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Andrikian

[11] **3,851,279**

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[54] **TEE JUNCTION WAVEGUIDE CIRCULATOR HAVING DIELECTRIC MATCHING POSTS AT JUNCTION**

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[52] **U.S. Cl.** ..... **333/1.1,** 333/9, 333/98 M

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

[58] **Field of Search** ..... 333/1.1, 9, 98 M

[56] **References Cited**

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[57] **ABSTRACT**

A broadband tee junction waveguide circulator of improved design is disclosed. A ferrite element of triangular cross-section is disposed in the region of the junction of the two waveguides. Dielectric matching "posts" extending between the broad walls of the waveguide junction near each of the apexes of the ferrite element provide improved impedance matching. The matching posts present independently adjustable capacitive susceptances to the propagating wave energy in the three arms of the device for matching purposes and minimize higher order mode conversion. Those higher order modes which are generated are below cut-off and decay rapidly. The advantages of this configuration are its light weight, relatively small size and ease of tuning.

6 Claims, 2 Drawing Figures

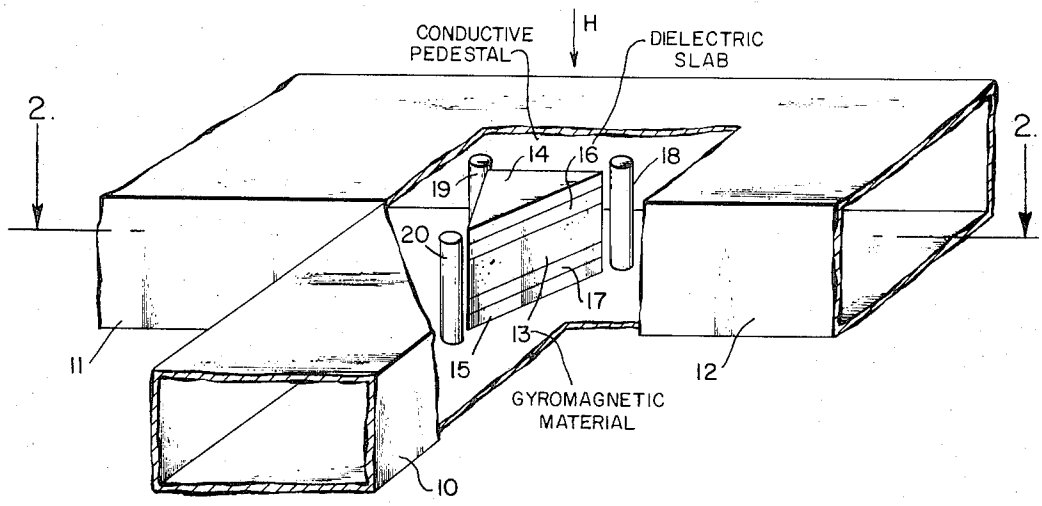


Fig. 1.

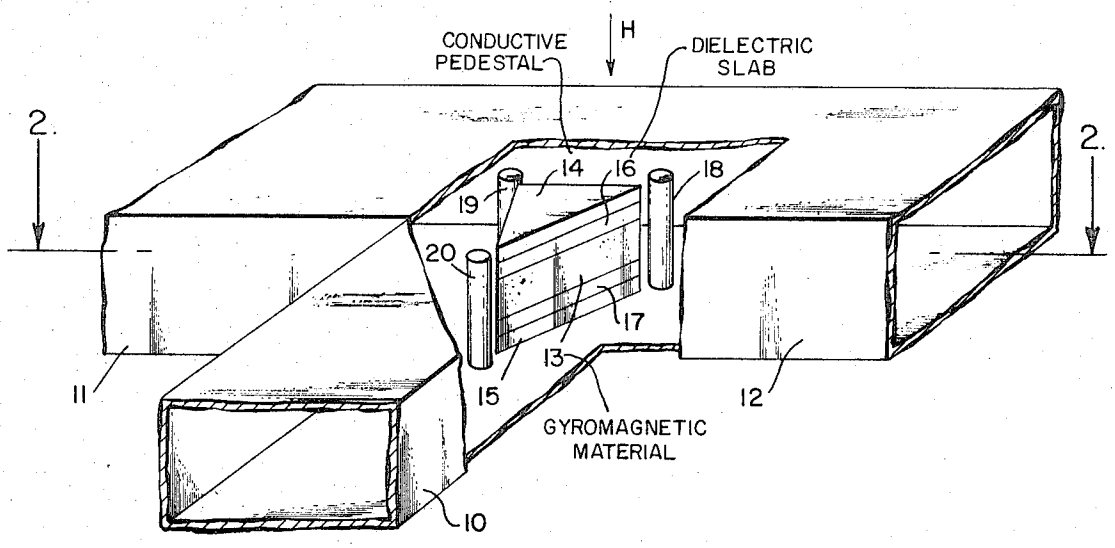
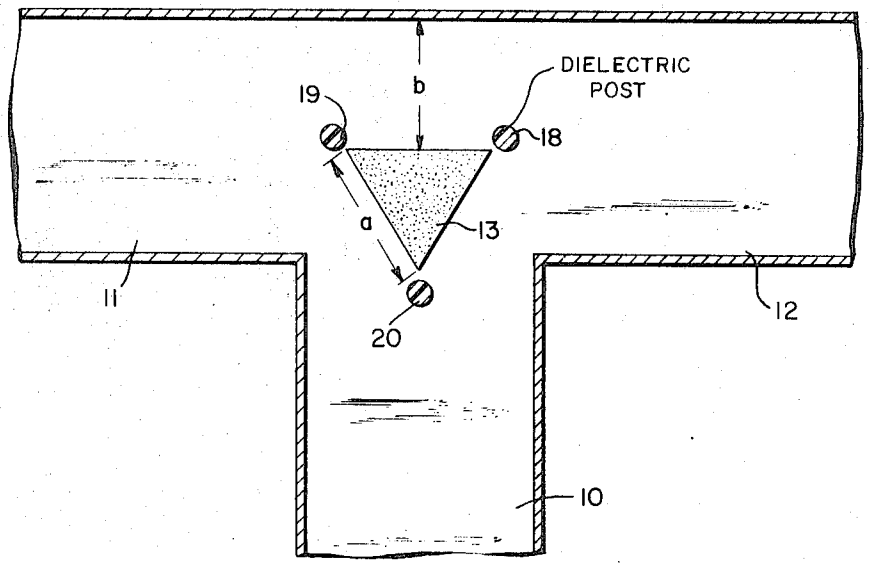

H
CONDUCTIVE PEDESTAL
DIELECTRIC SLAB
2.
2.
14
16
18
19
20
17
13
15
11
12
GYROMAGNETIC MATERIAL
10

Fig. 2.


DIELECTRIC POST
b
19
18
a
13
11
12
20
10

TEE JUNCTION WAVEGUIDE CIRCULATOR HAVING DIELECTRIC MATCHING POSTS AT JUNCTION

FIELD OF THE INVENTION

This invention relates generally to ferrite devices and more particularly to broadband tee junction waveguide circulators.

DESCRIPTION OF THE PRIOR ART

In the operation of microwave equipment it is frequently desirable to transfer electromagnetic wave energy between various portions of the equipment and to control the path of such transfer by circulators, isolators or switching means. In the past, a large number of such means have been proposed and used, some of which have been acceptable for most applications. Probably the most successful circulators and switches for use in the microwave spectrum employ an element of gyromagnetic material such as a ferrite. Commonly, this material is disposed in the junction of one or more sections of waveguides through which the microwave energy is propagated. By creating a magnetic flux field through this element there will be a gyromagnetic effect which may be effectively utilized to control the microwave energy in the desired manner.

Unfortunately, the presence of such a gyromagnetic element in a waveguide causes a change in the impedance of the junction through which the electromagnetic energy is propagated. The resultant mismatching of impedances, in turn, causes standing waves and other losses to occur in the device. In an effort to overcome this effect many schemes have been proposed to match the impedance of the section of waveguide containing the ferrite with the surrounding portions of the waveguides. Since the equipment utilizing such devices is required to operate over a relatively wide band of frequencies it is desirable that the devices themselves have broadband frequency response characteristics. In other words, the impedance match of the device must be within acceptable limits over a relatively broad range of frequencies.

Because of their inherent symmetry, waveguide circulators of the Y-junction variety have been used in applications requiring broadband response characteristics. Various techniques have been employed to achieve broadband operation in such structures. U.S. Pat. No. 3,104,361, which was issued to J. G. Leetmaa and G. S. Uebele on Sept. 17, 1963 describes a broadband waveguide circulator of the Y-junction type. In some applications, for example, where weight and space limitations are important it is desirable to use waveguide circulators of other than the Y-junction variety. For example, because of the fact that the arms of the Y-junction circulator are mutually 120° apart, it is generally necessary to provide additional waveguide bends at at least two of the ports of the junction. Due to this fact, it is desirable to use circulators of the tee junction variety. When this is done, however, the inherently asymmetrical geometry of the tee junction gives rise to much greater problems of impedance matching, particularly impedance matching over frequency ranges comparable to those obtainable with circulators of the Y-junction variety.

Due to symmetry, Y-junction waveguide circulators generally utilize identical matching obstacles in all three ports. However, because the tee junction is asymmetrical matching obstacles of different values are generally required. The problem then is one of obtaining matching obstacles whose values can be adjusted without substantial interaction with the other obstacles. The feature of independently adjustable matching obstacles also allows greater design freedom and relaxed manufacturing tolerances.

Accordingly, it is a general object of the present invention to provide an improved waveguide circulator of the tee junction type having broadband characteristics.

It is another object of the present invention to provide a tee junction circulator having independently adjustable matching obstacles.

SUMMARY OF THE INVENTION

It is therefore proposed, in accordance with the present invention to provide tee junction waveguide circulators in which the energy may be controlled more uniformly over a considerably greater bandwidth. More particularly, this is accomplished not only by utilizing the proven impedance matching and broadbanding techniques employed with Y-junction circulators; but by also including unique dielectric matching structures for the gyromagnetic element. These techniques include the mounting of the gyromagnetic element within the junction formed by the constituent waveguides between metallic pedestals and insulating members and by also including dielectric posts in the vicinity of the corners of the triangular gyromagnetic element. The use of dielectric posts rather than other impedance matching obstacles minimizes the generation of higher order modes which are capable of being supported within the constituent waveguides.

BRIEF DESCRIPTION OF THE DRAWINGS

The above-mentioned and other features and objects of this invention will become more apparent by reference to the following description taken in conjunction with the accompanying drawings, in which like reference numerals correspond to like structural elements and, wherein:

FIG. 1 is a partially broken-away pictorial view of a preferred embodiment of the present invention; and

FIG. 2 is a cross-sectional plan view of the embodiment of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring more specifically to the drawing, FIG. 1 is a partially broken-away pictorial view of a tee junction waveguide circulator according to the present invention. In FIG. 1 three sections of rectangular conductively bounded waveguide **10, 11** and **12** meet in a common H-plane tee junction. Waveguide sections **11** and **12** are arranged coaxially and can comprise, for example, a single rectangular waveguide. Waveguide section **10** abuts waveguide sections **11** and **12** at a right angle to form the junction. Disposed within the junction in a manner to be discussed in greater detail hereinbelow is a triangular slab-like gyromagnetic element **13,** together with its triangular matching and supporting structures.

The supporting structure for element **13** comprises an upper conductive pedestal **14,** a lower conductive pedestal **15,** and upper and lower dielectric slabs **16** and **17,** respectively. Conductive pedestals **14** and **15**

are jointed and conductively bonded to the upper and lower broad walls of the junction, respectively. Upper and lower dielectric members **16** and **17** provide insulating support for element **13** and can be conveniently bonded in place by means of a suitable low-loss adhesive. The composite structure, therefore, resembles a triangular shaped, multi-layer sandwich with gyromagnetic element **13** being sandwiched between dielectric elements **16** and **17** and this combination, in turn, being sandwiched between conductive pedestals **14** and **15.**

In practice, dielectric members **16** and **17** can be fabricated of dielectric material such as Teflon having a dielectric constant on the order of 2.1. An external magnetic field generated, for example, by a permanent magnet or by a suitably energized electromagnet is directed through the gyromagnetic element in a direction perpendicular to the broad wall of the junction. As shown in FIG. **1,** the magnetic field H is directed from above. However, as is well-known in the art, this field can be reversed, thereby reversing the direction of energy circulation.

Although the broadbanding characteristics of the composite pedestal, dielectric member, gyromagnetic element struture of FIG. **1** is well-known, it has been found that in circulators of the tee junction variety, mismatches and narrow band operation can still occur. With the tee junction circulator of FIG. **1,** therefore, additional impedance matching obstacles are employed. These obstacles comprise dielectric posts **18, 19** and **20** which are disposed near the apexes of element **13** and its composite supporting structure. Dielectric posts **18, 19** and **20,** in the shape of right circular cylinders, extend across the interior of the waveguide junction between the broad walls thereof. In general, the dielectric constant of dielectric posts **18, 19** and **20** should be relatively high, on the order of nine to 15. These limits, however, are not absolute but rather represent a good design compromise.

Dielectric posts **18, 19** and **20** present a capacitive susceptance to the wave energy propagating within the guides. The value of the respective capacitive susceptance is a functiotn of the dielectric constant of the material, the diameter of the posts, and their location within the junction. In general, a higher dielectric constant allows a smaller post diameter. Lower dielectric constant and correspondingly greater post diameter may give rise to undesirable multimode effect. Higher dielectric constants and correspondingly smaller post diameters, on the other hand, may result in posts which are more fragile than desirable. In any event, once located, posts **18, 19** and **20** can be bonded in place by a suitable low loss adhesive such as epoxy resin.

Referring now to the cross-sectional view of FIG. **2,** the arrangement of the dielectric posts **18, 19** and **20** is shown, together with the location of gyromagnetic element **13** within the tee junction. Element **13** is preferably disposed within the junction with one apex thereof coinciding with the axis of waveguide section **10.** The opposite side of the gyromagnetic element extends parallel to the axes of waveguide sections **11** and **12** and may be slightly displaced therefrom in the direction of waveguide section **10.** Also the planar top and bottom surfaces of element **13** are parallel to the top and bottom broad walls of the junction. The location of element **13** in this manner is to approximate as nearly as possible symmetrical loading to the wave energy in all three of the waveguide sections forming the junction. Dielectric posts **18, 19** and **20** are individually disposed adjacent each of the apexes of triangular element **13.**

The optimum position for each of the dielectric posts **18, 19** and **20** can be conveniently obtained experimentally. In general, for a given post diameter and dielectric constant, the proper phase position of the compensating capacitive susceptance is found by varying the position of the post longitudinally along the direction of its adjacent waveguide axis (e.g., to the right or left for ports **18** and **19**). The magnitude of the capacitive susceptance presented by the post is adjusted by varying the post position transversely to the waveguide section. The optimum spacing between the apexes of element **13** and its corresponding post is a very small fraction of a wavelength of the propagating wave energy.

In operation, it is assumed that the tee junction circulator of FIG. **1** is interconnected in a microwave circuit by flange couplers or other means well-known in the art. In a typical application waveguide section **11** may be coupled to a source of electromagnetic wave energy and waveguide section **12** may be coupled to a utilization device. Waveguide section **10** may be coupled to a matching load impedance. Such an arrangement comprises an isolator structure widely used in microwave systems. The wave energy is thus coupled into waveguide section **11** and, depending upon the direction and magnitude of the magnetic biasing field H, out of waveguide section **12** or **10.** If it is assumed that the direction and strength of the magnetic field is such as to cause the energy to be coupled out of waveguide section **12,** then any energy entering the junction from waveguide section **12** will be coupled out of waveguide section **10** and any energy entering waveguide section **10** will be coupled out through waveguide section **11.**

Other elements such as screws, capacitive irises and metallic buttons have been proposed for matching purposes. In general, however, these elements are characterized by conductive discontinuities of the sort which give rise to higher order mode conversion. (i.e., modes other than the dominant TE_{10} mode.) In general, higher order modes are to be avoided. Since the dielectric posts present no discontinuities in the vertical or E-field direction mode conversion is minimized. Any other higher order modes caused by the presence of the dielectric posts **18, 19** and **20** are such that they are above cut-off for the waveguide sections **10, 11** and **12.** Thus, they propagate only a short distance in these waveguide sections.

