielectric region with a first dielectric medium disposed in a first portion of the region and a solid dielectric medium disposed in a second portion of the dielectric region. An impedance transformer is formed integrally with the solid dielectric medium which provides an impedance transition between the portion of the transmission line with said solid dielectric medium and the portion of the line with the first dielectric medium. The quantity of solid dielectric material in the dielectric region is variable without introducing discontinuities in the impedance of the transmission line. For example, one portion of the line may be filled with air and another portion filled with a solid dielectric structure. The solid dielectric structure is movable in an axial direction along the transmission line, and the variation in the relative lengths of the two portions effects a change in the electrical length of the transmission line section. Such a device functions as a phase shifter in which the movement of the solid dielectric structure is linearly proportional to the actual phase shift. A second impedance transformer typically is employed which complements the first transformer. The two transformers are effectively connected in cascade so that each transformer provides a transition between a transmission line portion of standard impedance (e.g., fifty ohms) and a transmission line portion whose impedance is typically a non-standard value which is determined by the configuration of the transmission line. The ratio of the impedances of the two sections remains constant, however, as the solid dielectric structure is moved and, hence, optimum impedance transformations can be provided. The structure of the invention may employ a transmission line component which is folded to provide a plurality of parallel sections so that the rate and range of signal variation may be increased. The variation in signal delay or phase shift provided by the apparatus is a direct and linear function of the position of the movable component of the apparatus and, hence, its calibration and operation are facilitated. The invention provides a structure that is inexpensive to construct and reliable in operation. A further advantage is that the characteristic impedance of the device does not change throughout its range of adjustment and, hence, the device introduces no impedance discontinuities into the system to which it is connected.

Other objects, features, and advantages of the invention will be seen as the following description of preferred embodiments thereof progresses, in conjunction with the drawings, in which:

FIG. 1 is a plan view with portions broken away of a phase shifter device constructed in accordance with the invention;

FIG. 2 is a sectional side view, taken along the line 2—2 of FIG. 1, showing additional construction details of the phase shifter device;

FIGS. 3 and 4 are sectional views taken along the lines 3—3 and 4—4, respectively, of FIG. 1, showing further details of that device;

FIG. 5 is a perspective view of the components of the phase shifter device shown in FIG. 1;

FIG. 6 is a plan view with portions broken away of a second form of phase shifter constructed in accordance with the invention;

FIG. 7 is a sectional view, taken along the line 7—7 of the embodiment shown in FIG. 6;

FIG. 8 is a top plan view of still another form of phase shifter constructed in accordance with the invention;

FIG. 9 is a sectional view of the phase shifter shown in FIG. 8, taken along the line 9—9 of FIG. 8;

FIG. 10 is a diagrammatic view of a further form of

apparatus constructed in accordance with the invention; FIG. 11 is a sectional view of a coaxial cable configuration of phase shifter constructed in accordance with the invention; and

FIGS. 12-15 are sectional views taken along the lines 12-12, 13-13, 14-14, and 15-15, respectively, of FIG. 10.

The phase shifter structure illustrated in FIGS. 1-5 is constructed in stripline configuration and includes two ground planes 10, 12 and two center conductors 14, 16 that are superimposed in alignment on opposite sides of a dielectric support sheet 18. These conductors may be formed by conventional chemical etching techniques from one mil copper sheet that has been laminated to the dielectric support 18. The center conductors 14 and 16, as thus seen in FIGS. 1 and 5, are formed to provide four parallel sections of equal length. The ground planes 10 and 12 and the center sheet 18 are maintained in spaced relation by conventional support members 20, 22, 24, and 26.

An input transducer member, here shown as a coaxial connector 30, is connected to one pair of ends of the conductors 14 and 16, as indicated in FIGS. 1 and 4, and an output transducer member, here shown as coaxial connector 32, is connected to the other pair of ends of the two conductors.

