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MICROWAVE STRIP TRANSMISSION LINE CIRCULATOR HAVING STEPWISE CHANGES IN CENTER CONDUCTOR WIDTH FOR IMPEDANCE MATCHING PURPOSES

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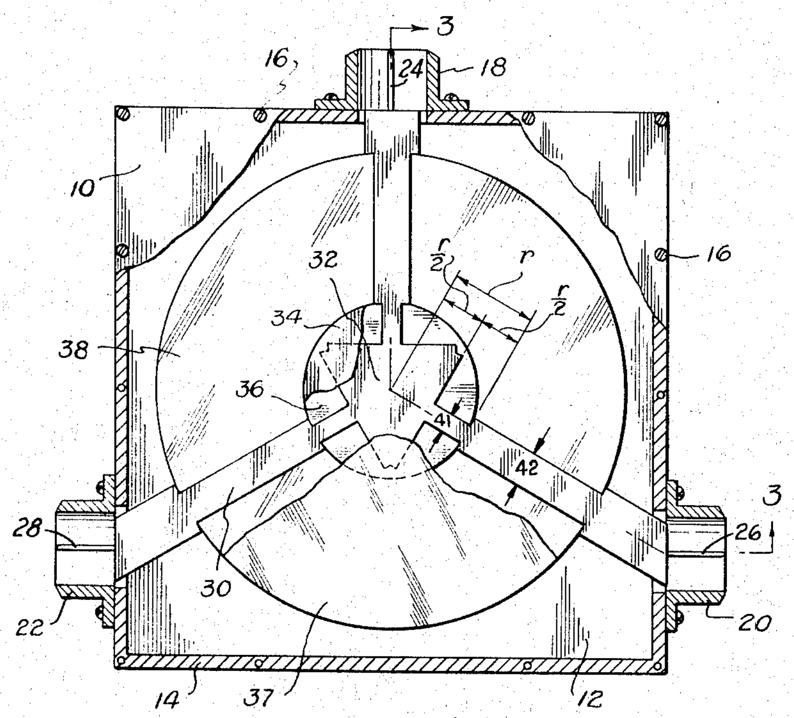

