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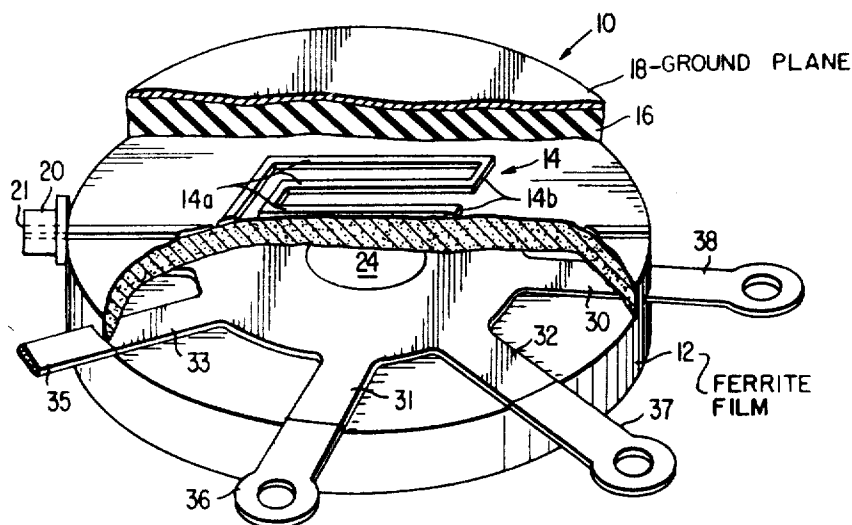
**[54] RECIPROCAL FERRITE FILM PHASE SHIFTER
HAVING DIGITALLY CONTROLLED RELATIVE
PHASE SHIFT STEPS
10 Claims, 6 Drawing Figs.**

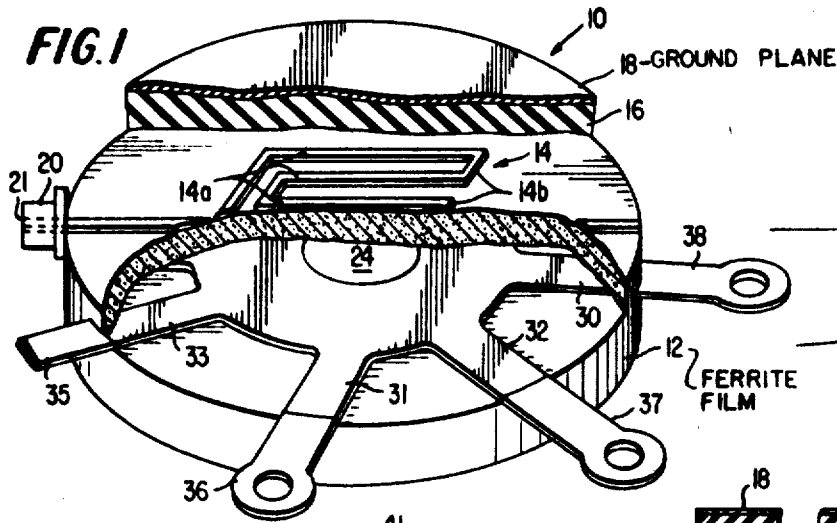
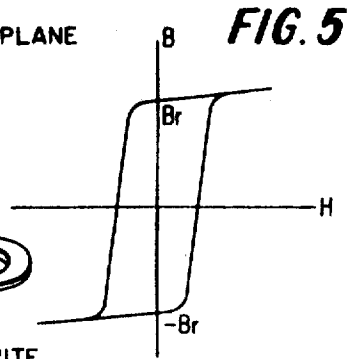
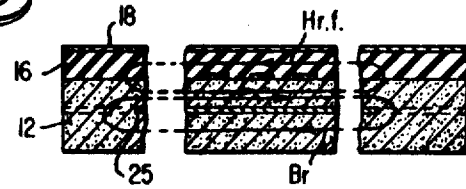
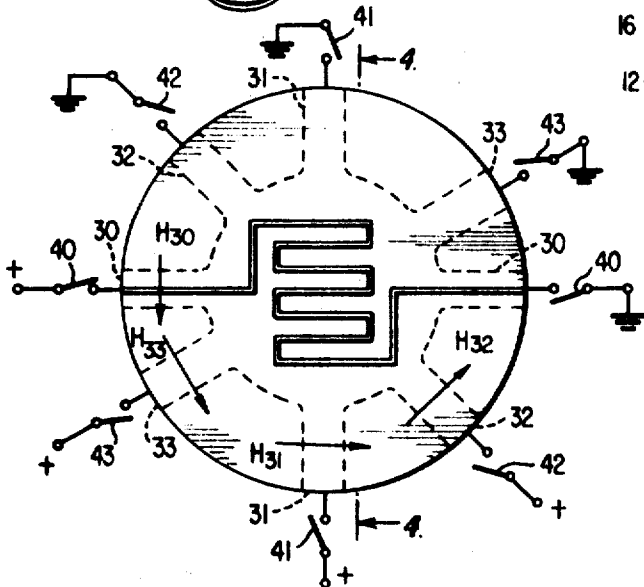
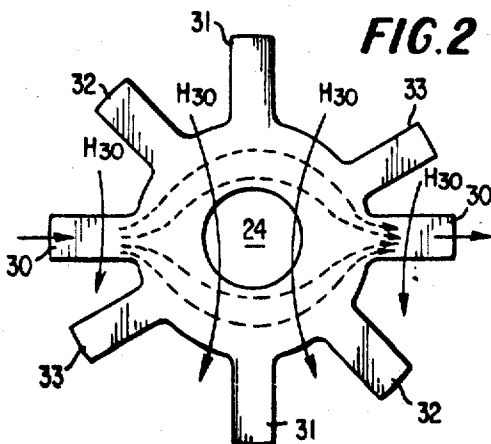
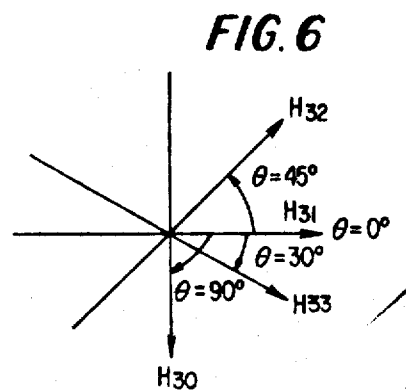
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[51]	Int. Cl.	H01p 1/18
[50]	Field of Search	333/1.1, 24.1, 24.2, 31