Disposed in a first section of the transmission line on either side of the center support 18 is a slab or block 40, 42 of dielectric material, which blocks substantially completely fill the spaces between the ground planes 10, 12 and the conductors 14, 16. Each dielectric block 40, 42 has an impedance transformer section formed at one end which, as shown in FIG. 2, has two stepped levels 44, 46. This impedance transformer section provides a transition between the impedance of the transmission line in the solid dielectric region (fifty ohms) and the adjacent region which is filled with a second dielectric (air). As the line configuration in the two sections is the same, the impedance of the air-filled section is directly related to the standard impedance by the square root of the dielectric constant of the material of blocks 40, 42. For example, if the dielectric constant of the solid dielectric is four and the normalized impedance of the system is fifty ohms (that being the impedance in the solid dielectric region), the characteristic impedance of the line in the air-filled region is one hundred ohms.

The two dielectric blocks 40, 42 are mounted for sliding movement as a unit through a "port" area 48 in the transmission line (to the left of terminals 30, 32 as viewed in FIG. 1). Blocks 40, 42 slide in ways 52, which are supported adjacent the side walls 24, 26 of the enclosure. The dielectric support sheet 18 has a slot 50 therein which receives an adjusting mechanism in the form of a micrometer screw structure generally indicated at 60. That structure is coupled to the dielectric blocks 40, 42 and acts to move those blocks in an axial direction (that is, parallel to each folded section of the conductors 14, 16). Springs 62, connected to the blocks 40, 42, act to bias the blocks to the left as viewed in FIG. 1 into firm engagement with the micrometer screw structure 60.

It will be seen that each parallel section of the transmission line is disposed in part in a region filled with solid dielectric and in part in a region filled with air. The lengths of the line sections in each region is changed as the blocks 40, 42 are moved in an axial direction by adjustment control 60, while the portions of the line adjacent terminals 30, 32 remain filled with the solid dielectric. The electrical length of the line changes as the amount of solid dielectric disposed therein is changed, and, hence, a phase shift is produced.

In this embodiment the four transformers are identical, but in order to optimize the impedance match, the transformer design may be different for each longitudinal section of the serpentine center strips 14, 16 so that, for

example, the "zero's" of the transformer response occur at different frequencies for the different longitudinal sections. Also, the sliding dielectric blocks may be made of a lossy dielectric in which case the device will function as a variable attenuator.

A second form of phase shifter device is diagrammatically indicated in FIGS. 6 and 7 in which the transmission line center conductors 14' and 16' are folded into two parallel sections and the ends connected to the input and output terminals 30', 32', which are disposed adjacent the air-filled region of the component. The transformer sections formed in the dielectric blocks 40', 42' provide a transition between the system impedance in the air-filled region and a lower impedance in the solid dielectric region. Suitable adjustment structure 60' is employed for moving the dielectric blocks 40', 42' in the axial direction to adjust the electrical length of the transmission line of the device.

Still another form of the invention is shown in FIGS. 8 and 9 which employs a stripline configuration, having ground planes 10'', 12'' and a central dielectric sheet 18'' which supports two superimposed center conductor sections 14'', 16'' which are connected between input terminal 30'' and output terminal 32''. Each dielectric member 40'', 42'', disposed adjacent the input terminal for movement in an axial direction towards the output terminal, has an impedance transformer section of tapered configuration, indicated at 70. Complementary impedance transformer sections 72 are formed on fixed dielectric members 74, 76 disposed adjacent output terminal 32''.

Another form of apparatus is indicated diagrammatically in FIG. 10. A transmission line section including conductor 14''' is connected between terminals 30''' and 32'''. A fixed solid dielectric block 80 is disposed in the device adjacent terminal 30'''. The forward surface 82 of the block is disposed at a skew angle to conductor 14''' and serves as a guide for sliding dielectric block 84. Formed on the forward end of block 84 is an impedance transformer (levels 86, 88, 90) which provides a transition between the air-filled portion of the line and the solid dielectric filled portion of the line. Suitable means such as a drive rod 92 acts to move the block 84 through a "port" outside of the main transmission line to vary the effective electrical length of the transmission line connected between terminals 30''', 32'''.

