ELIMINATION OF MODE SPIKES IN MICROWAVE FERRITE PHASE SHIFTERS

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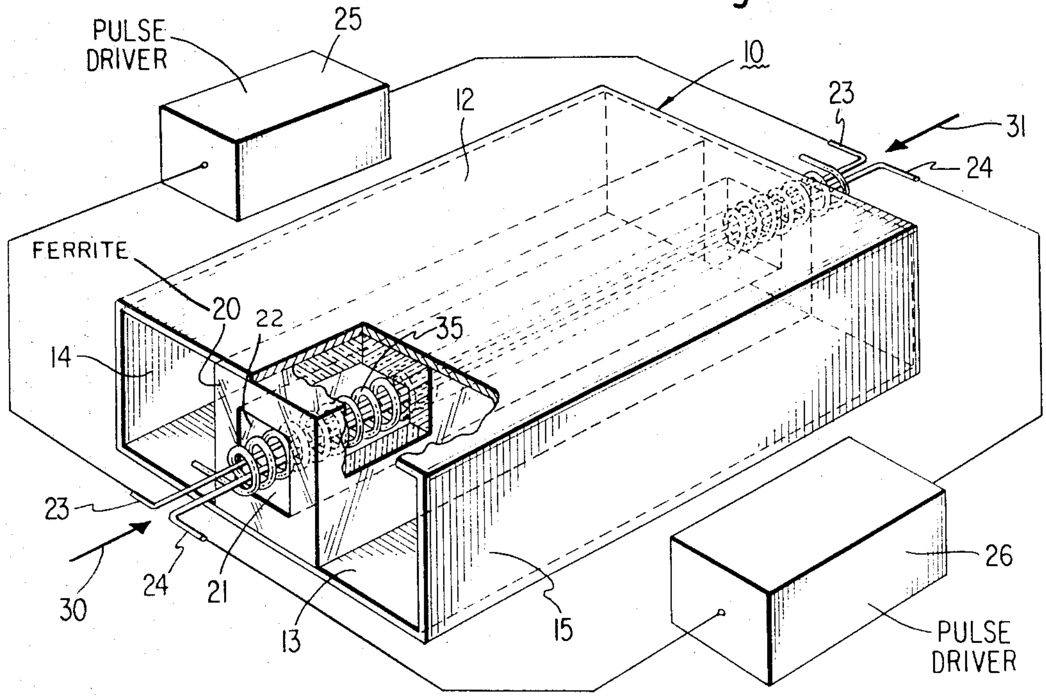
Fig. 1.



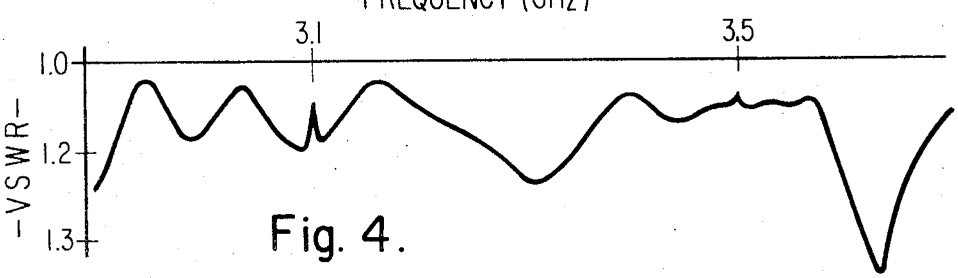


Fig. 4.

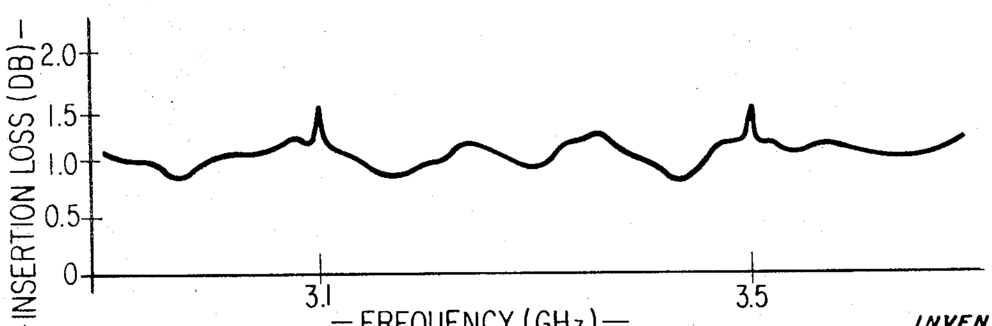


Fig. 5.

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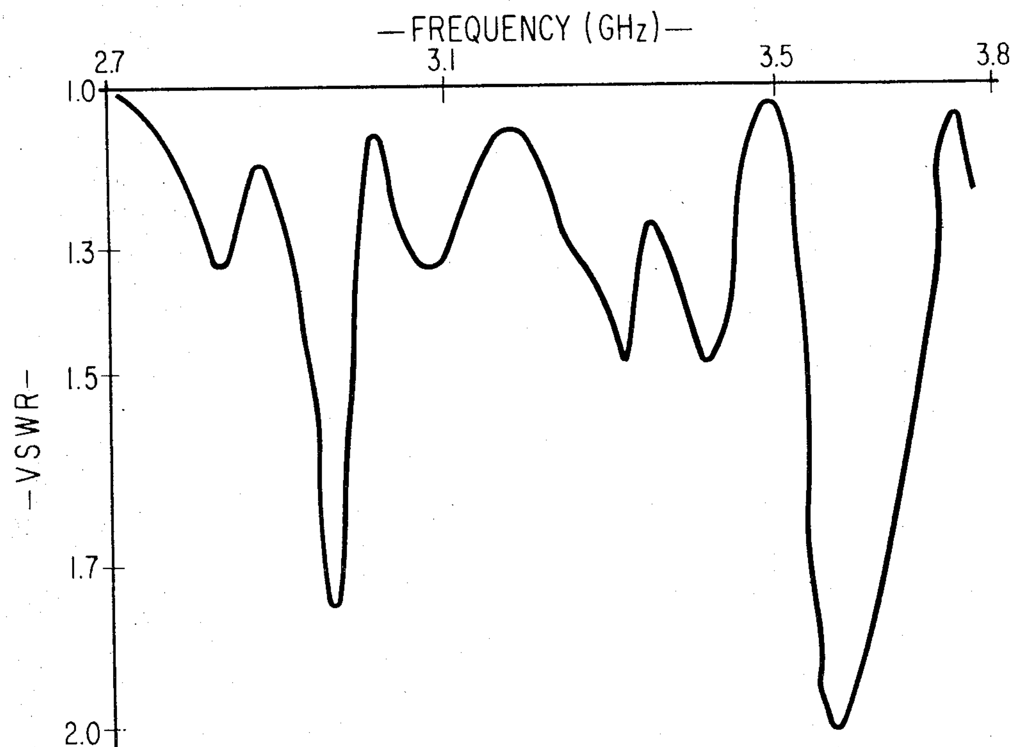

Fig. 2.

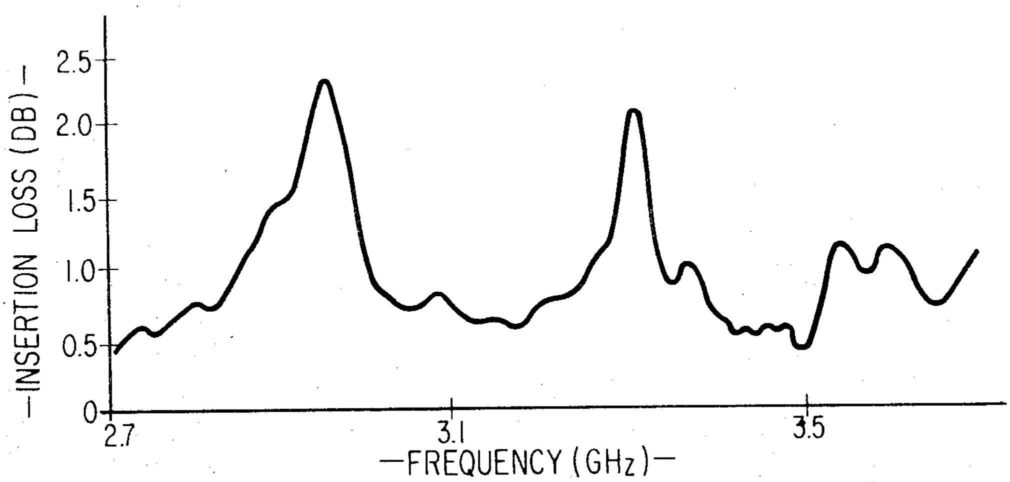

Fig. 3.

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ELIMINATION OF MODE SPIKES IN MICROWAVE FERRITE PHASE SHIFTERS

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U.S. Cl. 333—24.1 4 Claims

ABSTRACT OF THE DISCLOSURE

A typical microwave phase shifter includes, for example, a rectangular toroid of ferromagnetic or ferrimagnetic material mounted in the center of a rectangular waveguide with the toroid being biased by a magnetizing wire which passes through the center and along the length of the toroid. Elimination of mode spikes which result from this arrangement is provided by spiral wrapping a separate wire about the magnetizing wire.

BACKGROUND OF THE INVENTION

This invention relates to microwave phase shifters and more particularly to the type of microwave phase shifter which includes a ferrimagnetic or ferromagnetic toroid mounted in a waveguide and having a magnetizing wire passing through the center and along the length of the toroid.

Microwave phase shifters are widely used, for example, in phased array antennas. In such applications, it is desirable to switch the phase shifter from one phase shift condition to another phase shift condition. A convenient way of controlling the amount of phase shift is to pass a magnetizing wire through the slot in a toroid of gyromagnetic material which toroid is placed in the center of a waveguide and extends along the length of the waveguide. The term gyromagnetic material refers both to ferromagnetic and ferrimagnetic materials. A more complete description of such materials can be found in chapters 2 and 3 respectively, in "Microwave Ferrites and Ferrimagnetics" by Lax and Button, published by McGraw-Hill. One of the problems associated with shch a phase shifter design has been the existence of narrow insertion loss and VSWR (voltage standing wave ratio) spikes within the desired operating frequency band of the phase shifter device. These spikes are the result of the generation and propagation of higher order modes within the toroid propagating waveguide at appropriate resonant frequencies. The toroid section acts as a cavity and considerable energy may be absorbed.

It is an object of this invention to eliminate the mode spikes associated with the type of phase shifter having a magnetizing wire passing through the center of a toroid of gyromagnetic material which toroid is located along the center of a waveguide structure.

SUMMARY OF THE INVENTION

Briefly, the above and other objects of this invention are accomplished by the spiral wrapping of a wire about the magnetizing wire placed along the center of a slot in a toroid which toroid is of gyromagnetic material and is located along the center of a waveguide. The size of the spiral wrapped wire and the number of turns per inch is arranged so that to allow the flux from the magnetizing wire to reach and magnetize the toroid and yet suppress the undesirable electrical modes which are otherwise present.

DESCRIPTION OF A PREFERRED EMBODIMENT OF THE INVENTION

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

FIG. 1 is a perspective view of a microwave phase shifter in accordance with one embodiment of the present invention,

FIG. 2 illustrates the level of the VSWR spikes versus frequency (gHz.) for a ferrite phase shifter like that described in FIG. 1 without the spiral wrapping of a magnetizing wire,

FIG. 3 illustrates the level of the insertion loss (decibels), versus frequency for a ferrite phase shifter like that in FIG. 1 without spiral wrapping of the magnetizing wire,

FIG. 4 illustrates the level of the VSWR spikes versus frequency for the ferrite phase shifter shown in FIG. 1 with a spiral wrapped wire about the magnetizing wire, and

FIG. 5 illustrates the level of the insertion loss (decibels) versus frequency (gHz.) for the ferrite phase shifter shown in FIG. 1 with spiral wrapping of the magnetizing wire.

