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[54] **MEANS OF SECURING FERRIMAGNETIC CORE IN A MICROWAVE PHASER**

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[51] **Int. Cl.** **H01p 1/32**

[58] **Field of Search** ..... 333/24.1, 24.2, 98 R

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[57] **ABSTRACT**

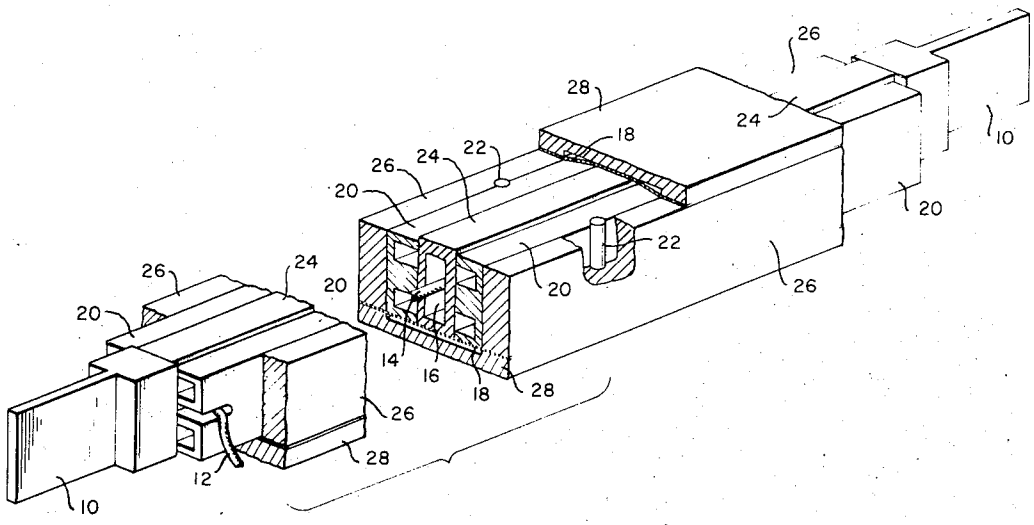
A mounting assembly for mounting a rectangular ferrimagnetic core longitudinally within a rectangular waveguide of a high-power-mode phase shifter comprising:

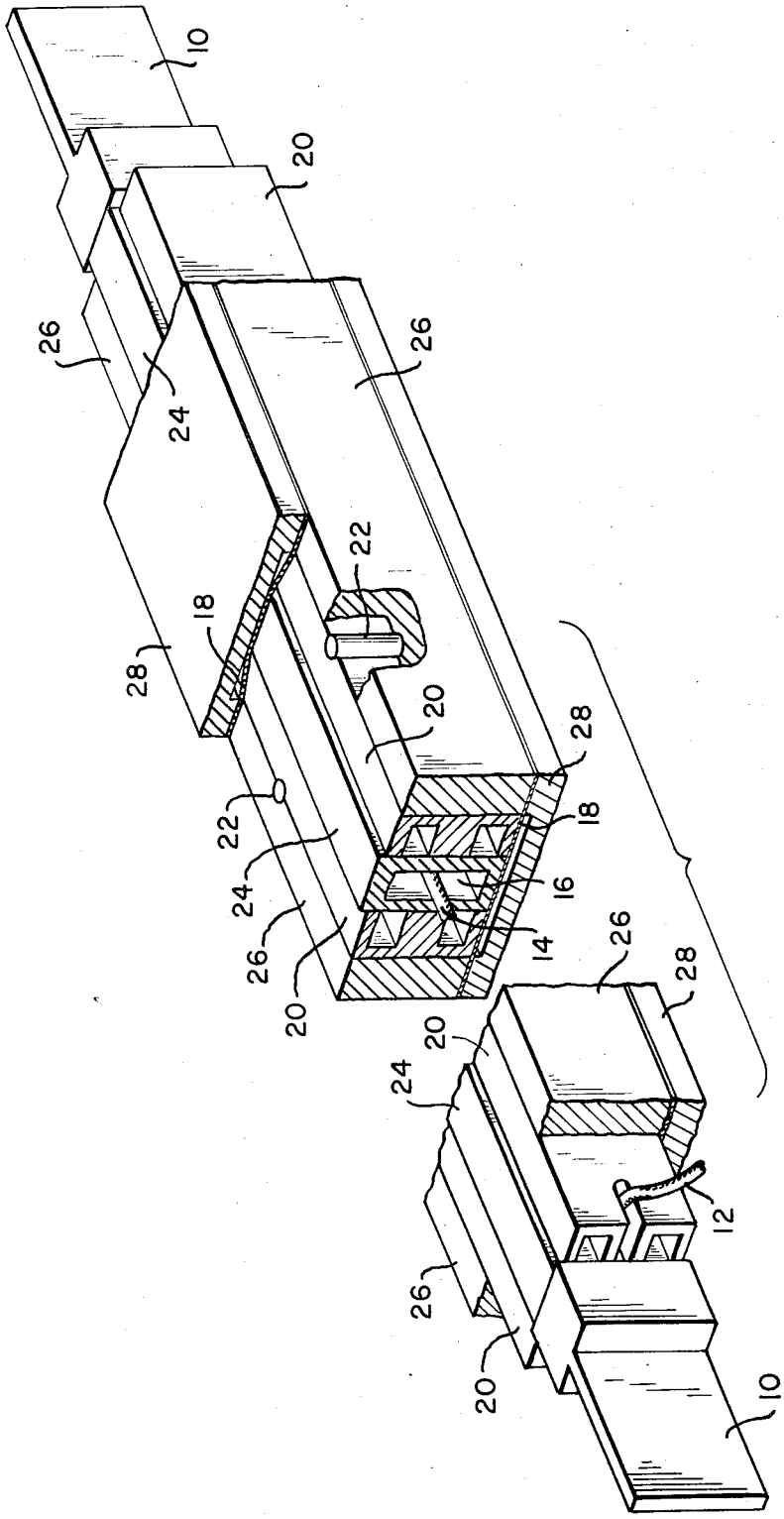
a. heat conducting elements on two opposite sides of the ferrimagnetic core extending longitudinally along the core;

b. dielectric transformers at each end of the core so as to partially overlap the ends of the heat-conducting elements thereby restricting motion of the core with respect to the waveguide;

c. dielectric pins inserted into pin-holes positioned partially in the waveguide and partially in the heat-conducting elements to restrict longitudinal motion of the heat-conducting elements with respect to the waveguide.

6 Claims, 1 Drawing Figure

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MEANS OF SECURING FERRIMAGNETIC CORE IN A MICROWAVE PHASER

FIELD OF THE INVENTION

The present invention relates generally to microwave phase shifters and more particularly to antenna phase shifters utilizing ferrite materials.

DESCRIPTION OF THE PRIOR ART

Ferrite phase shifters have been in wide use for some time, most notably in antenna array applications. Generally these devices comprise a rod of ferrite material mounted within a waveguide section and means for producing a magnetic field surrounding the material. By varying the strength of the magnetic field, the phase shift caused by the ferrite rod can be varied.

In the phase shifter used to illustrate the present invention a hollow rectangular ferrimagnetic core is mounted longitudinally within a rectangular waveguide. A wire mounted in a dielectric slab is inserted in the space within the hollow ferrimagnetic core. The phase is varied by sending a current pulse through the wire which acts to induce a magnetic flux in the toroid. When the current pulse has dissipated and thus $H = 0$, there will still be some remanent magnetic flux density B in the toroid due to hysteresis effects. The remanent flux density change will cause a change in the propagation constants in the toroid. Thus the microwave signal will pass through the ferrimagnetic toroid either faster or slower depending on whether the flux density is increased or decreased from its last level. This change in the electrical length of the toroid will cause the phase shift in the microwave signal. The flux density is proportional to the size of the current pulse through the wire. Thus the phase shift can be varied by varying the size of the current pulse.

This invention concerns itself with mounting the toroid of ferrimagnetic material in the longitudinal center of a rectangular waveguide. Ferrimagnetic core materials are generally fragile and magnetostrictive and therefore must be attached to, and supported in, the waveguide in a movement-restricting manner; yet the stresses on the ferrimagnetic materials resulting from the differential thermal expansions of the different materials in the phase shifter must be limited to an acceptable level.

