United States Patent

[11] 3,573,666

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[21] Appl. No. **802,924**
[22] Filed **Feb. 27, 1969**
[45] Patented **Apr. 6, 1971**
[73] Assignee **General Electric Company**

[54] **FREQUENCY ADJUSTABLE MICROWAVE STRIPLINE CIRCULATOR**
4 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** **333/1.1,** 333/84
[51] **Int. Cl.** **H01p 5/12,** H01p 3/08
[50] **Field of Search** 333/1.1, 24.1, 24.2

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ABSTRACT: A microwave stripline circulator is disclosed which is adjustable for operation over a wide range of frequencies. This is accomplished by a combination of an incremental coarse tuning means and a fine tuning means. The coarse tuning means comprises an arrangement providing for a selectable number of attachment screws around the periphery of the resonator disc of the circulator, and the fine tuning means comprises an arrangement for providing adjustable pressure to a garnet disc positioned at the resonator disc.

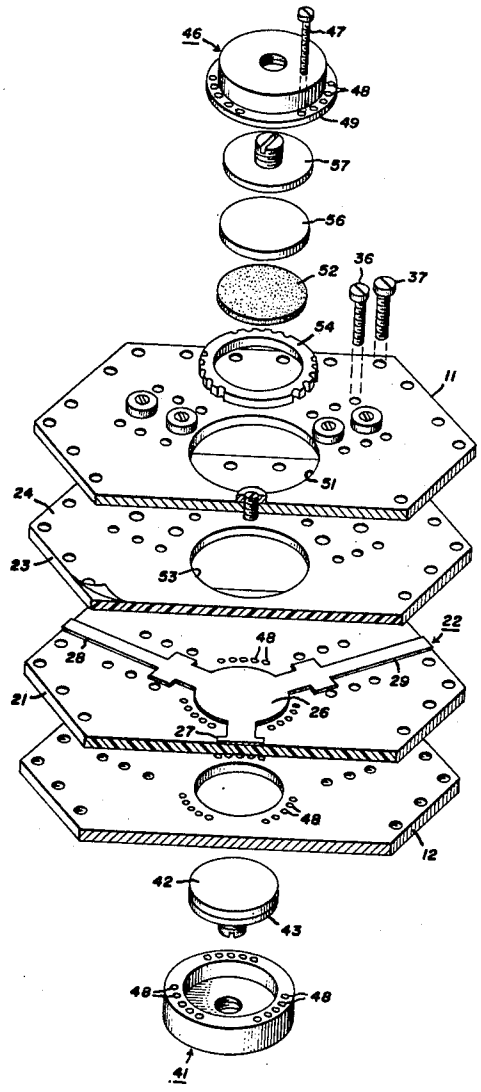

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FIG.1.

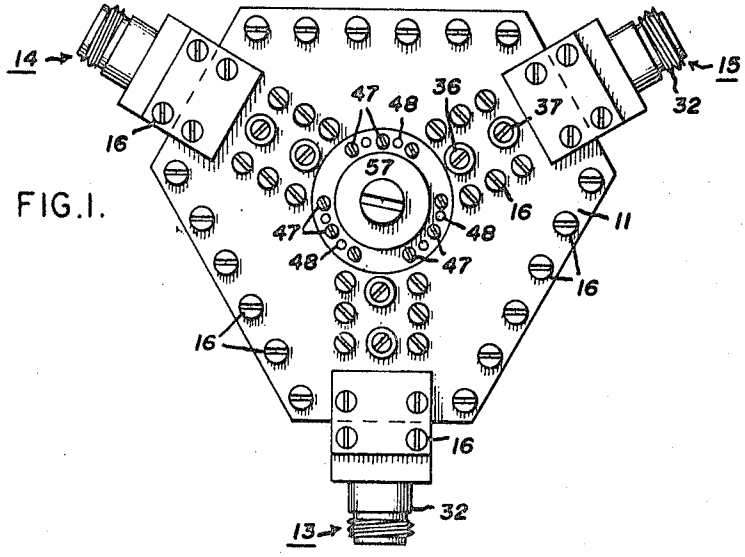

FIG.2.

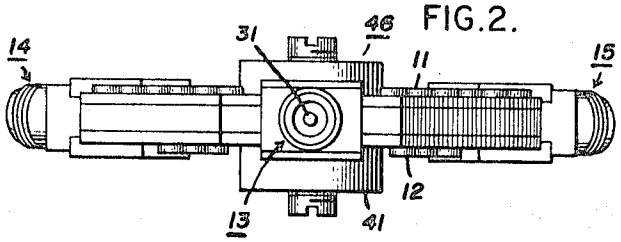

FIG.3.

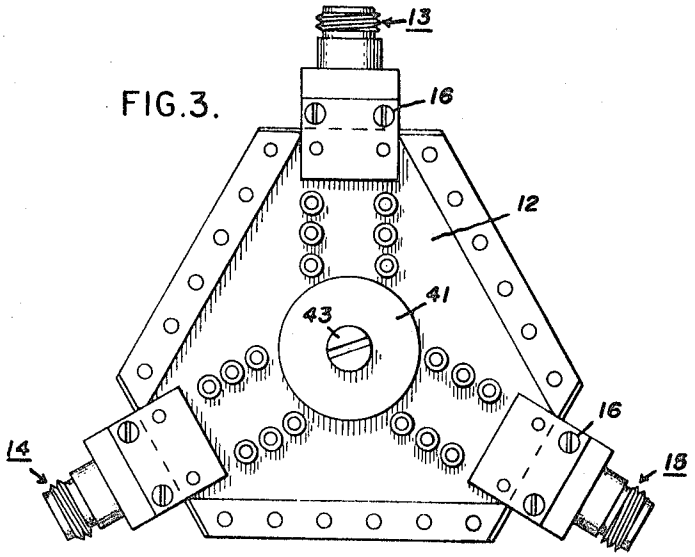

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FIG.5.

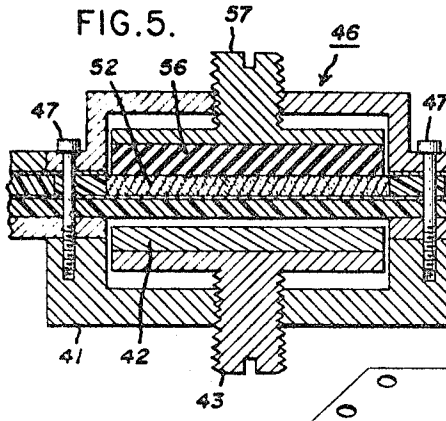

FIG.4.

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FREQUENCY ADJUSTABLE MICROWAVE STRIPLINE CIRCULATOR

BACKGROUND OF THE INVENTION

The invention herein described was made in the course of or under a contract or subcontract thereunder, with the United States Army. The invention is in the field of electrical microwave circulators, of the stripline type, having a plurality of microwave signal input and output ports coupled to a resonator plate.

Microwave circulators are used as duplexers, isolators, attenuators, and switches for electrical signals in the microwave frequency region. The usual construction provides an enclosed circular resonator plate for the electrical signals, and a magnetic field is provided transversely through the resonator plate in order to cause directional changes of the signals. A plurality of signal ports are coupled to the resonator plate at symmetrically spaced points around the periphery thereof. The circulator couples the signal power from one port to another in a desired manner. For example, a three-port circulator may have one port connected to an antenna and the other ports respectively connected to a transmitter and to a receiver; the circulator functions to couple signal power from the transmitter port to the antenna port only, and from the antenna port to the receiver port only.

The circulator must have certain critical dimensions in order that it will function properly at the desired frequency or over a desired frequency bandwidth. The stripline construction, which has become widely used, employs a layer of electrically conductive material, shaped in a suitable pattern to form the resonator plate and its matching structure, suitably supported between and insulated from a pair of ground planes. To achieve circulator action, a disc or plate of garnet or other suitable material is positioned between the resonator plate and one of the ground planes, and a magnetic bias is applied to the garnet in a direction transverse to the plane of the resonator disc.

Since it is difficult to manufacture microwave circulators sufficiently accurately to insure operation at the desired frequencies, various means have been devised for adjusting the frequency of operation. One such means is to provide for adjustment of the magnetic field, by various methods. This means, however, tends to undesirably affect the directional coupling of the signals. Other means that could be used for tuning a circulator include mechanical arrangements for varying the circulator dimensions. This incurs problems of mechanical complexity.

SUMMARY OF THE INVENTION

Objects of the invention are to provide an improved circulator for electromagnetic waves, to solve or diminish the prior-art tuning problems described above, to provide improved tuning means for a circulator, and to tune a circulator over a wide range of frequencies.

The invention comprises, briefly and in a preferred embodiment, a microwave circulator of stripline construction provided with a resonator plate and having a plurality of signal ports connected to said resonator plate at spaced points around the periphery thereof. A garnet member is positioned between the resonator plate and a ground plane, and a transverse magnetic field is provided through the garnet member. In accordance with a feature of the invention, a plurality of assembly screws are provided through the stripline boards and cover plates thereof, around the periphery of the resonator plate and garnet member, there being openings provided through the assembly for more than the nominal number of screws required for holding the assembly together. A selected number of the assembly screws of electrically conductive material are inserted through the openings therefor, both to hold the assembly together and also to adjust the operating frequency of the circulator to the nearest desired value or to a value at which the fine tuning can tune to the desired frequency. By inserting a greater or lesser number of the assembly screws through the openings therefor, the operating frequency band of the circulator is adjustable in incremental steps for achieving coarse tuning.

In accordance with another feature of the invention, an adjustable pressure means is positioned against the garnet disc for varying the pressure thereon whereby the operating frequency of the circulator is continuously tunable ("fine" tuning) over the frequency ranges between the incremental coarse tuning frequency values. The aforesaid combination of coarse and fine tuning adjustments achieves a wide continuous tuning range, for example over a range of 90 Megahertz from 1270 Megahertz to 1360 Megahertz.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a top plan view of a microwave stripline circulator in accordance with a preferred embodiment of the invention,

FIG. 2 is a side view of the embodiment of FIG. 1,

FIG. 3 is a bottom plan view of the embodiment of FIG. 1,

FIG. 4 is an exploded perspective view, partly in cross section, of the embodiment of FIG. 1, and

FIG. 5 is a cross-sectional view of a portion of the embodiment of FIG. 1, taken through the center thereof.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The circulator shown in the drawing comprises a top plate 11 of metal, (usually nonmagnetic) a bottom plate 12 of metal (usually nonmagnetic), and three coaxial signal connectors 13, 14 and 15 suitably disposed around the edge of the circulator. These parts of the assembly are secured together by means of screws 16 or other suitable means.

As best shown in FIGS. 4 and 5, sandwiched between the top and bottom plates 11 and 12 there are a stripline circuit board 21 of electrically insulative material adjacent to the bottom plate 12 and carrying an electrically conductive pattern 22 on the upper surface thereof, and a ground-plane board 23 of electrically insulative material and carrying a layer of copper 24 on the upper surface thereof. The stripline circuit pattern 22 on the insulative board 21 comprises a central circular conductive region 26, and three connector strips 27, 28, and 29 joining the circular plate 26 to the center conductors 31 of the coaxial connectors 13, 14, and 15, respectively, in a well-known manner in the circulator art. The outer portions 32 of the coaxial connectors 13, 14 and 15 are connected to the metal top and bottom plates 11 and 12. A pair of adjustment screws 36 and 37 are threaded through the top plate 11 and pass through openings in the ground plane plate 23, so as to have their bottom ends adjustably spaced from the stripline connector segments 27, 28, and 29, in order to vary the capacitance thereof with respect to electrical ground, for achieving impedance matching and a small degree of frequency tuning.

A cup-shaped bottom pole piece 41 of magnetic material is secured to the bottom plate 12 centrally thereof. A permanent magnet 42, of disc shape, is secured to an adjustable threaded member 43 threaded in the member 41, so that the permanent magnet 42 can provide an adjustable magnetic field transversely through the conductive plate 26 and a garnet member as will be described.

In accordance with a feature of the invention, a cup-shaped top pole piece 46 of magnetic material is positioned centrally over the top of the structure in order to complete the biasing magnetic field path and also to provide magnetic shielding, and a plurality of attachment screws 47 are provided through openings 48 in the various parts of the assembly around the periphery of the resonator plate 26, in each segment between the connector strips 27, 28, and 29. The attachment screws 47 pass through the openings 48 in the upper cup member 46, the ground plane plate 23, the stripline plate 21, the bottom conductive plate 12, and are threaded into the bottom member 41, thus securing the assembly tightly together around the periphery of the resonator plate 26. In the embodiment shown, the top pole piece 46 is provided with a flange 49

which fits within an opening **51** in the top conductor plate **11**. A greater number of openings **48** for the attachment screws **47** is provided than is necessary for the required number of screws for holding the assembly together, in order to permit a selectable number of attachment screws **47** to be employed in order to provide coarse frequency tuning increments for the device, as will be described more fully later on.

A disc **52** of garnet or other suitable material is positioned in an opening **53** of the ground plane board **23**, adjacent to the resonator plate **26**. For convenience in manufacturing, a spacer ring **54** is positioned around the garnet disc **52** within the opening **53**. A rubber or other resilient disc **56** is positioned over the garnet disc **52**, and a threaded pressure plate **57** is threaded into a central opening of the upper housing **46**, so that rotation of the pressure member **57** provides adjustable pressure on the garnet disc **52**. The resilient disc **56** assures even distribution of pressure on the garnet, and prevents undesired fracturing of the garnet due to localized high pressure gradients caused by irregularities on the surfaces of the garnet **52** or pressure plate **57**.

The magnetic field produced by the permanent magnet **42** transversely through the garnet member **52** causes microwave signals fed in from certain of the ports to be directed to certain other ports nonreciprocally, in well-known manner.

It will readily be understood that the manufacturing tolerances for the various component parts of the stripline circulator are critical in order that it function at the desired frequency or over the desired frequency bandwidth. In accordance with the coarse and fine tuning features of the invention, the stripline circulator is tunable in steps over a wide frequency range, thereby enabling correction for out-of-tolerance manufacturing, or permitting looser tolerances for the manufacturing, or permitting tuning to a different frequency than for which the circulator was originally designed. The attachment screws **47** are of electrically conductive material, and their presence around the periphery of the resonator plate **26** has an effect on the frequency tuning thereof, due to their effect on the leakage or fringing electromagnetic field around the resonator plate and garnet assembly. As has been explained, more attachment screw holes **48** are provided than are actually required for securing the circulator parts together at the periphery of the resonator plate **26**, so that, by providing more or less than the nominal number of screws **47** required for proper attachment, the frequency tuning of the circulator can be adjusted in discrete steps without adding appreciably to the manufacturing cost. Preferably the screws **47** are disposed in similar patterns in each of the three segments between the junction feed strips **27, 28, 29**. For example, as shown in FIG. **1**, five screw openings **48** are provided in each segment, and screws **47** are provided in openings numbers 1, 3, and 5 in each segment. The following table shows the center frequency and the 36 decibel frequency bandwidths achieved with different numbers of screws **47** positioned in different patterns in the arrangement as shown having five screw holes **48** in each of the three segments, the holes being numbered 1 through 5 consecutively in each segment for purposes of the

Location of screws in each Segment	Center frequency, M Hz.	36 db bandwidth, M Hz.
Holes 1-2-3-4-5	1,383	251
Holes 1-2-4-5	1,362	252
Holes 1-3-5	1,339	248
Holes 2-3-4	1,308	242

By providing a greater number of adjustment screw openings **48** in each sector than the five shown in the drawing, a greater number of incremental frequency adjustments may be achieved.

Fine tuning adjustment is achieved by turning the threaded pressure plate **57**, to vary the pressure on the garnet disc **52**. This variation of pressure on the garnet changes its magnetic characteristics so as to affect the frequency tuning of the circulator. It has been found possible to vary the fine tuning, as thus described, over the frequency ranges achievable by the incremental coarse tuning arrangement.

From the foregoing description, it is evident that the invention achieves its objectives of providing an improved stripline circulator tuning arrangement of economical and reliable construction, for tuning the circulator over a wide range of frequencies at microwave or other frequency ranges.

While a preferred embodiment of the invention has been shown and described, other embodiments and modifications thereof will be apparent to persons skilled in the art, and will fall within the scope of invention as defined in the following claims.

I claim:

1. An electrical signal circulator comprising an assembly of a pair of spaced-apart ground planes, a resonator plate positioned between said ground planes, a plurality of signal junctions connected to said resonator plate at spaced points around the periphery thereof, a member of garnet or like material positioned between said resonator plate and one of said ground planes, and means for providing a magnetic field transversely through said resonator plate and garnet member, said assembly being provided with a plurality of openings transversely therein positioned around and spaced from the periphery of said resonator plate and garnet member in each segment between said signal junctions, said openings being adaptive to receive assembly screws for holding the assembly together, a selected number of assembly screws positioned in at least some of said openings in each section for holding said assembly together and also constituting conductive members for effecting incremental coarse frequency tuning of the circulator, and a fine frequency tuning means for said circulator comprising means for adjustably applying pressure to said member of garnet or like material.

2. A circulator as claimed in claim **1**, including a bracket member positioned over and spaced from said member of garnet or like material and provided with openings in alignment with said plurality of openings, said assembly screws being positioned in said bracket member openings for holding the bracket member in place, said means for adjustably applying pressure to the member of garnet or like material comprising a pressure member in threaded engagement with said bracket member.

3. A circulator as claimed in claim **2**, including a pressure distribution member of resilient material positioned between said pressure member and said member of garnet or like material.

4. A circulator as claimed in claim **2**, including a second bracket member positioned below and spaced from said resonator plate and provided with openings in alignment with said plurality of openings, said assembly screws being positioned in said second bracket member openings for holding the second bracket member in place, said means for providing said magnetic field comprising an adjustable magnetic structure in threaded engagement with said second bracket member.