Fig. 1

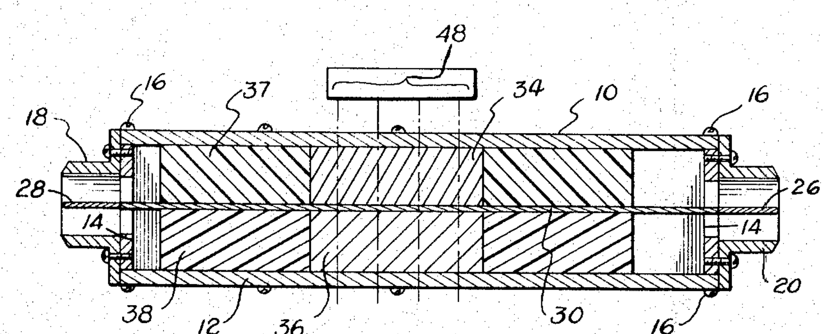

Fig. 3

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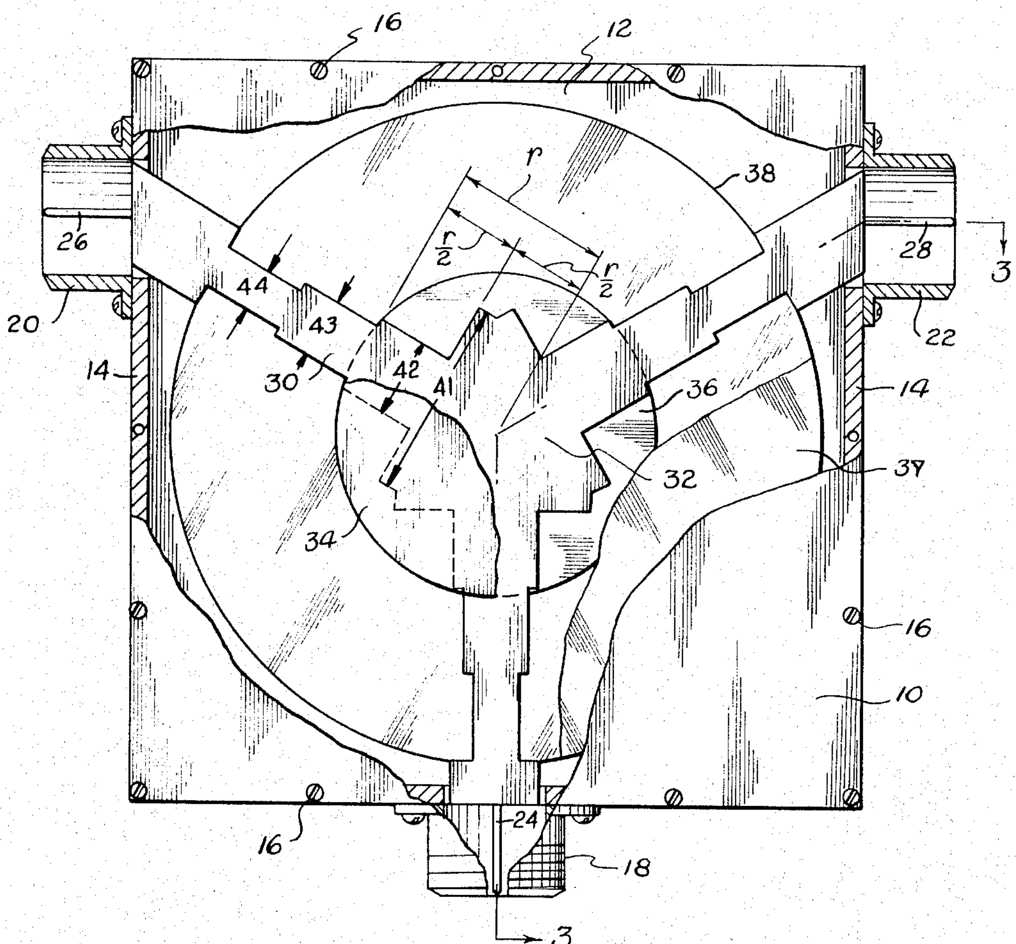

Fig. 2

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MICROWAVE STRIP TRANSMISSION LINE CIRCULATOR HAVING STEPWISE CHANGES IN CENTER CONDUCTOR WIDTH FOR IMPEDANCE MATCHING PURPOSES

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Continuation of application Ser. No. 389,580, Aug. 14, 1964. This application June 1, 1967, Ser. No. 642,974
8 Claims. (Cl. 333—1.1)

ABSTRACT OF THE DISCLOSURE

A microwave transmission device having spaced ground planes and a Y-shaped planar conductor between them. The central portion of the planar conductor is covered by gyromagnetic bodies and outer portions of the planar conductor are covered by dielectric bodies. The legs of the Y-shaped planar conductor each have at least one stepwise change in width for matching purposes.

This application is a continuation of Ser. No. 389,580, filed Aug. 14, 1964, now abandoned.

This invention relates in general to microwave circulators and in particular to such devices for use in strip line microwave transmission systems.

Circulator devices which utilize the unique properties of energized gyro-magnetic material, such as ferrite, at a junction in microwave transmission systems are well known in the art. One of the most popular varieties is the Y circulator developed by U.S. Naval Research Laboratory scientists H. N. Chait and Dr. M. L. Kales, which has had considerable application in both coaxial and hollow waveguide systems.

It has been demonstrated that the Y type circulator is especially adaptable to TEM mode systems and that by such adaption many of the attendant advantages of a single mode microwave transmission system may be achieved in a relatively compact assembly. In addition, it has been demonstrated that the strip line coaxial embodiment of the prior art Y circulator affords heat dissipation advantages and improved bandwidth and size advantages, as well.

It is recognized, however, that the basic adaption of a Y circulator in accordance with essentially straight forward strip line techniques has not provided a solution to many problems in the transmission of microwave energy. In particular, difficulties have been experienced in maintaining a proper impedance match due to temperature sensitivity and frequency sensitivity of the ferrite material. It will be appreciated that such impedance deviation at the junction point adversely affects bandwidth characteristics and that greater temperature and frequency stability are essential requirements for optimum performance of microwave transmission line hardware in selected applications.

Accordingly: It is an object of this invention to provide a Y circulator for strip line transmission systems having a relatively wide bandwidth characteristic per unit size.

It is also an object of this invention to provide a Y circulator which is relatively insensitive to temperature deviations.

It is another object of this invention to provide a Y circulator which is relatively insensitive to frequency deviations.

It is still another object of this invention to provide a Y circulator which may be easily manufactured.

It is a further object of this invention to provide a Y circulator for strip line transmission systems which will handle relatively high power.

It is an additional object of this invention to provide a relatively compact Y circulator having a broadband characteristic in the UHF range.

Other objects of this invention will become apparent upon a more comprehensive understanding of the invention for which reference is had to the following specification and drawings wherein:

FIGURE 1 is a plan cutaway showing of a first embodiment of the device of this invention.

FIGURE 2 is a plan cutaway view showing of a second embodiment of the device of this invention.

FIGURE 3 is a cross-sectional showing of a typical embodiment of the device of this invention.

Briefly, the device of this invention is a Y circulator of the strip line variety having a structural assembly which affords an improved impedance transition between coaxial ports with a minimum enlargement of the junction.

Referring now to the drawings: FIGURES 1 and 2 each depict a three port circulator of the strip line variety in plan view without the magnetic field producing means by which the device is energized to provide a circulator action. It will be appreciated that a magnetic field producing means is essential to the operation of the device and that its omission in FIGURES 1 and 2 is merely for purposes of clear illustration.

In the embodiments of FIGURES 1 and 2 a pair of circulator ground plane members **10** and **12** are shown mounted in parallel spaced-apart relationship by means of a peripheral cover member **14**, with the plates **10** and **12** and the member **14** together forming the body of the circulator. These three members are of electrically conductive material, and may conveniently be secured together by any suitable means, for example, by a plurality of threaded fasteners **16** disposed about the peripheries of the two plates **10** and **12**. A plurality of coaxial connectors **18**, **20** and **22** are symmetrically disposed about the cover member **14** to form the ports of the circulator. The center conductors **24**, **26** and **28** of the three coaxial connectors are connected to the ends of respective arms of a conductive spider member **30**, such spider member having a central portion **32** in substantial registry with the central portions of the ground plane members **10** and **12**.

As will be evident to those skilled in the art, energy in coaxial lines connected to the connectors **18**, **20** and **22** will be propagated into the circulator of the present invention by means of the strip transmission line configuration of the components therein, and, similarly, microwave energy within the circulator will be propagated in a nonreciprocal manner by such strip transmission line configuration to one or more of the ports formed by the connectors **18**, **20** and **22**, for transmission through coaxial lines connected thereto.

In order to render this three port Y junction a circulator, a pair of gyromagnetic bodies **34** and **36** are suitably mounted (by means not shown) on opposite sides of the conductive spider member **30**, and in substantial registry with the central portion **32** thereof. The particular composition of the members **34** and **36** is not critical in the present invention, and any substantially electrically nonconductive material exhibiting ferrimagnetic or gyromagnetic effects may be employed. Selected iron garnet polycrystalline materials are exemplary for this purpose.

In the embodiment of FIGURE 1, each arm of the spider member **30** has a stepwise reduction in width, indicated at **41**, in the region of the ferrite **34**, **36** and is increased in width, as indicated at **42**, in the region of the dielectric rings **37** and **38** which surround the ferrite. It will be appreciated that the width and therefore the direction of the stepwise change in width in the region of the dielectric is determined by the relative dielectric constants of the ferrite 34, 36 and the dielectric rings 37, 38.

In the embodiment of FIGURE 2 each arm of the spider member 30 has a stepwise reduction of width, indicated at 41, in the region of the ferrite 34, 36 and is further reduced in width as indicated at 43 and 44 in the region of the dielectric rings 37 and 38, which surround the ferrite.

It will be appreciated that the size and shape of the ferrite 34, 36 may differ from that shown in FIGURES 1 and 2 and that the dielectric constants of the ferrite members 34, 36 and the dielectric rings 37 and 38 surrounding may be in any selected relation. For example, in a typical UHF embodiment designed for operation in the .5–1.0 gc. range, the ferrite may have a dielectric constant K=14 and the dielectric rings may have a dielectric constant K=15.