The prime problem in such phase shifters results from the face that the thermal expansion of the metal of the waveguide is much greater than the thermal expansion of the ferrimagnetic core. Thus during high-power-mode operation, when the ferrimagnetic core dissipates large amounts of heat, the waveguide will expand much more than the core, and thus the core will have a tendency to slip out of its mounting within the metal waveguide. A mounting that allows sufficient clearances for thermal and magnetostrictive expansion and yet restricts the movement of this core is therefore desirable.

SUMMARY OF THE INVENTION

Briefly, the invention comprises a mounting designed to properly restrict the movement of the ferrimagnetic core of a high-power-mode phase shifter, while allowing space for the thermal and magnetostrictive expansion of the ferrite material of the core.

Thus in a phase shifter where a toroid core of ferrimagnetic material is mounted longitudinally in a waveguide, movement of this toroid core is restricted by

a. positioning heat-conducting elements on the sides of the core between it and the waveguide so as to extend longitudinally along the core and restrict lateral movement;

b. positioning dielectric transformers at each end of the core to completely cover the ends of the core and partially overlap the ends of the heat-conducting elements in order to restrict longitudinal motion of the core with respect to the heat-conducting elements;

c. placing a plurality of dielectric keys into a plurality of keyways, the keyways being positioned partially in the waveguide wall and partially in the heat-conducting elements and acting to restrict longitudinal motion of the heat-conducting element with respect to the waveguide;

d. restraining movement of the core top and bottom walls of the waveguide.

OBJECTS OF THE INVENTION

An object of the present invention is to mount a ferrimagnetic core in a waveguide such that movement of this core will properly be restricted while still allowing space for thermal and magnetostrictive expansion.

A further object is to provide the ferrimagnetic core from slipping out of its mountings in a waveguide.

BRIEF DESCRIPTION OF THE DRAWING

The single FIGURE of the drawing is an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The drawing shows the basic ferrimagnetic-core phaseshifter that will be used to illustrate the present invention. The walls of the rectangular waveguide **26** are made of metal. The rectangular, ferrimagnetic, toroid core **24** is positioned in the longitudinal center of the waveguide **26.** This core consists of a bonded stack of one or more ferrimagnetic toroids. The wire **14,** embedded in a coaxial dielectric insert **16** in the center of the toroid core, acts to conduct the pulse of current which will change the remanent flux density B, and thus change the phase of the phase shifter by making the toroid appear electrically shorter or longer to the microwave energy. This wire **14** is fed into the toroid core by the feedline **12.**

On either side of toroid core **24** are heat-conducting elements **20** in the shape of "E"s. Since the toroid core **24** dissipates large amounts of heat in a high-power mode, the optimum design for the heat-conducting element for optimum thermal conduction would be to completely surround the toroid core with the element. The problem is that the more material is placed around the toroid core **24,** the poorer becomes the toroid core's electrical performance. Taking these two factors into consideration, it has been found that the optimum design is in the shape of an "E". This design will provide a small surface against the toroid core, while providing a large surface (back of the "E") to transfer thermal energy to the waveguide wall where it can be dissipated.

Appropriate clearances are provided between the ferrimagnetic core **24** and the heat-conducting elements **20** to allow for thermal and magnetostrictive expansion. Thus, since the core is free to move within

these clearances, the stresses in the ferrite core due to expansion are limited to an acceptable value.

A transformer **10** is bonded to each end of the ferrite toroid core. This transformer is a dielectric, impedance-matching transformer which acts to match the high impedance of the empty waveguide to the very low impedance of the ferrimagnetic toroid (dielectric constant $E = 16$).

Multi-step transformers have been found best suited to perform this matching function. The more steps used to provide intermediate steps between the two extremes, the better the broad-band matching characteristics.

In this particular case a two-step impedance-matching transformer is used, though the invention is by no means limited to a two-step transformer, and any number of steps are possible.

