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Cox et al.

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[45] **Sept. 11, 1973**

[54] **COPPER FOIL FERRITE PHASE SHIFTER**

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[73] Assignee: **The Bendix Corporation,** Baltimore, Md.

[22] Filed: **May 15, 1972**

[21] Appl. No.: **253,372**

[52] **U.S. Cl.** ..... **333/24.1,** 29/600, 333/98 R

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

[58] **Field of Search** ..... 333/24.1, 95 R, 98 R; 174/DIG. 8; 29/600

[56] **References Cited**

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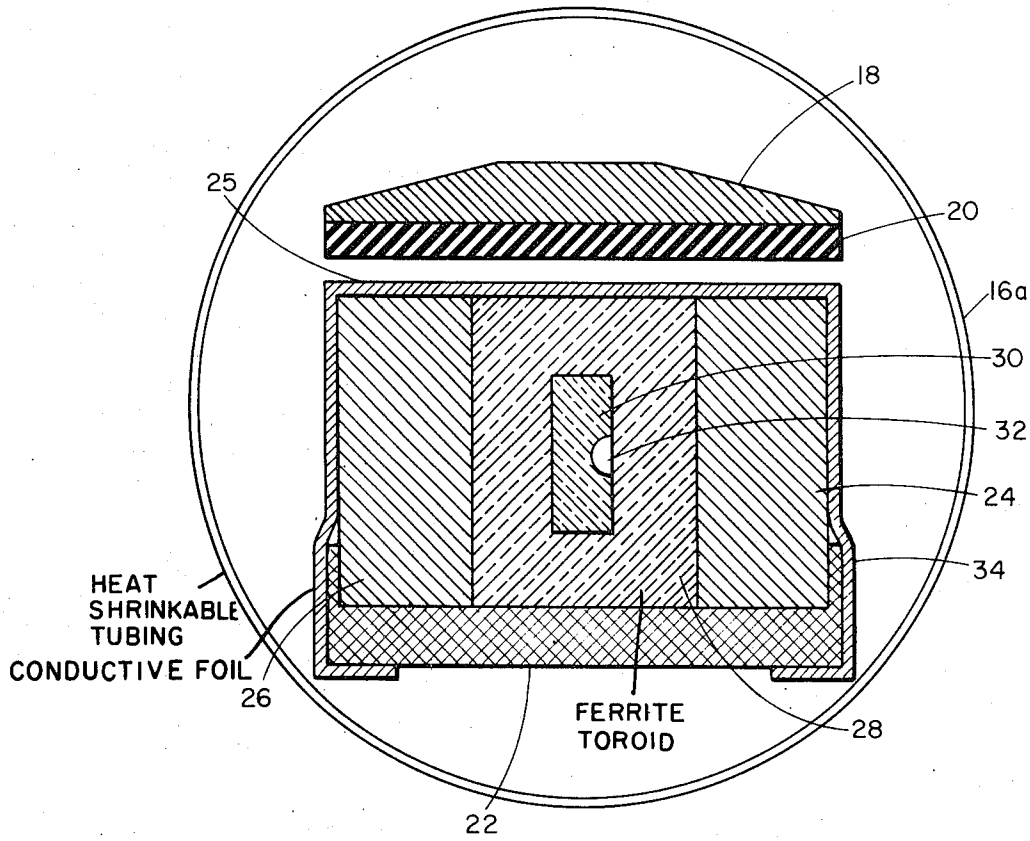
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[57] **ABSTRACT**

A microwave phase shifter is comprised of thin aluminum channel base in which are placed a ferrite toroid and dielectric slabs to define a waveguide. A metal foil encloses the assembly, held in place by heat shrinkable tubing.