[56] **References Cited**
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ABSTRACT: The phase shifter comprises a ferrite film structured to define a multiple toroid configuration and having deposited on one surface thereof a microwave transmission line defining the direction of propagation of microwave energy. Flux driving means are digitally controlled for selectively driving the film to remanent conditions of magnetization of predetermined orientations relative to the direction of microwave propagation. In a preferred embodiment, the flux driving means includes a conducting film deposited between two layers of the ferrite film, which layers are integrally formed about the boundaries of the conducting film to define the multiple toroid configuration. Energization of selected latching current paths defined by the film provides for the selective flux driving of the film. Where β is the propagation constant of the microstrip, relative differential phase shift is expressed as $(\Delta\beta/\beta)$, and is a function of the remanent field strength in the direction of propagation. Selective current pulsing of the conducting film to establish latching current in selected ones of the current paths permits rapid switching of each step of relative phase shift.





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RECIPROCAL FERRITE FILM PHASE SHIFTER HAVING DIGITALLY CONTROLLED RELATIVE PHASE SHIFT STEPS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a reciprocal ferrite film latching phase shifter for microwave transmission in the T.E.M. mode, and more particularly, to such a phase shifter of improved, integral construction providing for digitally controlled, selective steps of relative phase shift.

2. Description of the Prior Art

Heretofore in the prior art, substantial study and investigation has been made of the effects of propagation of microwave energy, particularly in ferrite-loaded microwave transmission circuits. Ferrite loading of such circuits provides for selective control of the amount of relative, or differential phase shift of the microwave energy propagated through the circuits. The amount of phase shift is a function of the frequency of the microwave energy, the circuit configuration, the characteristics of the ferrite, and the strength of the component of the DC magnetizing field in the direction of propagation of microwave energy through the microwave transmission circuit.