Referring to FIG. 1, there is shown a rectangular waveguide **10** having broad walls **12, 13** and narrow walls **14, 15.** A rectangular ferrite toroid **20** is centered between the narrow walls **14, 15** and extends along a portion of the length of the waveguide **10.** The toroid **20** has a rectangular slot **21.** The slot **21** is preferably filled with a suitable dielectric material **22,** for example, a magnesium titanate dielectric such as D–16 manufactured by Trans-Tech, Inc. Gaithersburg, Md. The dielectric material **22** serves to center two magnetizing wires **23, 24** within the toroid **20** along the length of the toroid **20.** The wire **23** is coupled at both ends to a pulse driver **25** by which pulses are applied in one direction through the toroid **20** to latch the toroid **20** in one sense to provide, for example, a frequency shift of 90° for electromagnetic waves applied in the direction of arrow **30** through the waveguide **10.** Wire **24** is connected to a pulse driver **26** so that the application of a pulse from the driver **26** latches the toroid **20** in different sense, for example, to provide zero degrees phase shift for electromagnetic waves propagated in the direction of arrow **30.** In accordance with the particular application, only a single pulse driver may be used with a single magnetizing wire where a pulse in one direction from the driver is used to latch the toroid **20** in one sense. A pulse in the opposite direction from the driver is used to bias the toroid **20** in the opposite sense. Also, while one wire may be used for pulsing and consequently latching the ferrite toroid **20,** a second wire may be used for a control pickup as in the case of a linear flux control circuit like that described in U.S. Pat. application Ser. No. 689,036, by Johnson, Tomsic and Goodrich now Pat. No. 3,510,675.

In the operation of a phase shifter as described above, it is believed that the magnetizing wires **23, 24,** for example, support longitudinal RF current upon the application to the waveguide **10** of electromagnetic waves in the direction of the arrow **30** or **31.** The support of such RF current makes the wires **23, 24** act like antennas in that they strongly couple to undesirable high order modes within the cavity of the toroid **20** and the ferrite loaded waveguide **10.** Microwave tests conducted without the wires **23, 24** in the toroid **20** have indicated that only small VSWR spikes are generated. When the longitudinal magnetizing wires are simply placed within the toroid **20** as shown in FIG. 1, the mode spikes are very large and cannot be reduced to a satisfactory level. FIG. 2 is a plot of the VSWR versus frequency for a phase shifter like that shown in FIG. 1 for frequencies between about 2.7 gHz. (gigahertz) and 3.8 gHz. illustrating this condition. FIG. 3 is a plot of the magnitude of the insertion loss (decibels) versus frequency (gHz.) for a phase shifter like that shown in FIG. 1 for the same range of frequencies as in FIG. 2, illustrating the effect of the undesirable mode generation.

A solution to the mode problem has been found by wrapping a small diameter wire **35**, for example, from 0.5 to 10 mils in diameter in a spiral around the magnetizing wires **23**, **24** with a pitch of the spiral wire being arranged so as to provide about 10 to 50 turns per inch of magnetizing wire. The spiral wrapped wire **35** encompasses the magnetizing wire or wires for the length of the toroid **20**. Any RF current must then flow in the spiral wire **35** due to the skin effect, thus minimizing the longitudinal coupling currents. Also, the larger inductance of the spiral helps to prevent the unwanted RF currents. By the use of the spiral wrapped wire **35** in FIG. 1, the mode spikes are essentially eliminated as illustrated in FIG. 4, providing satisfactory and useable microwave phase shifters of the type having toroid and magnetizing wires extending through the slot of the toroid. FIG. 4 shows the improved low level VSWR versus frequency curve for a phase shifter with spiral wrapped wire over approximately the same range of frequencies as in FIGS. 2 and 3. FIG. 5 shows the improved low insertion loss versus frequency characteristic of the phase shifter with the spiral wrapped wire.

What is claimed is:

1. A microwave phase shifter comprising:

a waveguiding structure,

a toroid of gyromagnetic material centered along the length of the waveguiding structure, said toroid having a slot extending the length of the toroid,

at least one magnetizing wire having terminals adapted to be coupled to a pulse driver, said magnetizing wire passing through said slot and extending the length of said toroid to latch said toroid in the presence of a pulse supplied by said driver, and

a spiral wire located within said toroid and wrapped about said magnetizing wire so as to suppress undesirable mode spikes.

2. The combination as claimed in claim **1** wherein said spiral wrapped wire is from 0.5 to 10 mils in diameter.

3. The combination as claimed in claim **2** wherein said spiral wrapped wire has a pitch in the direction of the magnetizing wire so that there are from about 10 to 50 turns of wire per inch of magnetizing wire about the magnetizing wire.

4. The combination as claimed in claim **3** wherein said waveguiding structure is a rectangular waveguide and said toroid is centered between the narrow walls of said waveguide.

References Cited

UNITED STATES PATENTS

3,277,401 10/1966 Stern ______________ 333—24.1

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