3 Claims, 4 Drawing Figures



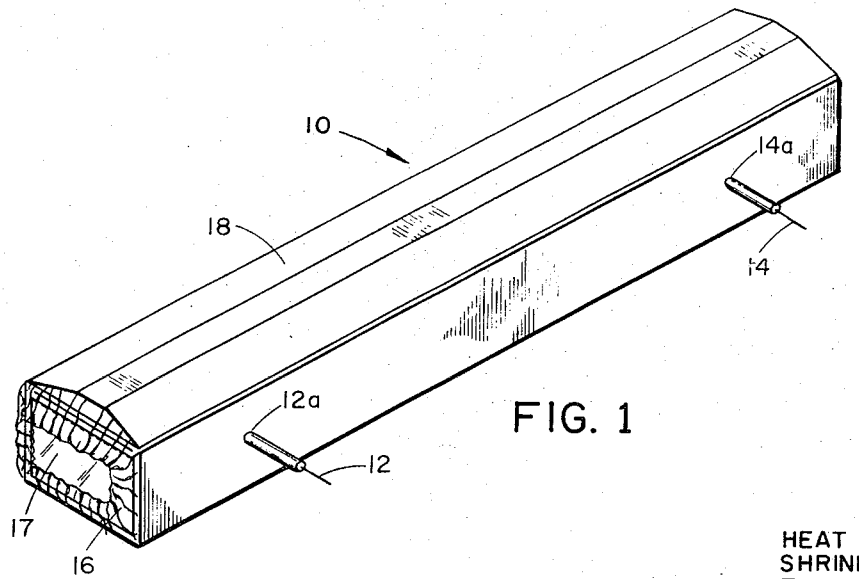


FIG. 1

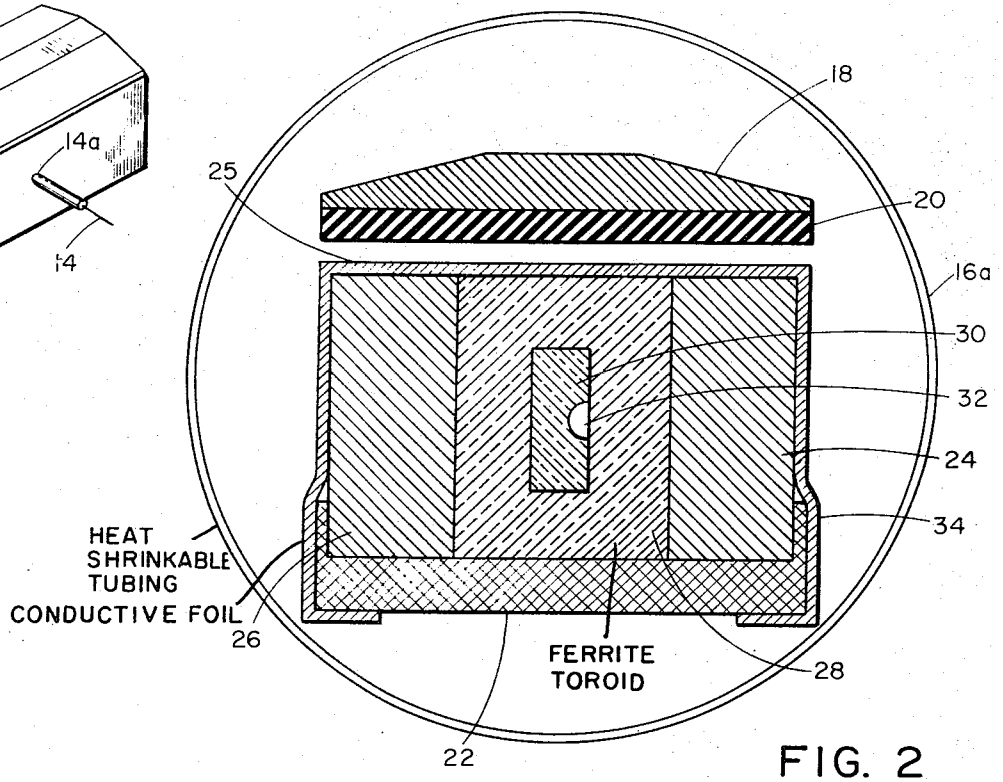


FIG. 2

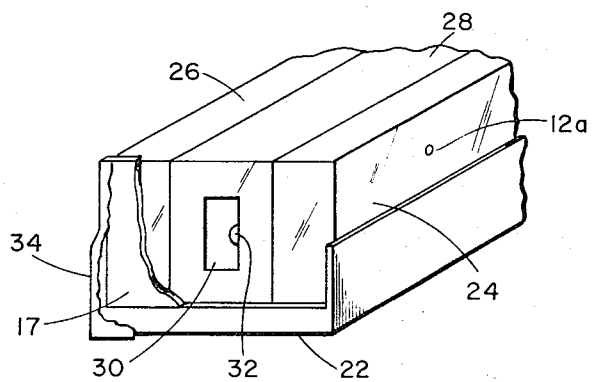


FIG. 3

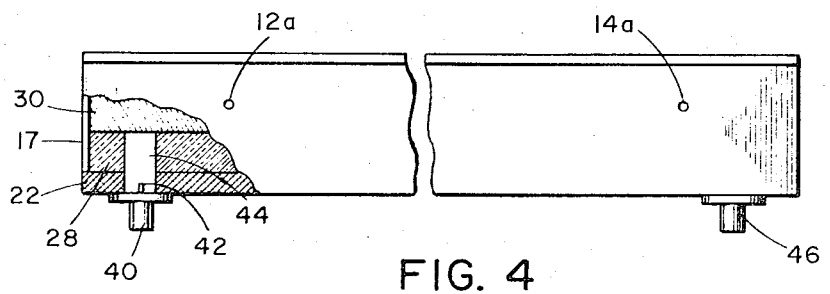


FIG. 4

COPPER FOIL FERRITE PHASE SHIFTER

BACKGROUND OF THE INVENTION

This invention relates to metallic shell devices and more particularly to microwave waveguides and phase shifters.

Microwave phase shifters normally use as the phase shifter a ferrite toroid, where the word ferrite is used as a general term to cover both ferrite and garnet materials. The toroid is enclosed within a waveguide and is contacted at its top and bottom by the waveguide walls. The contact between the toroid and the waveguide is very critical. Since ferrite materials are magnetostrictive there can be little pressure exerted on the ferrite by the waveguide without loss in phase shift per unit length. In addition, there must be very little air gap along the contact surface. Any voids along this contact surface will cause exitation of unwanted waveguide modes which will result in increased phase shifter insertion loss. As a result, the ferrite fit within the waveguide is usually held to a 0.0005 inch tolerance to insure the required close fit. These limitations on the fit of the toroid within the waveguide necessitate very high precision machining on both the ferrite and the waveguide housing, resulting in high construction cost.

SUMMARY OF THE INVENTION

In the embodiment to be described the usual waveguide housing is replaced by a thin aluminum, or other suitable material, channel. A toroid and two dielectric slabs, Rexolite or other suitable material, are placed in the channel. The perimeter of the toroid and the dielectric slabs define the inside surface of a waveguide which is formed by wrapping the assembly with a metal foil. A rubber shim and a lighweight protective spacer may be placed external to the metal foil and the entire device inserted into and held together by a heat shrunk tube. During construction, the heat shrinkable tubing is collapsed around the spacer, metal foil and channel forcing the foil into contact with the toroid and slabs. The rubber shim between the spacer and the metal foil insures foil to toroid contact without excessive localized pressure on the ferrite. The aluminum channel provides mounting surfaces for electrical ports which communicate with the device and adds rigidity to the overall package.

It is thus an object of this invention to provide an inexpensively produced foil clad device.