Generally, the component of magnetization in the direction of propagation of the microwave energy through a ferrite-loaded microwave transmission circuit controls the effective permeability of the ferrite to that microwave energy propagation. This control of the effective permeability in turn controls the phase velocity of the microwave signal propagated through the circuit. By varying the effective permeability in the direction of propagation, varying amounts of differential phase shift of the microwave signal may be realized.

The applied magnetizing field for the ferrite loading element may be established either by continuous supply of a magnetizing current to suitable conductor means, such as a solenoid, associated with the ferrite element or by a latching magnetizing current which controls the ferrite element to a remanent state of magnetization. Generally, the latching type operation is preferred since it requires less power, and the amplitude control of the magnetizing current is not as critical. Also, the latching operation is more readily adapted for digital control.

Reciprocal phase shift in a ferrite-loaded microwave transmission circuit requires that at least a component of the applied DC magnetization be parallel to the direction of propagation of the microwave energy. By contrast, non-reciprocal phase shift results from the condition that the applied DC magnetization is perpendicular to the RF (radio frequency) magnetic field associated with the microwave propagation, and which field is elliptically polarized. This latter condition produces the nonreciprocal effect of different amounts of phase shifts for different directions of wave propagation.

As is well known, a waveguide transmission circuit cannot support a T.E.M. mode of transmission. Therefore, the condition for reciprocal phase shift cannot be realized in a ferrite-loaded waveguide. By contrast, a microstrip circuit may support a T.E.M. mode, and thus the condition for reciprocal phase shift may be realized in a ferrite-loaded microstrip circuit.

Heretofore, reciprocal latching, or remanent, ferrite phase shifters operable with T.E.M. microwave transmission systems have been very unsatisfactory in their design and effectiveness. As noted, reciprocal phase shift is achieved by applied DC magnetization in the direction of propagation. In general, however, a latching current cannot be developed in the direction of propagation in one of the conductors of a T.E.M. transmission system to achieve latching, because a current directed in the direction of propagation of the wave energy cannot produce a magnetic field having a component in that

direction. As a result, the latching circuit configurations developed heretofore have been of complex design to assure avoidance of interference of the latching current and resultant applied DC magnetizing field with the microwave propagation.

One design of the prior art is the so-called coplanar type of reciprocal ferrite T.E.M. latching phase shifter. In this structure, the applied magnetization field is coplanar with the microwave transmission line, and there results a poor distribution of the applied magnetizing field about the microwave transmission line or strip. Typically, the applied fields are oriented either parallel or perpendicular to the direction of microwave propagation to correspondingly establish remanent fields providing respectively for maximum or minimum amounts of relative phase shift. In neither of the conditions, however, is the applied magnetization exactly parallel or perpendicular, respectively, to the direction of propagation of microwave energy.

Other phase shifters of the subject type proposed heretofore have required stringent and impractical control of the dimensions and configurations of component portions of the phase shifter structures and particularly of the ferrite which sustains the remanent DC magnetizing field. Such devices are not only unfeasible for commercial production but also introduce undesirable and unacceptable operating parameters, such as prohibitively high insertion losses.

Where selectively controlled amounts of relative phase shift are desired to be attained in a single phase shifter structure, prior art structures become particularly unsatisfactory. The poor field distribution attained in coplanar type devices particularly does not afford sufficiently precise control of the component of magnetization developed in the direction of propagation of microwave energy and thus, particularly on a production scale, the amount of relative phase shift cannot be consistently maintained and accurately predicted for each phase shift step. Further, the complexity of prior art phase shifters is compounded when an effort is made to construct a stepped phase shifter due to the additional control elements required.

SUMMARY OF THE INVENTION

The foregoing and other defects of prior art reciprocal ferrite film latching phase shifters, for use with microwave transmission systems in the T.E.M. mode, are overcome by the stepped phase shifter of the invention.

The present invention comprises an improvement of the inventions disclosed and claimed in the copending applications entitled "Reciprocal Ferrite Film Latching Phase Shifter" of Daniel C. Buck and Leonard Dubrowsky, Ser. No. 821,344 filed May 2, 1969 "Reciprocal Ferrite Film Phase Shifter Having Latching Conductor Film" of Daniel C. Buck, Ser. No. 821,423 filed May 2, 1969, both assigned to the assignee of the present invention, and filed concurrently herewith. Each of those inventions relates to a reciprocal ferrite film latching phase shifter having a ferrite film and including flux driving means for that film for establishing orthogonally related remanent fields of magnetization in the ferrite film. In each, the ferrite film is structured to define a double toroid, the toroid of which are selectively driven to a remanent state by current pulsing of respectively associated latching conductors. The microwave transmission line deposited on the ferrite film defines the direction of microwave propagation and is positioned with respect to the double toroid film construction such that the orthogonal remanent fields of magnetization are established in exactly parallel or in exactly perpendicular orientation with respect to the direction of microwave propagation.

