Dec. 3, 1968 D. A. CASWELL 3,414,846

MICROWAVE ISOLATOR

Filed Nov. 23, 1966

Fig. 1

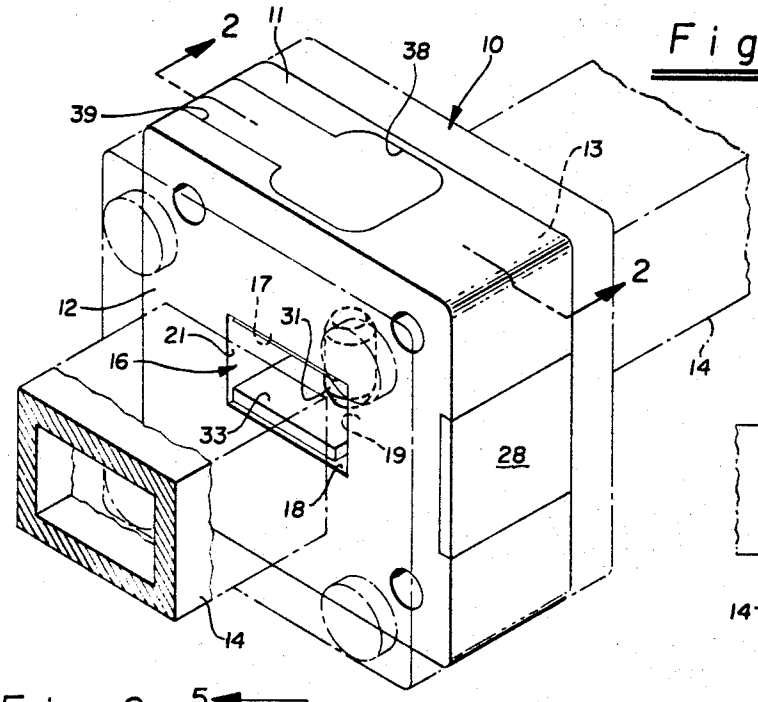


Fig. 6

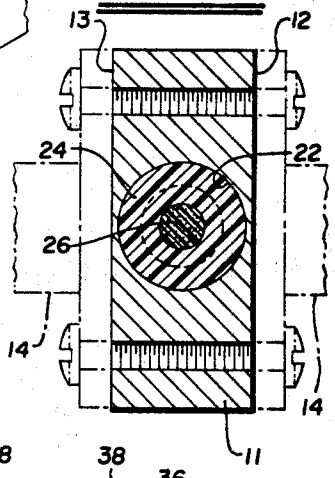
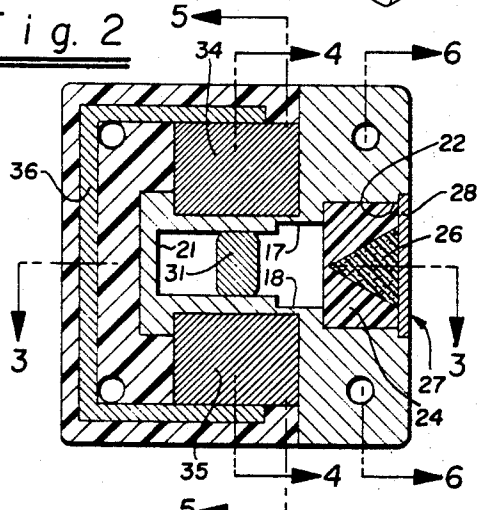