Tee junction circulators of the type shown in FIGS. **1** and **2** have been constructed and operated in the 4 GHz and 6 GHz regions. Such structures have displayed performance characteristics comparable to broadband Y-junction circulators of the type described in U.S. Pat. No. 3,104,361 cited hereinabove. Such circulators have displayed a bandwidth on the order of 12 percent measured between the 20 db points. In a typical device design for the 4 GHz region the following approximate dimensions and parameters were utilized:

TABLE I

Waveguide	
Sections 11 and 12	1.145 × 2.29 in.
Section 10	1.145 × 1.87 in.

TABLE I-Continued

Gyromagnetic element 13	
Material	Trans-Tech G-1010 Garnet
Equilateral triangle base (a)	0.87 in.
Thickness	0.50 in.
Dielectric slabs 16 and 17	
Material	Teflon
Thickness	0.127 in.
Conductive pedestals 14 and 15	
Thickness	0.195 in.
Dielectric Posts 18, 19 and 20	
Dielectric constant	9.5
Diameter (range)	0.190 - 0.227 in.
Spacing Dimension (b)	1.22 in.
Spacing - posts to apex	
Variable - to secure best match (approx.)	0.03 - 0.07 in.

In all cases it is understood that the above-described embodiment is merely illustrative of but one of a number of the many possible specific embodiments which can represent applications of the principles of the present invention. Numerous and varied other arrangements can be readily devised in accordance with these principles by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A microwave circulator comprising, in combination:

three rectangular conductively bounded waveguide sections joined to form a common tee junction and having a pair of opposite broad walls at said junction;

at least one slab-like element of gyromagnetic material of substantially triangular shape disposed within said junction, one apex of said gyromagnetic element being substantially coincident with the axis of the side arm of said tee junction;

three dielectric elements of substantially solid cylindrical cross-section disposed within said junction, each of said dielectric elements extending between said opposite broad walls with one element being immediately adjacent each of the apexes of said gyromagnetic element; and

means for subjecting said gyromagnetic element to a magnetic field directed normal to said broad walls.

2. The circulator according to claim **1** wherein said element of gyromagnetic material is supported within said junction between a pair of dielectric support members and conductive pedestals.

3. In a microwave circulator structure of the type having three sections of rectangular conductively-bounded waveguide sections abutting to form an H-plane tee junction, at least one triangular shaped element of gyromagnetic material disposed within said junction, means for biasing said element with an external magnetic field, and impedance matching members disposed within said junction; the improvement comprising a completely dielectric post extending across the interior of said junction adjacent each apex of said element of gyromagnetic material.

4. The microwave circulator according to claim **3** wherein said posts have a dielectric constant between nine and 15.

5. A microwave circulator comprising, in combination:

first, second and third sections of rectangular, conductively bounded waveguide, said waveguide sections abutting to form a common H-plane tee junction with said first and second sections extending coaxially and said third section extending at a right angle to said first and second sections;

at least one slab-like element of gyromagnetic material of substantially triangular shape disposed within said junction;

at least three dielectric elements of substantially solid cylindrical cross-section disposed within said junction, one of said dielectric elements being adjacent each of the apexes of said gyromagnetic element, and

means for subjecting said gyromagnetic element to a magnetic field.

6. The circulator according to claim **5** wherein one apex of said gyromagnetic element substantially coincides with the axis of said third waveguide section and the opposite side of said gyromagnetic element substantially coincides with the common axis of said first and second waveguide sections.

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