As referred to above, the width of each portion of the arms of the spider member 30 in each embodiment is largely dependent upon the dielectric constant of the ferrite and the dielectric rings. For example, in the embodiment of FIGURE 2, considering a 50 ohm air dielectric width at the coaxial connector, the arms of the spider member 30, which may be made of .032 inch stock, may have a width 2.540 inch in the region of the ferrite indicated at 41, a width 1.255 inch in the region of the ferrite, indicated at 42, and a width .830 inch in the region of the dielectric ring indicated at 43 and a width of .275 inch at 44. In such a UHF embodiment, several sections of reduced width indicated at 41 and 42, may have lengths of .735 inch where r which is the radius of the ferrite disk is the perpetual measure measured from the center of the ferrite. These lengths may be $\lambda m/4$ and the dielectric ring may have a length of $\lambda m/2$, where λm is the wavelength in the particular dielectric medium. Thus, the sections may have lengths of $\lambda m/4$ where λm is the wavelength in the particular medium (gyromagnetic medium having a particular dielectric constant or dielectric medium having a particular dielectric constant) which covers the section under consideration. The outer diameter of the dielectric ring 38 largely determines the over-all size of the circulator, of course, and thus it will be appreciated that for any given ferrite structure the circulator of this invention is substantially smaller than circulators affording somewhat comparable impedance transition by use of conventional center conductor and a plurality of ¼ wavelength dielectric rings surrounding the ferrite.

For the dimensions exemplary set forth above, the device of FIGURE 2 provides an impedance transition from 50 ohm line to a ferrite impedance of approximately 5.6 ohms in steps of 26.3 ohms, 13.6 ohms, and 10.3 ohms. At higher frequencies, for example, C-band (4–8 gc.) an impedance step-down of 42 ohms, 27 ohms and 16.3 ohms might be obtained by judicious selection of dimensions.

In operation of the embodiments of FIGURES 1 and 2, a unidirectional magnetic field producing means is adapted to apply a magnetic field of determined magnitude in a direction perpendicular to the plane of the spider member 30, as shown in the cross-sectional view of FIGURE 3. This may be accomplished by any suitable means 48. To obtain circulator action, the magnitude of the field is such that the ferrite is maintained either above or below resonance, and the requisite magnitude is determined by the size and type of gyromagnetic material employed.

For a given direction of magnetic field, into the sheet for FIGURES 1 and 2, microwave energy incident on coaxial port 18 will exit the circulator via coaxial port 20 with no output at coaxial port 22. Likewise, microwave energy incident on port 20 will exit the circulator via port 22 with no output at port 18, microwave energy incident on port 22 will exit port 18, etc. As recognized by those skilled in the art, the clockwise direction of travel, above described, may be reversed merely by reversal of the direction of the magnetic field.

As shown in FIGURE 3, wherein parts corresponding to those shown in FIGURES 1 and 2 are identified with like reference numbers, the ground plane members 10 and 12 are supported in parallel spaced apart relationship by means of the cylindrical cover member 14, the latter having a plurality of coaxial connectors mounted thereon. The conductive spider member 30 is mounted in parallel relation with the ground planes 10 and 12 at the midpoint therebetween with the outer ends of the arms of the spider member 30 connected to the center conductors of respective ones of the coaxial connectors mounted on cover member 14. Also as shown, the ferrite members 34 and 36, and the dielectric members 37 and 38 as well, are mounted on opposite sides of the spider member in juxtaposition with the ground plane members 10 and 12 and the spider member 30 such that the members 10, 12 and 30 are in heat transfer relation with the ferrite and dielectric and thus serve to dissipate the heat energy generated therein. It is recognized, of course, that suitable auxiliary cooling means, not shown, may be employed in accordance with standard microwave techniques to dissipate the generated heat energy.

The device of this invention has been exemplary described in several embodiments. It will be appreciated, however, that this invention is not limited to these embodiments and that numerous modifications in accordance with the present state of the art are within the purview of this disclosure. For example, the spider member 30 may include more than the number of stepped sections shown in the several embodiments, if desired, and more than one dielectric ring with or without a stepped section may be employed in applications where minimum size is not a critical requirement. Likewise, the device of this invention is not restricted to three ports nor to use in conventional coaxial systems as well. In addition, the means for magnetizing the gyromagnetic material may provide a magnetic field other than as shown in the drawings.

It has been found that the compact device of this invention provides a substantial improvement in bandwith. More particularly, the three step embodiment of FIGURE 2 has demonstrated a bandwidth improvement of over an octave in comparison with comparable size devices of the prior art.

Finally, it is understood that this invention is to be limited only by the scope of the claims appended hereto.