The present invention comprises a reciprocal ferrite film latching phase shifter having formed thereon a microwave transmission line defining the direction of microwave propagation through the phase shifter. Flux driving means are provided for selectively driving the ferrite film to a remanent

condition of magnetization in any desired one of a number of predetermined orientations with respect to the direction of microwave propagation.

Preferably, the flux driving means comprises a conducting film formed intermediate lower and upper layers of the ferrite film with those lower and upper layers formed integrally about the boundaries of the conducting film to structure the film in a multiple toroid configuration. The conducting film defines plural latching current paths respectively associated with the multiple toroids defined by the film. The latching current paths defined by the film may be selectively energized for flux driving the ferrite film to remanent magnetization of a desired one of a number of predetermined orientations with respect to the direction of propagation.

The RF magnetic field resultant from the microwave propagation through the transmission line exists within the ferrite. The remanent DC field of the ferrite, produced by current pulsing through a selected latching current conductor path, interacts with the RF magnetic field of the microwave to produce a resultant differential phase shift.

Where β is the propagation constant of the microstrip, the relative phase shift can be expressed as $(\Delta\beta/\beta)$ and is a function of the component of the applied DC magnetization field in the direction of propagation. The total phase shift $\Delta\beta$, is the product of the length times the propagation constant, and, as is well known, is a function of the frequency of the microwave transmission, and of the circuit configuration and characteristics of the ferrite, including its length in the direction of propagation. Thus, as the component of DC magnetization in the direction of propagation is selectively controlled in amount by selective pulsing of the conducting film to establish remanent magnetization of the film at a corresponding, predetermined orientation with respect to the direction of microwave propagation, the amount of relative phase shift produced is thereby correspondingly adjusted, or stepped.

The relative phase shift effect is reciprocal and does not depend on the direction of the DC magnetizing field but only its angle or orientation with respect to the direction of microwave propagation. This characteristic permits for compact design of the phase shifter by forming the microstrip into a spatially periodic circuit such as a meander line. The meander line is centrally positioned on the ferrite film, and provides maximum interaction of the RF and DC magnetization fields. However, at high frequencies such as X band, the guide wavelength is so short that for applied magnetizing fields of reasonably high amplitude, the meandering is not required.

The phase shifter of the invention utilizes the desirable characteristics of latching, or remanent, magnetization and the reciprocal phase shifting effect to achieve a structure compact in size yet highly effective in producing rapidly and easily controlled phase shifting of microwave transmission in the T.E.M. mode. The structure as described provides for maximizing the remanent fields of magnetization at prescribed orientations with respect to the direction of propagation of microwave energy, thus affording precise and consistently reproducible characteristics of the phase shifters. In particular, the integral structure of the deposited conducting film and the ferrite film affords a more uniform distribution of the latching currents and the DC magnetizing fields produced thereby, and thus a more uniform region for interaction of the resultant fields of remanent magnetization of the ferrite and the RF magnetic fields generated by the propagated microwave. Thus, in addition to providing a simplified structure of compact size, the phase shifter of the invention is very effective in operation and provides for highly accurate, and quickly and easily selectively controlled phase shifting of microwave signals.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a phase shifter in accordance with the invention, with certain portions of the structure broken away to facilitate the illustration of internal portions thereof;

FIG. 2 is a planar view of a latching conductor film enclosed within the phase shifter structure and shown in part in FIG. 1 and in hidden lines in FIG. 3;

FIG. 3 is a planar view of the phase shifter of the invention with selected, upper layers thereon removed to better illustrate the internal structure thereof;

FIG. 4 is a cross-sectional view of the phase shifter in accordance with the complete structure thereof as illustrated in FIG. 1, but taken along the line 4-4 as illustrated in FIG. 3;

FIG. 5 is a plot of a hysteresis curve defining the magnetization characteristics of the ferrite film employed in the phase shifter of the invention; and

FIG. 6 is a vector plot of applied magnetizing fields generated in response to the flow of current in selectively energized conductor paths defined by the latching conductor film.