The transformer may take any shape, the only requirement being that it completely cover the end of the toroid core and partially overlap the heat-conducting elements. The purpose of this overlap is to restrict the longitudinal movement of the toroid core with respect to the heat-conducting elements.

Dielectric keys **22** are inserted in keyholes positioned partially in the waveguide wall and partially in the heat-conducting surface. These keys act to restrict the longitudinal movement of the heat conducting elements **20** with respect to the waveguide walls **26.** The keys may be made of a dielectric material since if any highly conductive material such as a metal is used, the key appears to be an electrical bump in the waveguide. This electrical bump tends to disrupt the waveguide field and affect the V.S.W.R.

In the drawing, dielectric pins or pegs are used as the keys. There is no real limitation as to what shape the key may take so long as it rests partially in the heat-conducting element and partially in the waveguide.

Due to the very high dielectric constant E of the ferrite material, if there is a low dielectric-constant gap between the ferrite toroid and the waveguide ceiling a number of unwanted modes are set up in the waveguide. Furthermore, there are unwanted absorptions and resonances such that the guide cannot work over a proper bandwidth. Thus a very tight fit between the waveguide and the toroid is desired. In order to accomplish this a thin metallic sheet **18,** for example of aluminum, extends completely from one sidewall of the waveguide to the other sidewall and acts as the top and the bottom of the waveguide over the toroid.

The toroid core is made slightly higher than the adjacent heat-conducting elements. Thus, when the thin metallic sheet is placed over the toroid **24** and the heat-conducting elements **20,** the toroid will push-up on the metallic sheet while an aluminum cover **28** pushes down on the sheet thus giving a very tight contact between the waveguide metallic sheet **18** and the toroid core **24.**

Thus the toroid core **24** is (1) restricted by the heat-conducting elements **20** from lateral movement, (2) restricted by the top and bottom of the waveguide from vertical movement, (3) restricted by the transformer **10** from longitudinal movement with respect to the

heat-conducting elements **20.** The longitudinal movement of the heat-conducting elements **20** with respect to the waveguide is restricted by the dielectric keys **22.**

Obviously, many modifications and variations of the present invention are possible in 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 mounting assembly for mounting a core of ferrimagnetic material in a waveguide of a high-power microwave phase-shifter comprising:

a waveguide;

a ferrimagnetic core mounted longitudinally within said waveguide;

a plurality of heat-conducting elements positioned on two opposite sides of said ferrimagnetic core and extending longitudinally along said ferrimagnetic core with a predetermined clearance between said ferrimagnetic core and said heat conducting elements to allow for thermal expansion;

a plurality of dielectric transformers, one bonded to each end of said ferrimagnetic core, completely covering the ends of said core and partially covering the ends of said heat-conducting elements thereby limiting the longitudinal motion of said core with respect to said heat-conducting elements;

a plurality of dielectric keys inserted into a plurality of keyways, said keyways being positioned partially in said waveguide wall and partially in said heat-conducting elements and acting to restrict longitudinal motion of said heat-conducting elements with respect to said waveguide;

said ferrimagnetic core being restrained from motion in the sidewise direction by the heat-conducting elements, said ferrimagnetic core being restrained in the vertical direction by the top and bottom walls of said rectangular waveguide.

2. A mounting assembly as in claim **1,** wherein said heat-conducting element is formed in the shape of an "E", the long backside of the "E" being positioned against said waveguide and the three legs being positioned to face said ferrimagnetic core.

3. A mounting assembly as in claim **1,** wherein said ferrimagnetic core is formed in the shape of a rectangular toroid.

4. A mounting assembly as in claim **1,** wherein said dielectric keys are formed in the shape of pins.

5. A mounting assembly as in claim **1,** wherein said transformers are two-step, microwave, impedance-matching, dielectric transformers.

6. A mounting assembly as in claim **1,** wherein the top and bottom walls of said waveguide are formed by a thin metallic sheet, and further, wherein said ferrimagnetic core has a higher height dimension than said heat-conducting elements such that said ferrimagnetic core pushes up on said thin metallic sheet thus making a tight contact between the top and bottom of said ferrimagnetic core and said waveguide.

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