I claim:

1. In a broadband microwave transmission device, the improvement comprising, in combination:

first and second ground plane members disposed in spaced parallel relation to each other;

conductive planar means disposed between and in parallel relation with and spaced from said ground plane members, said conductive planar means having a central portion and a plurality of elongated members extending therefrom at equal angles, the spacing of said elongated members of said planar means with respect to said ground plane members being sufficient to support TEM-mode energization;

at least two bodies of gyromagnetic material adapted to be magnetized by a magnetic field and having a first selected dielectric constant disposed on opposite sides of at least said central portion of said planar means;

at least two bodies of material having a second selected dielectric constant on opposite sides of said elongated members of said planar means;

each of said elongated members of said planar means having like stepwise changes in width along the length thereof defining like discrete width regions such that there are impedance transformations which provide a wider bandwidth than if there were no stepwise changes, at least one of said stepwise changes in width being disposed between said bodies of gyromagnetic material.

2. A device as defined in claim 1 wherein there are two stepwise changes in width substantially between said bodies having a second selected dielectric constant.

3. A device as defined in claim 1 wherein said bodies of gyromagnetic material have a predetermined dimension with respect to said common point of said elongated members and one stepwise change is substantially at the mid-point of said predetermined dimension.

4. In a broadband microwave transmission device, the improvement comprising, in combination:

first and second ground plane members disposed in spaced parallel relation to each other;

conductive planar means disposed between and in parallel relation with and spaced from said ground plane members, said conductive planar means having a central portion and a plurality of elongated members extending therefrom at equal angles, the spacing of said elongated members of said planar means with respect to said ground plane members being sufficient to support TEM-mode energization;

gyromagnetic means adapted to be magnetized by a magnetic field and having a first selected dielectric constant and disposed on said central portion of said planar means;

dielectric means having a second selected dielectric constant and disposed on said elongated members of said planar means;

each of said elongated members of said planar means having a plurality of like stepwise changes in width along the length thereof defining like discrete width regions such that there are impedance transformations which provide a wider bandwidth than if there were no stepwise changes, at least one of said stepwise changes in width being under said dielectric means.

5. In a broadband microwave transmission device, the improvement comprising, in combination:

first and second ground plane members disposed in spaced parallel relation to each other;

conductive planar means disposed between and in parallel relation with and spaced from said ground plane members, said conductive planar means having a central portion and a plurality of elongated members extending therefrom at equal angles, the spacing of said elongated members of said planar means with respect to said ground plane members being sufficient to support TEM-mode energization;

gryomagnetic means adapted to be magnetized by a magnetic field and having a first selected dielectric constant and disposed on said central portion of said planar means;

dielectric means having a second selected dielectric constant and disposed on said elongated members of said planar means;

each of said elongated members of said planar means having a plurality of like stepwise changes in width along the length thereof defining like discrete width regions such that there are impedance transformations which provide a wider bandwidth than if there were no stepwise changes, said dielectric means abutting said gyromagnetic means, and at least one

of said stepwise changes in width being disposed in substantial alignment with the area where the dielectric means and the gyromagnetic means abut.

6. A device as defined in claim 5 wherein at least one of said stepwise changes in width is under said dielectric means.

7. A device as defined in claim 5 wherein the length of the elongated members between stepwise changes is equal to an integer multiple of a quarter wavelength.

8. In a broadband microwave transmission device, the improvement comprising, in combination:

first and second ground plane members disposed in spaced parallel relation to each other;

conductive planar means disposed between and in parallel relation with and spaced from said ground plane members, said conductive planar means having a central portion and a plurality of elongated members extending therefrom at equal angles, the spacing of said elongated members of said planar means with respect to said ground plane members being sufficient to support TEM-mode energization;

gyromagnetic means adapted to be magnetized by a magnetic field and having a first selected dielectric constant and disposed on said central portion of said planar means;

dielectric means having a second selected dielectric constant and disposed on said elongated members of said planar means;

each of said elongated members of said planar means having a plurality of like stepwise changes in width along the length thereof defining like discrete width regions such that there are impedance transformations which provide a wider bandwidth that if there were no stepwise changes, said gyromagnetic means including at least two bodies on opposite sides of said planar means, and said dielectric means including at least two bodies on opposite sides of said planar means, said bodies of gyromagnetic material being discs which extend between the ground plane members and the conductive planar means, and said bodies of material having a second selected dielectric constant being annular having their inner peripheries engaging the peripheries of said discs and extending between said ground plane members and said conductive planar means so that the conductive planar means and the ground planes are in heat transfer relation with the bodies of gyromagnetic material and of said second selected dielectric material to dissipate the heat energy generated therein.

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