It is another object of this invention to produce a device of the type described which is useful as a microwave ferrite phase shifter.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a phase shifter built in accordance with this invention.

FIG. 2 shows greatly enlarged a transverse section of the device of FIG. 1.

FIG. 3 is a perspective view of the invention cut away to better show the details of the internal construction.

FIG. 4 is a side view of the invention cut away to illustrate the construction of an access port.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Refer to the figures wherein like reference numerals refer to like elements, and in particular, refer to FIG. 1. In this figure, a phase shifter **10** built in accordance with the invention is seen. The phase shifter is seen to be comprised of a waveguide shaped body having a generally arcuate cover **18.** Cover **18** is preferably light weight but rigid. The phase shifter is enclosed in tubing **16** which has been heat shrunk about the device to hold the parts in intimate contact. A toroid bias wire of the type known to those skilled in the art enters the phase shifter at end **12** and exits at end **14** at access holes **12*a*** and **14*a***, respectively. An end plate **17** is seen within the heat shrunk tubing. Another end plate, identical to the end plate **17** shown, is provided at the other end of the phase shifter but is not visible in the drawings.

Referring now to FIG. **2** a lightweight channel **22,** suitably of aluminum, forms a structural strength member of the device. Located within the channel and defining the interior of a waveguide are the microwave window slabs **24** and **26,** suitably Rexolite. Sandwiched between the Rexolite slabs is a ferrite toroid **28.** The Rexolite slabs **24** and **26** are generally of equal thickness so that the toroid is centrally located within the transverse dimension of the waveguide.

As is common in the art, a ceramic filler **30** fills the toroid void. The ceramic is preferably chosen to have the same dielectric constant as the ferrite material. A groove **32** within the ceramic material is provided for the bias wire whose ends are seen in FIG. **1.** Of course, at the higher microwave frequencies the void within the toroid will be smaller and the ceramic spacer may not be required. In any event a toroid void filler is an option of the device designer.

An electrically conductive foil, suitably copper, is wrapped about the device, at least to cover the exposed surfaces of the slabs **24** and **26** and the toroid **28.** It is desirable at this time to wrap the foil into intimate contact with the aforementioned pieces.

