United States Patent

Freibergs

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[54] **RECIPROCAL LATCHING FERRITE PHASE SHIFTER**

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[58] **Field of Search** .....333/24.1, 24.2, 31 A

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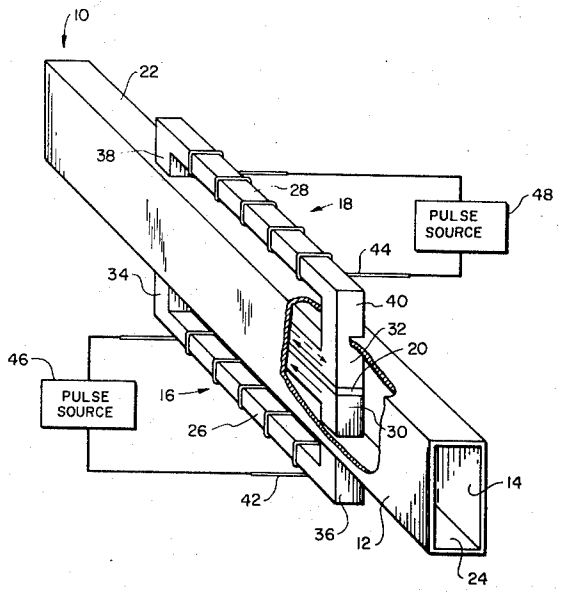
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[57] **ABSTRACT**

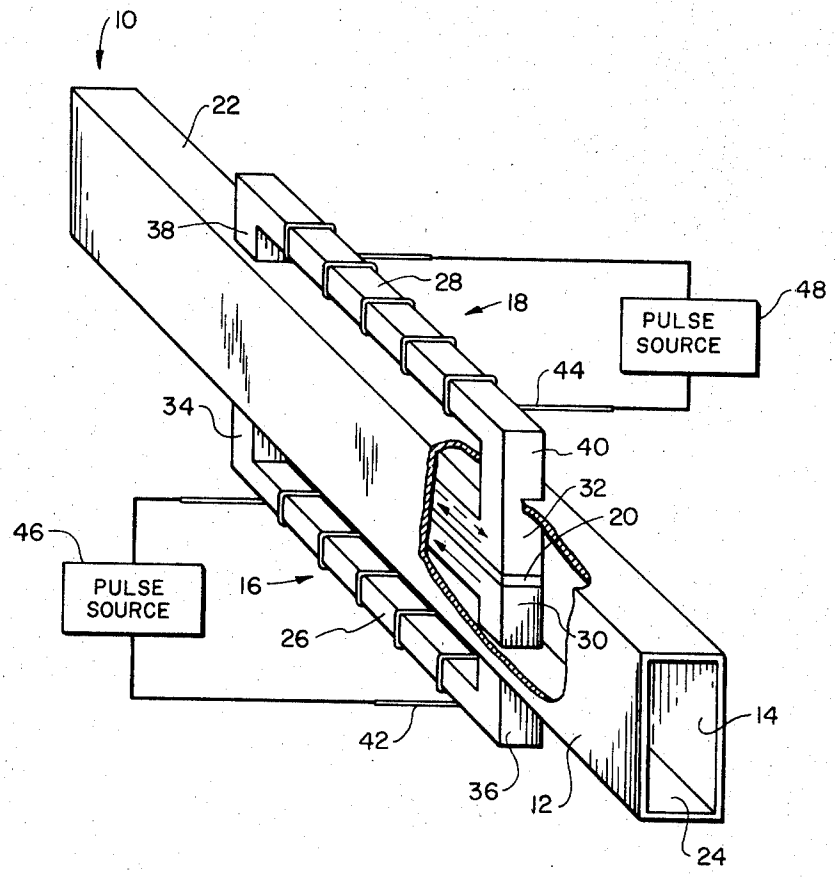
A microwave phase shifter includes a pair of spaced ferrite toroids centrally positioned within a rectangular waveguide adopted to propagate TE_{10} microwave energy. Each of the ferrites has a square hysteresis loop characteristic and each is independently energized.

2 Claims, 1 Drawing Figure



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RECIPROCAL LATCHING FERRITE PHASE SHIFTER

The invention described herein may be manufactured, used, and licensed by or for the Government for governmental purposes without the payment to me of any royalty thereon.

BACKGROUND OF THE INVENTION

This invention relates to reciprocal microwave phase shifters and more particularly to waveguide type microwave shifters utilizing ferrites. One type of latching ferrite phase shifter well known in the art employs a shape in which the magnetic flux lines are closed, for instance, in the shape of toroids. A phase shifting device incorporating ferrite toroids has the advantage that in operation of the device no external holding electrical current is required to maintain the requisite magnetization state. Switching may be performed between two remanent states of magnetization by means of current pulses. The direction of the current pulses either reverse the direction of magnetization or leave it unchanged. The toroid material is conventionally disposed along the central longitudinal axis of rectangular waveguide propagating energy in the fundamental mode, referred to as the TE_{10} mode in the art. Heretofore, some of the problems effecting the operation of ferrite reciprocal phase shifters within waveguides included high dielectric loading, high insertion loss, higher order moding and high power pulsing requirements.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an improved microwave reciprocal phase shifter wherein the above-noted limitations are overcome.