Fig. 2



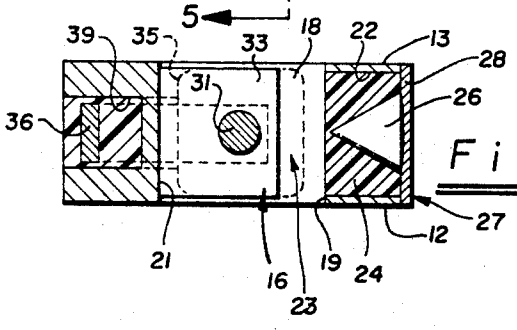


Fig. 3

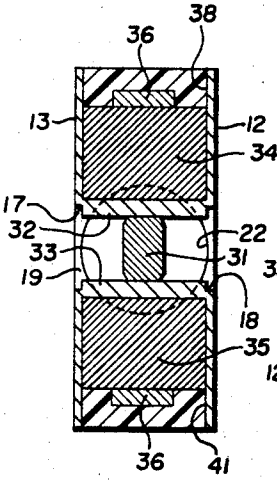


Fig. 4

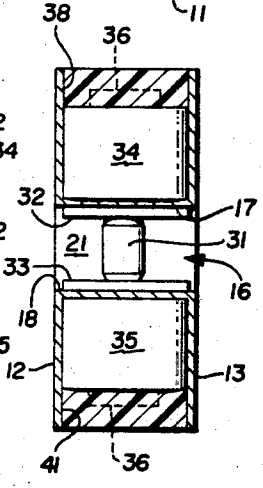


Fig. 5

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MICROWAVE ISOLATOR

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ABSTRACT OF THE DISCLOSURE

An isolator utilizing circulator principles in which one of a pair of joined rectangular waveguides is coupled by gyromagnetic material to a load contained in a shunt connected waveguide section of circular cross section. This provides for an improved impedance match over a wide band of operation.

This invention relates to microwave isolators and particularly to a compact form of such an isolator having a broad bandwidth characteristic.

Heretofore, such isolators have had a dimension in the direction of propagation at least as great as the maximum dimension of the waveguide structure itself and usually greater. Attempts to shorten this dimension and lighten the device have resulted in a narrowing of the bandwidth of its operation. Thus, in some applications such as portable installations, a compact, lightweight isolator having a broad bandwidth characteristic has not been available. There is, therefore, a need for a new and improved microwave isolator.

In general, it is an object of the present invention to provide a microwave isolator which has been miniaturized into a compact, lightweight form, but which retains a broad bandwidth characteristic.

Another object of the invention is to provide a microwave isolator of the above character which is lightweight and which has a minimum dimension in the direction of propagation of the system in which employed.

Another object of the invention is to provide a microwave isolator of the above character which is economical to manufacture, the parts thereof being formed by relatively simple machining operations.

Additional objects and features of the invention will appear from the following description in which the preferred embodiment is set forth in detail in conjunction with the accompanying drawings.

Referring to the drawings:

FIGURE 1 is an isometric view of a microwave isolator incorporating the present invention and showing the same incorporated in a section of waveguide.

FIGURE 2 is a sectional view of the isolator of FIGURE 1 taken along the lines **2—2**.

FIGURE 3 is a sectional view of the isolator of FIGURE 2 taken along the lines **3—3**.

FIGURE 4 is a sectional view of the isolator of FIGURE 2 taken along the lines **4—4**.

FIGURE 5 is a sectional view of the isolator of FIGURE 2 taken along the lines **5—5**.

FIGURE 6 is a sectional view of the isolator of FIGURE 2 taken along the lines **6—6**.

In general, the microwave isolator incorporating the present invention consists of a three arm circulator formed in a metal housing. The housing has first, second and third waveguide sections formed therein, the sections being interconnected by a junction containing a body of gyromagnetic material. Means including magnets, pole pieces and a magnetic return path are mounted about the housing for establishing a magnetic field which is transverse to the direction of propagation of electromagnetic energy through said waveguide sections to thereby bias said gyromagnetic material so that electromagnetic waves travel from one of the transmission line sections into only one of the other of the sections.

The first and second waveguide sections take the form of rectangular waveguides and joined together end to end to form a continuous rectangular waveguide through the device. A dielectrically loaded circular waveguide section having a characteristic impedance matching the characteristic impedance of the rectangular sections is transversely joined to the rectangular section to form a T configuration, the circular waveguide section being the leg of the T. The other end of the circular waveguide section leads into a load so that energy directed into the section is absorbed. Thus, energy travelling in one direction into one of the rectangular waveguide sections is directed through the isolator and out of the other section; whereas energy travelling in the opposite direction into the other rectangular waveguide section is directed into the circular waveguide section and dissipated in the load. It has been found that the impedance of the circular waveguide section with dielectric loading can be made to match the impedance of the rectangular waveguide over a broad bandwidth, and that, when so matched, the cross-sectional dimension of the circular waveguide section is less than the cross sectional width of the rectangular waveguide section.

Referring to the figures, the microwave isolator **10** shown therein consists of a metal housing **11** which is formed from a single block or body of metal, preferably aluminum. The body **11** has flat parallel end faces **12** and **13** which serve as flange faces for permitting the unit to be connected into a section of rectangular waveguide **14** as depicted in phantomed lines. A passage **16** having a rectangular shape in transverse cross-section extends between end faces **12** and **13** and defines upper and lower wide walls **17** and **18** and short side walls **19** and **21**. The size and shape of passage **16** coincides with that of the waveguide **14** so that the inside walls **17, 18, 19, 21** are continuous with and extend between the inside walls of waveguide **14**. As is usual, the upper and lower wide walls **17** and **18** are at least one-half of the wavelength of the wave energy to be conducted therein and the side walls **19** and **21** are about one-half of the wide dimension. Thus, rectangular passage **16** forms first and second rectangular waveguide sections in the housing which are continuous with each other.

A cylindrical passage **22** is bored through the housing and opens transversely into passage **16** through wall **19**, the axis of cylindrical passage **22** being normal to wall **19**. Cylindrical passage **22** serves as the third waveguide section of the circulator and defines a junction **23** with the rectangular waveguide sections where the three sections meet. By intersecting the short dimension side wall, the cylindrical section **22** forms a shunt T connection with the rectangular waveguide sections at the junction.

A low-loss microwave dielectric **24** having a dielectric constant of about 2.1 fills cylindrical passage **22**. Suitable materials are Teflon (*e* 2.08), or irradiated polyolefin (*e* 2.32) and sold under the designation Rexolene P by

Enka Corporation of Concord, Mass. The cross-sectional diameter of the circular waveguide and the dielectric constant of the material filling the guide are selected to achieve an impedance match with the rectangular waveguide sections at the center band of the frequencies being handled. By way of example, for a KU band device, the rectangular sections measured .622 by .311 inch, the diameter of the Teflon loaded cylindrical section was .469 inch, which is slightly less than the cross sectional width of the rectangular waveguide section.

Dielectric material **24** serves to support a suitable load such as a stanard conical load **26** as shown. The end **27** of the circular waveguide section away from the junction is terminated in an electrical short **28**.

A solid cylindrical element **31** formed of a suitable gyromagnetic material such as garnet is disposed at the junction **23**. The element **31** is mounted between raised matching platforms **32** and **33** formed in the wide walls **17** and **18** above and below the element. The platforms serve to cancel out reflections caused by the change of dielectric constant introduced by element **31**.

There is provided a bias magnet assembly consisting of a pair of suitable permanent pole magnets **34** and **35** magnetically connected by a soft iron yoke **36** to form a C-shaped magnet. Recesses **38**, **39**, **41**, are provided in the housing **11** for receiving the magnetic assembly so that its pole magnets are positioned on either side of element **31**. The magnets assembly biases the gyromagnetic element **31** to thereby create known circulator action which directs energy entering one waveguide section into one and only one of the other waveguide sections of the circulator.

The operation of the above-described isolator is as follows. The isolator **10** is connected into a section of rectangular waveguide **14** in which it is desired to propagate electromagnetic energy in one direction and to attenuate electromagnetic energy propagating in the opposite direction. The magnetic field induced within the gyromagnetic element **31** causes electromagnetic energy travelling into one of the rectangular waveguide sections to be directed into and out of the other rectangular waveguide section relatively unimpeded. Electromagnetic energy travelling into the other of the rectangular waveguide sections (i.e., in the opposite direction) is directed by the magnetically biased gyromagnetic element **31** into the third section, i.e. the circular waveguide section wherein its is dissipated in the load **26**.

By way of example, the previously described isolator for use in KU band had the following electrical characteristics and weight:

Isolation	db	18
Insertion loss	db	0.2
Bandwidth	gHz	0.5
Weight	ounce	1

Thus, it is apparent from the foregoing that there has been provided an improved isolator which has good bandwidth characteristics because of the good impedance match between the shunt connected dielectrically loaded circular waveguide and the rectangular waveguide sections.

Moreover, the isolator of the invention is compact and has a simple shape which is economical to manufacture. Thus, beginning with a solid block of aluminum, the rectangular waveguide sections are broached in a conventional manner. The circular waveguide section is drilled into the side of the block with an end mill until the passage **21** formed thereby opens into the side wall of the rectangular waveguide section. The recesses **38**, **39**, and **41** for magnet assembly are easily milled by cutting slots into the outside walls of the block. Each of the gyromagnetic element **31**, the dielectric **24** for the circular waveguide section and the load are of cylindrical or conical form and are therefore easily machined if they are not available in the required form. Assembly of the isolator is also simple, requiring only that the parts be slipped together and held in place as with cement.

It will be understood that many modifications and varying forms of the invention can be made without departing from the spirit and scope of the invention. For example, the disclosure herein specifically calls for a circular waveguide section, it will be appreciated by those skilled in this art that the circular waveguide section may be deformed slightly from the circular cross-section shown while still achieving an excellent impedance match with the rectangular sections. Thus, the cross-section could be altered when manufactured by shifting the boring tool transversely of the rectangular waveguide (i.e. back and forth relative to walls **17** and **18**). This would cause the cylindrical section to become oblong or in the direction of the shift, and, if limited would not depart from the teachings herein. Also, while there has been disclosed the use of a conventional conical load in the circular waveguide, it will be appreciated that many other common loads may be used, such as an appropriately placed resistance card. Accordingly, it should be understood that the disclosures and descriptions herein are illustrative and are not to be taken as a limitation on the invention, the scope of which is to be determined by reference to the appended claims.

I claim:

1. A microwave isolator comprising a three arm circulator including first and second rectangular waveguide sections joined together end to end to form a continuous junction in a rectangular waveguide, said rectangular waveguide sections having walls with a cross sectional width and height dimension suitable for propagating electromagnetic energy, the width dimension being larger than the height dimension, a circular waveguide section intersecting the walls of the rectangular waveguide sections at said junction and into that wall thereof associated with the height dimension, said circular waveguide section having the full inner dimension thereof in open communication with said rectangular waveguide sections to form a T-shunt connection therebetween, the cross sectional dimension of said circular waveguide section being slightly smaller than the cross sectional width dimension of said rectangular waveguide sections, an element of gyromagnetic material disposed at said junction in said rectangular waveguide sections, means for magnetically biasing said gyromagnetic material transversely to the direction of propagation of electromagnetic energy at said junction so that energy travelling in one direction through said rectangular waveguide sections is directed into the other one of said rectangular waveguide sections while energy travelling in the opposite direction is diverted by the action of said biased gyromagnetic material into said circular waveguide section, a dielectric material incorporated into said circular waveguide section, the dielectric constant of said material being selected to achieve an impedance match with the rectangular waveguide section, a load disposed in said circular waveguide section for absorbing electromagnetic energy travelling therein.

2. An isolator as in claim **1** wherein said dielectric material is Teflon.

3. In a microwave isolator, a three arm circulator comprising first and second rectangular waveguide sections joined together to form a junction and a circular waveguide section intersecting said rectangular waveguide sections at said junction to form a shunt connection therewith, said waveguide sections being formed in a solid block of metal having flat parallel faces spaced apart from each other a distance slightly greater than the diameter of said circular waveguide section, said block of metal having a passage passing between said end faces and perpendicular thereto, said passage having a lateral cross section which is rectangular in form, and a cylindrical passageway formed in the side of the block to communicate with the short dimension of said rectangular passage, a dielectric material incorporated into said circular waveguide section, the dielectric constant of said material and

the dimension of said circular waveguide section being selected to achieve an impedance match with the rectangular waveguide sections at the center band of the frequency of operation of the device, a load disposed in said circular waveguide section for absorbing electromagnetic energy travelling therein, an element of gyromagnetic material disposed at the said junction, and means for magnetically biasing said gyromagnetic material.

4. An isolator as in claim 3 wherein said first and second rectangular waveguides are aligned and joined together end to end to form a continuous rectangular waveguide through the isolator, and further, wherein said circular waveguide intersects said rectangular waveguide perpendicularly to the short wall dimension.

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