DETAILED DESCRIPTION OF THE INVENTION

The phase shifter of the invention is of very compact size and relatively simple in design, yet provides for highly accurate and rapid, selective control of the amount of relative, or differential phase shift of microwave energy propagated through a microwave transmission line associated therewith. In particular, the phase shifter provides for digital-type operation for selectively and rapidly switching to a desired one of a number of predetermined, relative phase shift conditions, or steps, as described more fully hereinafter. To facilitate an understanding of the construction and operation of the phase shifter of the invention, it has been shown in the drawings on a greatly enlarged scale, particularly in the thickness or height dimension.

In FIG. 1, the phase shifter 10 includes a ferrite film 12 of any ferrimagnetic material, and which may be formed on a support (not shown). A microwave transmission line, or microstrip 14 is deposited on the ferrite film 12. As shown, the microstrip 14 is formed as a meander line, including a number of convolutions having long, parallel legs 14a, and short, parallel legs 14b at right angles to the legs 14a. The legs 14a define the primary direction of propagation of microwave energy through the microstrip line 14. The spacing of the legs 14a preferably is approximately one-eighth the waveguide length.

A dielectric layer 16 is deposited on the surface of the film 12 and over the meander line 14. A ground plane 18 is formed on the dielectric layer 16. The microstrip circuit 14, the dielectric 16, and the ground plane 18 together provide the microwave transmission circuit of the phase shifter 10. Suitable coaxial connectors 20 and 22 are mounted on the phase shifter 10 with a common ground connection (not shown) to the ground plane 18 and having coaxial connector elements 21 and 23, respectively, connected to opposite ends of the meander line 14.

Each of the ferrite film 12, the line 14, the dielectric layer 16, and the ground plane 18 may be formed by suitable chemical deposition techniques.

The thicknesses of the component portions of the structure are greatly enlarged in scale, and in a practical circuit of the ferrite and dielectric layers 12 and 16 are of 25 to 50 mils in thickness, and the ground plane 18 may be of substantially less thickness. The meander line 14 may be less than 1 mil in thickness and 40 to 50 mil wide. For a lateral overall dimension of about 2 inches square for the phase shifter 10, the meander line 14 occupies a central area of about 1½ inches square, including a total length of about 5 inches. The dimensions are not critical, however, and may be varied as required. The only critical limit is that the ferrite film be of sufficient thickness to avoid Faraday rotation effects.

As discussed more fully hereinafter, the ferrite film 12 is flux driven to remanent magnetization in accordance with a selected one of a number of predetermined orientations. For this purpose, a conducting film 25 is provided intermediate upper and lower portions, or layers of the ferrite film 12. The conducting film 25 is substantially planar, and the configuration thereof is best seen in FIGS. 2 and 3.

In FIG. 2 is shown a planar view of the conducting film 25 exclusively of the remaining portions of the phase shifter. FIG. 3 is a planar, somewhat schematic view of the phase shifter serving both to illustrate the operation thereof and the configuration of the latching conductor film 25 and its relationship with the ferrite layer 12 and the meander line 24. Referring concurrently to FIGS. 1 through 3, the latching conductor film 25 includes a plurality of tab pairs 30, 31, 32, and 33, the outer extremity of the tabs extending to the outer periphery of the ferrite film 12. Suitable connectors may be provided for external electrical connection to the tabs such as illustrated by the connectors 35, 36, 37, 38, as shown in FIG. 1, connected to the tabs 33, 31, 32, and 30, respectively. If desired, an opening 24 may be provided in the interior of the film 25 to assure spreading of the current paths throughout the film, which are established between, and defined by, the tabs of each pair. The tab pairs therefore define the direction of current paths within the film 25. A representative current path defined by tabs 30 is shown in dotted lines in FIG. 2, and the resultant magnetizing by the arrows H_{30} . The arrows H_{30} are somewhat curved to represent the perpendicular relationship to the current path and the magnetic flux linking of the multiple toroids.

In FIG. 3, the latching film 25 is shown by hidden lines to indicate its central location with respect to the major dimensions, or edges of the film 12 in the completed structure and also to illustrate the structuring of the ferrite film 12 resultant from the provision of the film 25 therein. Particularly, interconnected portions of the ferrite film 12 adjacent each edge thereof provide for a completed magnetic path past the boundary of the edges of the film 12 and between the edges of adjacent ones of the tabs 30 through 33. These regions effectively define a multiple toroid construction of the ferrite film 12. The multiple toroid construction of the ferrite film, as defined by the conductor film 25, must be such that magnetic saturation of the ferrite film 12 does not occur in any region thereof, prior to that of the region of the film between the conductors and the plane of the meander line.

Referring again to FIG. 1, the film 25 is formed as an intermediate step in the formation of the film 12. Particularly, following deposition of a first portion or layer of the film 12, the conducting film 25 is deposited and suitably formed, as by conventional etching processes, to the configuration as best seen in FIG. 2. The film preferably is of platinum or a refractory metal. The conducting film 25 need not be more than a few mils in thickness. If desired, prior to or simultaneously with the completion of the deposition of the film 12, the connectors such as schematically illustrated at 35 through 38 may be affixed to the corresponding tabs. Preferably, the second layer of the ferrite film 12 above the conducting film 25 is of less thickness than the portion below the conducting film 12. For clarity of illustration, it has not been attempted in FIG. 1 to show the integral formation of upper and lower layers of the ferrite film 12 at the regions surrounding the outer boundary of the conducting film 12 and between the adjacent tabs thereof. However, it will be appreciated that such an integral formation of the film 12 is achieved.

For example, in the cross-sectional view of FIG. 4, taken along the line 4-4 of FIG. 3, it is clearly shown that the film 25 is surrounded at its outer boundaries and intermediate adjacent tabs by an integral formation of the ferrite film 12. FIG. 4 also illustrates the surrounding relationship of the dielectric layer 16 relatively to the meander line 14, a cross section of a few of the long legs 14a thereof being visible in FIG. 4. The parallel relationship of the conducting film 25, the ferrite film 12, the plane of the meander line 14, and the ground plane 18 is readily appreciated from FIG. 4.

In the planar view of FIG. 3, there is schematically shown a selective energization system for establishing latching current in the paths thereof defined by the film 25, at a desired one of predetermined orientations of those current paths. Particularly, each of the tab pairs 30 through 33 has respectively associated therewith a pair of switches 40 through 43, one of which is connected to a source of energizing current as illustrated by a positive power supply terminal and the other of

which is shown connected to a ground potential terminal. Upon closure of a selected one of the switch pairs 40 through 43, a pulse of energizing current is caused to flow through the conducting path thereby defined to create a coercive, or applied, DC magnetizing field of the corresponding, predetermined orientation for flux driving the ferrite film 12 to remanent magnetization in that same orientation.

As specific examples of such predetermined orientations which may be realized, and with concurrent reference to FIGS. 2, 3, and 6, the tab pair 30 is defined at an orientation of $\theta=0^\circ$. The tab pair 31 is orthogonally related to the tab pair 30 and, correspondingly, $\theta=90^\circ$. The tab pairs 32 and 33 are oriented to define current conducting paths of $\theta=45^\circ$ and $\theta=30^\circ$, respectively. The magnetizing field vectors resultant from current flow through the current conducting paths are, as is well known, at right angles to the direction of current flow and are so illustrated by the vectors H_{30} through H_{33} in FIG. 3. The relative orientations of the applied magnetizing fields, as represented by the vectors H_{30} through H_{33} , is shown in FIG. 6.

In FIG. 5 is shown a plot of the hysteresis curve of a magnetic medium, such as the ferrite film 12, in accordance with an applied magnetization field, such as generated by a latching current pulse conducted by any of the latching current paths as above defined. As is well known, the strength of the applied magnetizing field H is a function of the amplitude of the magnetizing current. Further, the resultant magnetization B of the medium, such as the ferrite film 12, is a function of the amplitude of the applied magnetizing field H , and increases with increasing values of H until magnetic saturation of the medium is reached. When the pulse terminates and thus upon reduction of the latching current to zero value, the value H of the magnetizing field similarly reduces to zero value. The magnetization of the medium then reduces to the remanent magnetization value identified as the remanent level B_r in FIG. 5. Similarly, a latching current of opposite polarity and of sufficient amplitude, creates a magnetizing field $-H$ which drives the ferrite medium to saturation in negative direction; upon termination of the current, the medium, returns to an opposite sense, or polarity, remanent level $-B_r$.

