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[54] **CIRCULATOR WITH CONNECTING ARMS DESIGNED IN ACCORDANCE WITH THE MIC TECHNIQUE**

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** ..... **333/1.1**; 333/84 M

[51] **Int. Cl.²** **H01P 1/38**

[58] **Field of Search** 333/1.1

[56] **References Cited**

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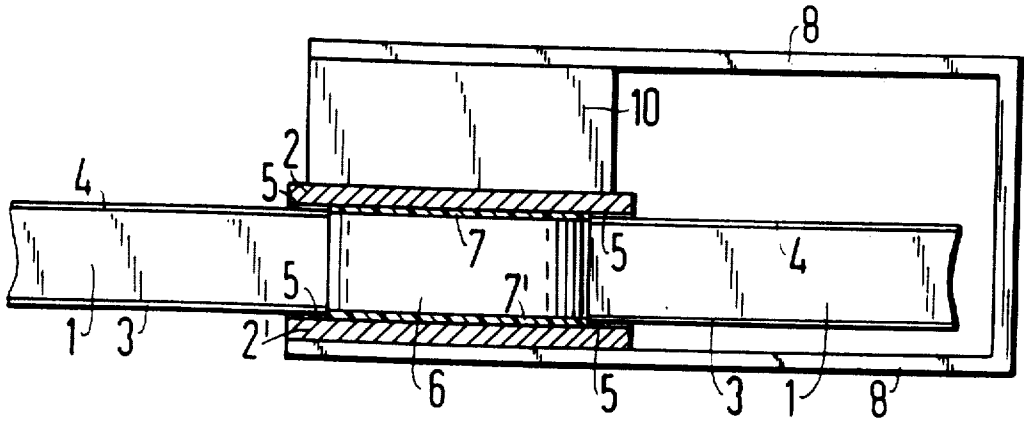
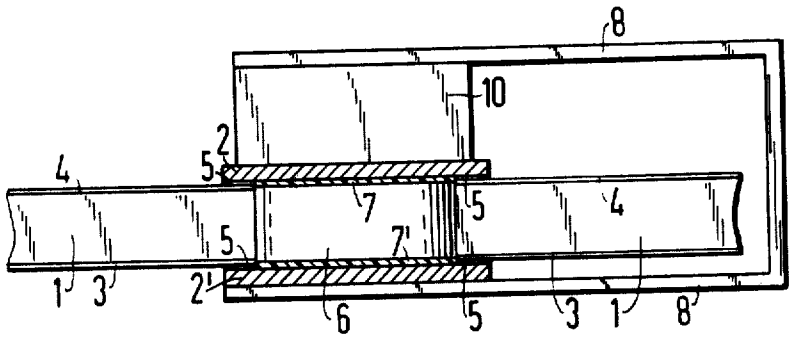
[57] **ABSTRACT**

A circulator includes connecting arms designed in accordance with the MIC technique which merged to form a branch, wherein a disc constructed of gyromagnetic material is arranged in the branching zone and is subjected to a constant magnetic field produced by a permanent magnet. The disc is surrounded by a plate constructed of dielectric material. On one side of the plate the connecting arms for the branch are provided and on the other side of the plate a continuous metallization is applied. An insert consisting of dielectric material is disposed between the line branch and the disc of gyromagnetic material, the dielectric constant of the insert being smaller than the dielectric constant of the gyromagnetic material.

2 Claims, 1 Drawing Figure




8
10
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7'
1'
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2'
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1
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CIRCULATOR WITH CONNECTING ARMS DESIGNED IN ACCODANCE WITH THE MIC TECHNIQUE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a circulator having connector arms constructed in accordance with the microwave integrated circuit (MIC) technique which are merged to form a branch circuit, and more specifically to such a circulator which has a disc of gyromagnetic material arranged in the branching zone and subjected to the influence of a constant magnetic field produced by a permanent magnet and surrounded by a layer of dielectric material. The connecting arms of the branching circuit are carried on one side of the disc while a continuous metallization is provided on the other side of the disc.

2. Description of the Prior Art

In the construction of microwave circuits circulators have found a wide field of application, as is well known, because the microwave energy fed into one arm is passed on almost completely to the other arm which follows in the direction of rotation of the circulator, while one or more additional connecting arms are decoupled as opposed to the connecting arms. A particular well known exemplary embodiment of such branching circulators are constructed so that a three-terminal line branching is provided. In the branching zone itself at least one ferrite or garnet disc is concentrically arranged. In addition, it is important for the electrical operation that the ferrite is subject to a constant magnetic field whose strength as well as the shape and type of the ferrite is determined for the operating frequency range of the circulator. For obtaining a method of construction wherein the circulator is as compact as possible, branching circulators are realized in accordance with so called MIC method of construction, i.e., the line branching or the individual connecting arms respectively, are designed as an integrated microwave circuit. The three connecting arms, and if required also the line branching, are applied onto a plate of dielectric material, such as a ceramic substrate for example, according to the known methods of printing or etching techniques. The opposite side of this plate is generally provided with a continuous metallization. A recess is formed in the plate of dielectric material in the form of a circular bore for example, and a disc consisting of gyromagnetic material is fitted into the recess. Known ferrite and garnet materials are appropriate for use as gyromagnetic materials. A permanent magnet is employed for creating the constant magnetic field as is already known for example from the German published application 2,042,146. The adaptation and the band width of such circulators is determined essentially by the difference between the input resistance of the circulators at the ferrite or the garnet, respectively, and the microwave resistance of the terminal lines. In the case of the prior art arrangements, the input resistance lies, for example, at approximately 10 to 15 ohms, while the wave resistance at the terminal lines amounts generally to approximately 50 ohms. In order to improve the adaptation and its band width, so called $\lambda/4$ termination lines are connected for example between the terminal lines and the intermediate circulator input. In spite of this measure, the bank width which can be achieved and exploited with such circulators is insufficient for many purposes of application since, as it is well known, the adaptation and the decoupling of the individual circulator arms is difficult because of the direct links therebetween.

SUMMARY OF THE INVENTION

A principle object of the present invention is to eliminate the above-mentioned difficulties as much as possible and to provide a circulator construction which is realized in accordance with MIC techniques, and more specifically to the provision of such circulators for obtaining large exploitable frequency band widths and small input reflection factors without disadvantageously influencing the remaining electrical features, such as the transit damping of the circulator for example.

Starting from a circulator having connecting arms constructed in accordance with the MIC technique and merged to form a line branching, wherein a disc of gyromagnetic material is arranged in the branching zone and subjected to a constant magnetic field produced by a permanent magnet and surrounded by a plate of dielectric material, the plate being provided with the connecting arms on one side thereof and a continuous metallized layer on the other side thereof, the above object is achieved according to the invention in that an insert consisting of dielectric material is positioned between the line branches and the disc of gyromagnetic material, the dielectric constant of the insert being smaller than the dielectric constant of the gyromagnetic material.

The invention is based on the realization that an improvement of the adaptation and an enlargement of the band width can be achieved by means of an increase in the input resistance of the gyromagnetic material. This increase of the input resistance can be attained by an artificial decrease of the dielectric constant of the active portion, namely the gyromagnetic material. The dielectric constant of the ferrite or garnet, respectively, is prescribed particularly by their crystalline structure and their chemical compound. The input resistance can be increased by a shifting of the dielectric constant, and the exploitable band width can be enlarged thereby, as is shown, by approximately 50 to 100 percent.

BRIEF DESCRIPTION OF THE DRAWING

Other objects, features and advantages of the invention, its organization, construction and operation will be best understood from the following detailed description taken in conjunction with the accompanying drawing, on which the single FIGURE is a sectional elevation of a circulator constructed in accordance with the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawing, a plate 1 of dielectric material, for example a ceramic material, is provided as a substrate. The connecting arms of the circulator are applied to the substrate in the form of conductor paths 4 on the upper surface of the plate 1 in a manner well known in the art. The connecting arms are merged to form a line branching circuit. On the opposite or bottom side of the substrate 1 a continuous metallized layer 3 is provided. A recess, e.g. a circular bore, is provided in the plate 1 and a disc 6 of gyromagnetic material is inserted into the recess in such a way that it completely fills the space thereof. As gyromagnetic mate-

rial, one may consider the utilization of known ferrite or garnet materials. In order to create a constant magnetic field, a permanent magnet **10** is employed which is located on the upper surface of the dielectric plate **1**, that is on the side which carries the conductor paths **4**.

In an advantageous construction, as is illustrated in the drawing, a pair of pole pieces **2** and **2'** are provided for the permanent magnet **10**. The pole pieces **2, 2'** are arranged facing one another and are disposed concentrically with respect to the ferrite or garnet disc **6**. The pole pieces **2** and **2'** consist of a magnetic material such as iron and are interconnected by a magnetically conductive member **8**. The pole pieces include, at least on the side which faces the conductor paths, a thin layer of electrically highly conductive material, for example, a silver layer. As it is illustrated in the drawing by the solder layers **5**, the upper pole piece **2** can be connected in a highly conductive or low resistance manner with the conductor paths **4** and the lower pole piece **2'** can enjoy the same type of connection with the continuous metallic layer **3**. Thus, the upper pole piece **2** acts as a line branching connection and the lower pole piece **2'** functions as a connection of the continuous metallization **3**. Both pole pieces operate to feed and render the constant magnetic field homogeneous adjacent to a gyromagnetic material **6**.

The previously mentioned shifting of the dielectric constant of the gyromagnetic material **6** can be provided in such a way that an insert **7** is inserted between the pole piece **2** forming the line branching and the disc **6**, which insert **7** consists of a dielectric material having a dielectric constant which is smaller than that of the gyromagnetic material **6**. The thickness of the insert **7** depends on the dielectric constant of the material employed and on the dielectric constant of the disc **6**. A material which has proven to be particularly useful for the insert **7** is a material which is sold under the trademark Teflon, whose relative dielectric constant is approximately **2**.

If necessary, a further increase of the input resistance of the circulator can be provided by the provision of an additional insert **7'** between the pole shoe **2'** and the continuous metallization **3** and the disc **6** of gyromagnetic material. The upper insert **7** may be omitted completely and only the lower insert **7'** be utilized.

An advantageous development of the invention is illustrated in the drawing wherein the permanent magnet **10** is arranged on the side of the ceramic substrate **1** which carries the conductor paths **4**. The constant magnetic field can therefore be closed by way of a magnetic yoke **8**, also consisting of magnetic material, whereby stray fields of the permanent magnet **10** which would otherwise cause interference are no longer effective. For the construction of larger circuit arrangements, the circulator can be arranged in this manner without difficulties in close proximity to magnetically and electrically conductive parts, such as frames, braces or the like, or close to magnetic elements, such as traveling wave tubes for example, without resulting in interfering reactions between the individual elements involved.

Apart from the previously mentioned increase of the input resistance of the circulator and the considerable increase in the useable band width by 50 to 100 percent, and the further resulting decrease of the input reflection factor, it is additionally achieved in the described integrated circulator the $\lambda/4$ transformation line which are possibly required can be more highly resistant and therefore narrower and a smaller part of interfering longitudinal components of the microwave field is stimulated. Since an increase of the diameter of the ferrite or garnet is necessary in general because of the shifting of the dielectric constant of the gyromagnetic material, such a construction is particularly suitable for frequencies in the X band because the normally small diameter of the ferrite can be increased.

Although I have described my invention by reference to a particular illustrative embodiment thereof, many changes and modificatins of the invention may become apparent to those skilled in the art without departing from the spirit and scope of the invention. I therefore intend to include within the patent warranted hereon all such changes and modifications as may reasonably and properly be included within the scope of my contribution to the art.

I claim:

1. A circulator comprising a disc of gyromagnetic material, connecting arms for forming a branch line, said disc disposed in the zone of branching, said connecting arms constructed in accordance with microwave integrated circuit technique and comprising a plate of dielectric material surrounding said gyromagnetic disc, a continuous metal layer carried on a first side of said dielectric plate, separate connecting arm metal layers carried on the second side of said dielectric plate, a permanent magnet adjacent said disc on said second side of said dielectric plate, a first pole piece of magnetic material carrying a highly conductive metal coating disposed between said permanent magnet and said connecting arm layers and electrically connected to said connecting arm layers, a second pole piece carrying a highly conductive metal coating disposed adjacent and electrically connected to said continuous metal layer, a magnet yoke connecting said permanent magnet and said second pole piece, and an insert of dielectric material having a dielectric constant which is smaller than the dielectric constant of said gyromagnetic disc disposed between said first pole piece and said gyromagnetic disc.

2. A circulator according to claim **1**, comprising a further insert of dielectric material having a dielectric constant which is smaller than the dielectric constant of said gyromagnetic disc disposed between said second pole piece and said gyromagnetic disc.

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