In accordance with the present invention, there is provided a reciprocal microwave phase shifter which includes a rectangular waveguide for propagating microwave energy in the TE_{10} mode and a pair of spaced side-by-side ferrite toroids positioned longitudinally within the waveguide but with respective side arms of each toroid outside the side walls of the waveguide. Included further are respective current pulsing means coupled with each of said outside arms for independently energizing the toroids.

BRIEF DESCRIPTION OF THE DRAWING

For a better understanding of the invention, together with other and further objects thereof, reference is had to the following description taken in connection with the single FIGURE of the accompanying drawing.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawing, at **10** there is shown a rectangular waveguide adapted to propagate conventional TE_{10} mode microwave energy. Longitudinally positioned in spaced side-by-side arrangement within waveguide **10** intermediate top and bottom waveguide walls **12** and **14** are two toroid sections **16** and **18** of identical construction and made of a suitable ferrite material capable of operating in the microwave frequency ranges. The ferrite material chosen must possess rectangular loop magnetization characteristics, preferably a square loop hysteresis characteristic. Toroids **16** and **18** are preferably square in cross section and are narrowly spaced apart by means of longitudinal dielectric separator **20** substantially centered between side waveguide walls **22** and **24**. The dielectric constant of separator **20** is preferably the same as that of the ferrite material of toroids **16** and **18**. As shown respective side arms **26** and **28** of toroids **16** and **18** are entirely outside the respective side walls of waveguide **10**, are in parallel alignment, and are symmetrically beyond the waveguide side walls. The dielectric spacer **20** is preferably 0.002 inches thick and its width is the same as that of the thickness of the ferrite toroids **16** and **18**. Arms **26** and **30** of ferrite toroid **16** are interconnected by end arms **34** and **36** that extend through side wall **24** of the waveguide to provide one closed loop magnetic path. Similarly, arms **28** and **32** of ferrite toroid **18** are interconnected by end arms **38** and **40** that extend through side wall **22** of the waveguide to form a second closed loop magnetic path. With the arrangement above, toroid sections **16** and **18** are positioned in a plane along the longitudinal axis of waveguide **10** symmetrically spaced from the top and bottom waveguide walls **12** and **14**, with the inner or proximal spaced arms **30** and **32** positioned substantially at the longitudinal axis of waveguide **10**. A first conductor winding **42** is coiled around exterior arm **26** of toroid **16** and has its terminals connected to a first pulsed D-C current source **46**. Similarly a second conductor winding **44** is coiled around exterior arm **28** of toroid **18** with its terminals connected to a second pulsed D-C source **48**. Both the current sources **46** and **48** may be of the variable and reversible type. Since the ferrite toroid side arms **26** and **28** are outside the waveguide **10**, the number of turns on the windings **42** and **44** does not affect the operation of the phase shifter.

Assuming a TE_{10} mode of electromagnetic energy propagating through waveguide **10**, it can be seen that the strongest waveguide fields are concentrated at the proximal spaced arms **30** and **32** of the ferrite toroids **16** and **18** respectively. The side arms **26** and **28** of respective ferrite toroids **16** and **18** will have a negligible effect on the operation of the device inasmuch as they are located outside the waveguide **10**. When the remanent flux flow is in the same direction along the inner proximal spaced toroid arms **30** and **32**, as indicated by the solid arrows, large phase shifts per unit length may be achieved. By maintaining the flux in either of the inner toroid arms **30** or **32** constant and reversing the current in the other inner side arm as indicated by the dashed arrow, the degree of differential phase shift may be varied from a maximum to a minimum. The dielectric separator **20** isolates the remanent flux flow in one toroid from the remanent flux flow in the other toroid in which the remanent flux flow is switched back and forth to affect reciprocal phase shift. It is to be understood of course that latching is obtained by using the square loop hysteresis characteristic of the ferrite material.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood, that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A reciprocal microwave phase shifter comprising:

a rectangular waveguide section for propagating microwave energy in the TE_{10} mode,

a pair of rectangular ferrite toroids that are made of the same ferrite material and that are identical in construction, said toroids being spaced and magnetically isolated by a dielectric separator

each toroid having a portion positioned longitudinally within said waveguide section in close proximity to the longitudinal axis of said waveguide section said portions of the respective toroids being on opposite sides of the axis and

being centrally between the wide walls of said waveguide section, each toroid having a winding coiled about a side arm that is entirely outside said waveguide,

and respective current pulsing means coupled to each of said windings for independently energizing said toroids.

2. The microwave phase shifter in accordance with claim 1 wherein said ferrite toroids have a square loop hysteresis characteristic.

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