The principal direction of propagation of microwave energy through the meander line 14 is that defined by the long legs 14a of the line 14. As previously described, the ferrite film 12 exhibits reciprocal latching characteristics and thus the opposite directions of propagation through alternate ones of the legs 14a are immaterial as to the relative phase shift effected. The amount, or steps, of phase shift is thus a function not of direction or polarity, but only of the orientation of the applied DC magnetizing field and thus of the remanent magnetization field. Further, since the ferrite phase shifter of the invention is reciprocal, the direction, or sense of the remanent magnetization, i.e., $+B_r$ or $-B_r$, which is established is immaterial to the control of the relative phase shift effected. Thus, by supplying a sufficiently high current pulse to a selected one of the latching current conductor paths 30 to 33, there are generated magnetizing fields H of sufficient intensity to drive the ferrite layer 12 to latched, or remanent conditions in corresponding orientations for producing corresponding amounts of relative phase shift in a microwave transmitted through the meander line 14.

Thus, with reference to FIGS. 2, 3, and 6 wherein $\theta=0^\circ$ for the principal direction of microwave propagation, the component of magnetization in the direction of propagation is a function of $\cos \theta$. Energization of the current path defined by tabs 31 and resulting in the DC magnetizing field of vector H_{31} will effect the maximum relative phase shift, and energization of those current paths corresponding to generation of applied magnetizing fields represented by vectors H_{32} , H_{33} , and H_{30} will result in successively smaller amounts of phase shift with the last, H_{30} , producing a minimum value. Since the effect is reciprocal, it is appreciated that the full range of relative phase shift may be realized for current paths and corresponding magnetizing fields confined within a range of $\theta=0^\circ$ to $\theta=90^\circ$.

L. However, again due to the reciprocal effect, for convenience of physical construction, tab pairs may be displaced through all quadrants and not confined within a single quadrant pair, thereby permitting a greater number of selectively available steps of relative phase shift.

In many applications, it is desirable to obtain equal increments of relative phase shift through each of successive steps, or bits. The angular locations of the connector tab pairs would then be defined by:

$$\theta_n = \sin^{-1}(n\pi/2N)$$

where n is the number of connector tab pairs, and N is the total number of bits, or steps, desired. The phase shifter herein disclosed thus comprises a four-bit phase shifter, for example.

The field interaction which accomplishes the relative phase shift is illustrated in the cross-sectional view of FIG. 4. To facilitate illustrating the relationship of the interacting fields, the cross-sectional view includes selected, or broken, sections across the width of the phase shifter 10, along the line 4-4 in FIG. 3. As above noted, the meander line 14 and the ground plane 18 define the microwave transmission line for the system. The T.E.M. mode of transmission is represented in FIG. 4 with respect to three of the major legs 14a of the meander line microstrip 14. The RF electric field vector is thus shown established between the legs 14a and the ground plane 18, traversing the dielectric layer 16, and the RF magnetic field is represented by closed elliptical paths labeled H_{RF} . The cross section of FIG. 4 further illustrates the remanent field in the ferrite 12 produced by pulsing of the current path 30, the remanent field similarly being shown as closed elliptical path labeled B_{r30} . Although not shown, it is readily apparent that the remanent field B_{r31} which is parallel to the major legs 14a of the meander line would be therefore perpendicular to the magnetic field H_{RF} produced by the propagated microwave. Similarly, the field B_{r30} will be perpendicular to the field H_{RF} in the region of the short legs 14b of the meander line and the field B_{r31} will be parallel to that field. Similarly, the remanent fields established by pulsing any other selected conductor path of described orientations will produce components of the remanent magnetization field of corresponding amounts for interaction with the RF magnetic fields generated by microwave propagation to effect corresponding, intermediate values of relative phase shift. The flux drive capability of the phase shifter of the invention thus provides for rotating the orientation of the saturated magnetization, or remanent magnetization, of the ferrite film in successive, accurately controlled steps, through a plane of rotation parallel to the plane of the microstrip line 14.

The phase shift of a phase shifter is measured as the total phase change between the input and the output as a function of the length of the conducting or transmission line therein. The differential phase shift, similarly, is a measure of the phase change per unit length of transmission line. The net differential phase shift for each step is a function of the difference between the total length of the major legs 14a and that of the minor legs 14b.

Remanent fields of plural orientations may be established by simultaneously energizing two or more different latching current paths. Such operation produces a resultant latching current oriented with respect to the direction of propagation at an angle which is approximately the average of the angles of the energized current paths. For example, simultaneous energization of current paths at angles $\theta=0^\circ$ and $\theta=90^\circ$ produces a resultant current path at $\theta=45^\circ$. A correspondingly oriented magnetic field is thereby established. Preferably, however, individual current path defining means, as provided by the conductor tabs associated with the conducting film, are employed for defining each such conducting path, thereby simplifying the control circuitry and providing more accurately defined relative phase shift characteristics.

In summary, the phase shifter of the invention provides for rapid and highly accurate control of the relative phase shift effected thereby through a plurality of, or to a desired one of, a number of predetermined relative phase shift amounts. The

phase shifter is of relatively simplified construction and compact in size, rendering it ideally suited for numerous microwave applications.

I claim:

1. A reciprocal latching phase shifter for microwave transmissions in the T.E.M. mode comprising:

a ferrite film,

a microwave transmission line associated with said film and defining the direction of microwave propagation with respect to said films

a conducting film received within said ferrite film and defining latching current paths therethrough in at least three predetermined orientations with respect to the direction of microwave propagation, and

means for selectively energizing said latching current paths for flux driving said ferrite film to magnetization in said orientations, respectively corresponding to minimum, intermediate, and maximum amounts of relative phase shift of a microwave propagated through said associated transmission line.

2. A phase shifter as recited in claim 1 wherein:

said conducting film is of planar configuration and integrally formed within said ferrite film to structure said ferrite film in a plurality of toroids associated with said latching current paths.

3. A phase shifter as recited in claim 1 wherein:

said conducting film is formed in parallel relationship with and intermediate lower and upper layers of said ferrite film, said conducting film having boundaries of smaller dimensions than said ferrite film,

said conducting film including a plurality of pairs of integral connector tabs, the tabs of each pair being disposed in alignment at opposite boundaries of said conducting film and defining a respectively associated latching current path therethrough, and

said tab pairs extending to the perimeters of said ferrite film for electrical connection thereto to permit selective energization of current paths respectively defined thereby.

4. A phase shifter as recited in claim 3 wherein said layers of said ferrite film are integrally formed in the portions of said film surrounding the boundaries of said conducting film and intermediate adjacent tabs thereof.

5. A phase shifter as recited in claim 3 wherein said plurality of tab pairs are displaced at unequal angular increments through said orientations thereof to provide for corresponding unequal successive amounts of relative phase shift.

6. A phase shifter as recited in claim 3 wherein said tab pairs of said conducting film defining said latching current paths are successively displaced through said angular orientations thereof to provide equal successive amounts of relative phase shift of a propagated microwave.

7. A phase shifter as recited in claim 3 wherein:

said conducting film includes at least one tab pair defining a current path oriented at an angle intermediate parallel and perpendicular orientations with respect to the direction of microwave propagation and lying within a first set of quadrants defined by said parallel and perpendicular orientations.

8. A phase shifter as recited in claim 7 wherein:

said conducting film includes a least a second tab pair intermediate said parallel and perpendicular orientations and of a different orientation than said first tab pair and lying in a second set of quadrants defined by said parallel and perpendicular orientations.

9. A phase shifter as recited in claim 3 wherein said latching current paths of said conducting film are displaced at successive orientations as defined by $\theta_n = \sin^{-1}(n\pi/2N)$ where θ_n is an angle of orientation of a given current path measured from a parallel orientation with the direction of propagation, n is the number of connector tab pairs and N is the total number of bits desired.

10. A phase shifter as recited in claim 9 wherein said energizing means provides for selective and sequential energization of said plurality of latching current paths.