Still another arrangement of the phase shifter apparatus constructed in accordance with the invention is shown in FIGS. 11-15 and employs a coaxial cable type of transmission line, having a center conductor 100 and an outer conductor 102. The device has an input terminal generally indicated at 104 and an output terminal 106. Disposed within the transmission line between the inner and outer conductors is a dielectric block 108 which is axially movable through a port in outer conductor 102 and which may be accurately positioned by suitable means (not shown). The dielectric block has a slot 110 in it for receiving a portion of the inner conductor connected between the input terminal 104 and the main length of the center conductor 100. (Slot 110 may extend throughout the length of block 108 and a fixed dielectric sheet equal in width to the diameter of center conductor 100 may extend between the input and output terminals should the capacitance effect of the variable length of slot 110 in the transmission line produce unacceptable distortions.) Dielectric block 108 has formed integrally therewith an impedance transformer in the form of step levels 112, 114, 116, 118 and 120 and is movable along the center conductor 100 between that conductor and the outer conductor 102. A complementary impedance transformer is formed adjacent output terminal 106 by gradually increasing the radius of the center conductor as indicated at steps 122, 124, 126. Dielectric support 128 positions the center conductor 100 adjacent the output terminal 106 in conventional manner.

Although the motion of the sliding dielectric components have been indicated as straight-line motion in the

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several disclosed embodiments, it will be obvious that where curved transmission line components are employed, the dielectric members may pivot about an actual or virtual center for movement along a curved path instead of a straight line. While several embodiments of the invention have been shown and described, it is recognized that a variety of modifications thereof will be obvious to those skilled in the art. Therefore, it is not intended that the invention be limited to the disclosed embodiments or to details thereof and departures may be made therefrom within the spirit and scope of the invention as defined in the claims:

What is claimed is:

1. Apparatus for varying an electrical signal comprising:

an input terminal,
an output terminal,
a transmission line connected between said input and output terminals,
said transmission line having electrical conductor means and a dielectric region,
a first dielectric medium disposed in a first portion of said dielectric region,
solid dielectric medium having a different dielectric constant than said first dielectric medium disposed in a second portion of said dielectric region,
said electrical conductor means of said transmission line being fixed and having the same cross-sectional configuration in said first and second portions of said dielectric region,
means for moving said solid dielectric medium in said dielectric region relative to said electrical conductor means of said transmission line,
and an impedance transformer formed integrally with said solid dielectric medium which provides an impedance transition between the first portion of said dielectric region and the second portion of said dielectric region so that movement of said solid dielectric medium does not affect the input impedance of said transmission line.

2. The apparatus as claimed in claim 1 wherein said transmission line extends from one portion of said dielectric region into the other portion of said dielectric region and then returns to said one portion of said dielectric region.

3. The apparatus as claimed in claim 1 wherein said solid dielectric medium is a lossy dielectric material.

4. Apparatus for varying an electrical signal comprising:

an input terminal,
an output terminal,
a transmission line connected between said input and output terminals,
said transmission line having a dielectric region,
a first dielectric medium disposed in a first portion of said dielectric region,
solid dielectric medium having a different dielectric constant than said first dielectric medium disposed in a second portion of said dielectric region,
means for changing the quantity of said solid dielectric medium in said dielectric region without affecting the impedance of said transmission line,
a first impedance transformer formed integrally with said solid dielectric medium which provides an impedance transition between the first portion of said dielectric region and the second portion of said dielectric region, and

a second impedance transformer disposed between said first portion of said dielectric region and one of said terminals for providing an impedance transition complementary to the impedance transition produced by the first transformer integral with said solid dielectric medium.

5. The apparatus as claimed in claim 4 wherein said

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second impedance transformer is also integral with said solid dielectric medium.

6. Apparatus for varying an electrical signal comprising:

an input terminal,
an output terminal,
a transmission line connected between said input and output terminals,
said transmission line having electrical conductor means and a pair of plane parallel outer conductors and a planar inner conductor disposed parallel to and between said inner conductors, said inner conductor being of lesser width than said outer conductors, and a dielectric region between said inner and outer conductors,
a first dielectric medium disposed in a first portion of said dielectric region,
solid dielectric medium having a different dielectric constant than said first dielectric medium disposed on either side of said inner conductor between said inner conductor and said outer conductors in a second portion of said dielectric region,
said electrical conductor means of said transmission line being fixed and having the same cross-sectional configuration in said first and second portions of said dielectric region,
means for moving said solid dielectric medium in said dielectric region relative to said electrical conductor means of said transmission line,
and an impedance transformer formed integrally with said solid dielectric medium which provides an impedance transition between the first portion of said dielectric region and the second portion of said dielectric region so that movement of said solid dielectric medium does not affect the input impedance of said transmission line.

7. Apparatus for varying an electrical signal comprising:

an input terminal,
an output terminal,
a transmission line connected between said input and output terminals,
said transmission line having electrical conductor means and a center conductor, a coaxial outer conductor and a dielectric region between said center and outer conductors,
a first dielectric medium disposed in a first portion of said dielectric region,
solid dielectric medium having a different dielectric constant than said first dielectric medium disposed between said center and outer conductors in a second portion of said dielectric region,
said electrical conductor means of said transmission line being fixed and having the same cross-sectional configuration in said first and second portions of said dielectric region,
means for moving said solid dielectric medium in said dielectric region relative to said electrical conductor means of said transmission line,
and an impedance transformer formed integrally with said solid dielectric medium which provides an impedance transition between the first portion of said dielectric region and the second portion of said dielectric region so that movement of said solid dielectric medium does not affect the input impedance of said transmission line.

8. Apparatus for varying an electrical signal comprising:

an input terminal,
an output terminal,
a transmission line connected between said input and output terminals having a dielectric region,
a port in said transmission line communicating with said dielectric region,

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a first dielectric medium disposed in a first portion of said dielectric region,

solid dielectric medium having a different dielectric constant than said first dielectric medium disposed in a second portion of said dielectric region adjacent said port,

means for moving said solid dielectric medium through said port to change the quantity of said solid dielectric medium in said dielectric region without producing a discontinuity in the impedance of said transmission line,

and an impedance transformer formed integrally with said solid dielectric medium which provides an impedance transition between the first portion of said dielectric region and the second portion of said dielectric region.

9. The apparatus as claimed in claim 8 wherein said transmission line comprises a pair of plane parallel outer conductors and a planar inner conductor disposed parallel to and between said inner conductors, said inner conductor being of lesser width than said outer conductors, and said solid dielectric medium is disposed on either side of said inner conductor between said inner conductor and said outer conductors.

10. A transmission line type of phase shifter comprising:

an input terminal,

an output terminal,

a transmission line section connected between said input and output terminals,

said transmission line section including a first portion that is air filled, and a second portion having a solid dielectric disposed therein,

said solid dielectric being movable along said transmission line section to vary the amount of solid dielectric in said transmission line section,

a first impedance transformer formed integrally with said solid dielectric to provide a first impedance transition between said first and second portions of said transmission line section,

and a second impedance transformer providing a second impedance transition complementary to said first

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impedance transition between said first portion of said transmission line and one of said terminals.

11. The apparatus as claimed in claim 10 wherein said transmission line section includes first and second conductors,

one of said conductors being folded to provide a plurality of parallel sections,

said solid dielectric overlying corresponding first portions of said parallel sections, and corresponding second portions of said parallel sections being disposed in said first portion of said transmission line section.

12. The apparatus as claimed in claim 11 wherein said second impedance transformer is integral with said solid dielectric.

13. The apparatus as claimed in claim 12 wherein said transmission line section is of the same cross-sectional configuration in said first and second portions.

14. The apparatus as claimed in claim 13 wherein said transmission line comprises a pair of plane parallel outer conductors and a planar inner conductor disposed parallel to and between said inner conductors, said inner conductor being of lesser width than said outer conductors, and said solid dielectric medium is disposed on either side of said inner conductor between said inner conductor and said outer conductors.

References Cited

UNITED STATES PATENTS

2,258,876	3/1958	Le Vine et al.	333—34
3,041,558	6/1962	Brown et al.	333—81
2,961,620	11/1960	Sommers	333—31
3,005,168	10/1961	Fye	333—31
3,139,597	6/1964	French et al.	333—31
3,146,413	8/1964	Butler	333—31
3,192,492	6/1965	Linder	333—31
3,215,958	11/1965	Isaacson	333—81

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