A relatively soft rubber-like shim **20** is sandwiched between the top surface **25** of the subassembly and a cover **18.** When the heat shrinkable tubing is shrunk around the final assembly shim **20** will conform to irregularities along its surface and together with cover **18** will gently force the foil into intimate contact with the top surface of toroid **28** and the toroid bottom surface into intimate contact with channel **22.** In this manner the toroid is not subjected to undesirable localized high pressure areas. The arcuate top surface of cover **18,** while not absolutely necessary to practice the invention, is desirable in that it permits the force exerted by the tubing as shrunk to be more evenly transferred to the shim.

The assembly as to this point described is now slipped into heat shrinkable tubing **16*a***. The tubing should best extend the entire longitudinal length of the assembly and even overextend both ends so that end plates **17,** one of which is seen in FIG. **1** will be held in position after the tubing is shrunk.

Refer now to FIG. **3** where the heat shrinkable tubing is not shown and plate **17** and foil **34** have been cut away to better show the construction of the device. Channel **22** together with slabs **24** and **26,** toroid **28** and filler **30** with groove **32** are seen. As shown, to provide a flush end the slabs and toroid stop short of the end of channel **22** to provide just enough space for the thinness of end plate **17.** Foil **34,** which in FIG. **2** was seen to comprise the inside surface of a resulting waveguide, is here shown folded over the end of the assembly so as to make electrical contact with end plate **17** and the end of channel **22.** The hole **12a** in spacer **24**

is provided for access into groove **32** by the bias wire.

Refer now to FIG. **4** which shows a side view of a phase shifter cut away in the vicinity of an electrical port. The port suitably comprises a coaxial connector **40** while a second part or connector **46** is also provided. The connectors are fastened onto the bottom surface of channel **22**, which, it will be remembered is the structural member of the device. The toroid **28** and filler **30** are also seen. A hole **44** is provided through channel **22** and toroid **28** to permit electrical communication between the connector center conductor **42** and the toroid void, which in this embodiment is occupied by filler **30**.

In this figure an end plate **17** together with bias wire access holes **12***a* and **14***a* are also seen.

Returning now to FIG. **1** it should be plain how the heat shrunk tubing holds the device together and overextending the ends of the device holds the end plates **17** in place.

The method of shrinking heat shrinkable tubing is well known and need not be repeated here. It is suffice to mention that the assembly as shown in FIG. **2** is suitably placed in an oven and baked to shrink the tubing. Of course, the tubing is cut away in the vicinity of ports **40** and **46** to provide access to these ports and to permit the port outer conductor to make good electrical contact with channel **22**. Holes **12**a and **14**a are provided through the tubing for bias wire access.

In a phase shifter built for S-Band, the cross sectional dimension was approximately 0.875 inches by 0.75 inches. A 0.001 inch copper foil was used together with Rexolite spacers. A **4** mil wall thickness heat shrinkable Mylar tube was used having an unshrunk diameter of 1.00 inch. Shrinking was performed in an oven at 185° F for 10 minutes.

The invention claimed is:

1. An electrical phase shifter comprising:

spacer means having a cross sectional size approximating the interior dimensions of a waveguide and comprised of a ferrite toroid sandwiched between material which is a relative window to microwave energy; said toroid being centrally located in the sandwich, the perimeter of said spacer means defining the interior surface of said phase shifter, a top and bottom surface of said toroid comprising at least a portion of said interior surface;

electrically conductive material means covering substantially the entire cross-sectional perimeter of said spacer means comprising a structural member which covers approximately one side of said device and a foil sheet which covers substantially the remainder of said cross-sectional perimeter including a first surface of said perimeter which includes said top surface of said toroid;

a rigid plate coextensive with said first surface;

a compressible member coextensive with said rigid plate overlying said first surface exterior of said foiled sheet, said rigid plate overlying said compressible member;

a shrinkable tubing enclosing said phase shifter at least to encircle said electrically conductive means, said rigid plate and said compressible member and shrunk to maintain said electrically conductive means in relatively intimate contact with said spacer means; and,

port means for providing electrical communication with the interior portion of said phase shifter.

2. The device of claim **1** wherein said foil sheet comprises copper foil.

3. The device of claim **1** wherein said shrinkable tubing comprises a heat shrinkable tubing.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,758,883 Dated September 11, 1973

Inventor(s) Richard M. Cox, Evan Savatgy

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

At claim 1, line 14, "device" should be -- cross-sectional perimeter -- .

Signed and sealed this 23rd day of April 1974.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents