

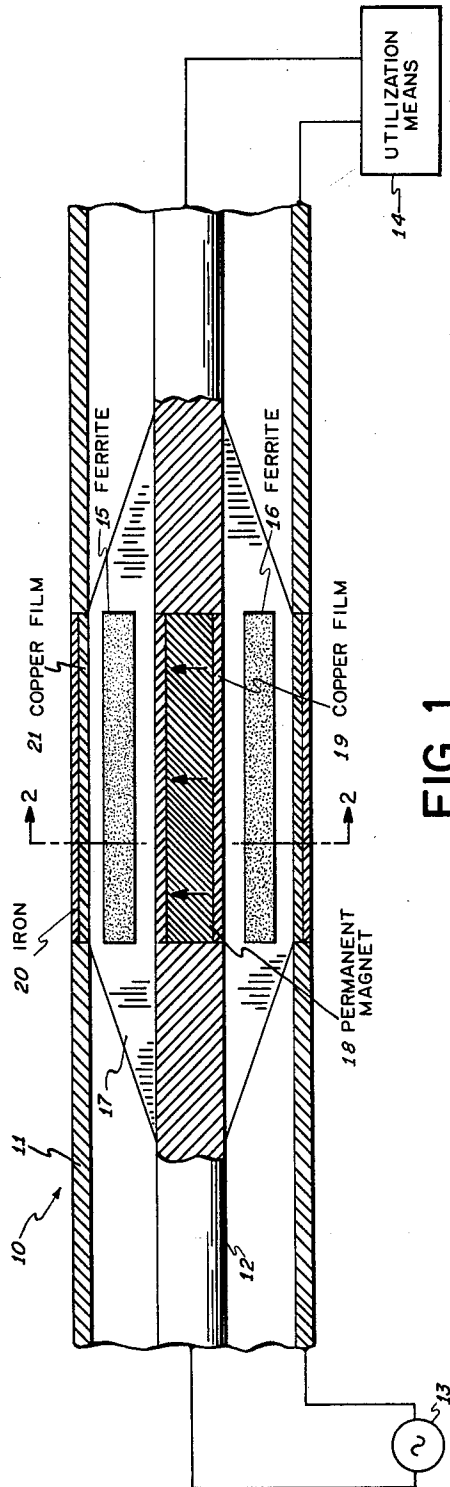
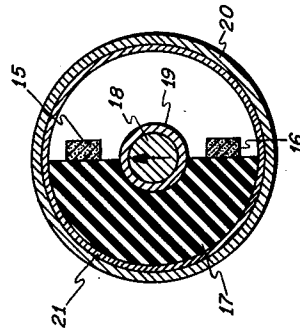
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W. C. HEITHAUS

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INTERNAL MAGNET COAXIAL LINE DEVICE

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INVENTOR.
WILLIAM C. HEITHAUS
BY
Henry H. Hays
ATTORNEY

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INTERNAL MAGNET COAXIAL LINE DEVICE

William C. Heithaus, Dunedin, Fla., assignor to Sperry Rand Corporation, a corporation of Delaware
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This invention relates to magnetic circuits, and more particularly it concerns an improved means for providing a magnetic bias to certain electromagnetic wave devices.

The present application is a division of copending application S.N. 2,259, filed January 30, 1960, and is particularly directed to an internal magnet coaxial transmission line type of device, of which I am the sole inventor.

The present state of the art in microwave technology is characterized by extensive use of certain new materials which, when magnetically biased in the presence of microwave energy will exhibit a gyromagnetic effect. By proper control of the amount and direction of the magnetic bias, this effect may be used to control incident microwave energy in any of a number of ways. In this manner such devices as switches, phase shifters, isolators, attenuators, duplexers, amplifiers and polarization rotators have been successfully built and operated.

The advantages of these devices, however, have remained subject to a major limiting factor; that of providing the required magnetic bias. In the case of isolators and attenuators, the material in the device is often biased to a point where gyromagnetic resonance occurs. This may require magnetic field strengths in the order of 2,000 oersteds. In order to provide these required values of magnetic field within the material to be biased, a magnet larger than the device itself is sometimes necessary. Conventional biasing techniques generally involve the use of large horseshoe type magnets encasing the coaxial structure. The size and configuration of these magnets present difficult problems in weight, cooling and accessibility, and may render these devices impractical for certain applications.

A second disadvantage which, under certain circumstances, may be as great a detriment as required magnet size, is the susceptibility of these devices to stray magnetic fields. These stray fields will add to or detract from the magnetic biasing field and cause erratic operation of the material within the device.

Consequently, it is an object of this invention to provide a light-weight, low-cost, means for effectively biasing a gyromagnetic element in a transverse electromagnetic mode propagating device.

It is a further object to provide a magnetically biased coaxial line type device, wherein a smaller size and more effective cooling are obtained through the elimination of externally mounted magnets.

Another object of this invention is to provide a magnetically biased coaxial line type device which makes most efficient use of the biasing field.

It is a still further object to provide such a device which is substantially unaffected by stray magnetic fields.

These and other objects of the invention will become more apparent from the following description and claims.

Briefly, this invention accomplishes its purpose in the following manner:

A permanent magnet is located within the coaxial line device and is shaped and positioned to fit within or to form the actual structure of its center conductor. The magnet is oriented and located to properly direct magnetic flux through the gyromagnetic material which is also located within the device. The outer walls of the device may be of a low magnetic reluctance material to provide

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an easy flux return path and to shield the device from stray externally generated magnetic fields. The walls also have conductive internal surfaces in order to contain the microwave field and to minimize electrical resistance losses in these surfaces.

In the drawings:

FIG. 1 is a longitudinal section view of one preferred embodiment of the invention;

FIG. 2 is a cross sectional view taken along the line 2—2 of FIG. 1.

FIGS. 1 and 2 show an embodiment of the invention as applied to a coaxial line isolator. This is a non-reciprocal device which permits microwave energy to flow in one direction but attenuates electromagnetic waves propagating in the opposite direction. The coaxial line 10 into which the device is integrated is seen to consist of a hollow tubular outer conductor 11 in coaxial alignment with and enclosing a cylindrical center conductor 12. The outer and inner conductors are electrically and magnetically insulated from each other and thus define a high frequency transverse electromagnetic mode propagating region in the space between them.

Two strips 15 and 16 of ferromagnetic material are placed longitudinally on either side of the center conductor. These strips are exposed to the propagating microwave field and when magnetically biased under proper conditions will either transmit or attenuate the field depending upon its sense of circular polarization. A dielectric insert 17 fills approximately half the volume enclosed by the outer conductor 11 in the vicinity of the ferromagnetic strips 15 and 16. This insert serves to distort the incident microwave magnetic field configuration, which in coaxial line normally propagates in a transverse electromagnetic mode. The distortion is of such a nature that the field exhibits a circularly polarized component. This circular polarization is necessary for non-reciprocal action in gyromagnetic microwave devices.

A portion of the center conductor 12 in the area of the ferromagnetic strips 15 and 16 is removed and replaced by a permanent magnet 18 of the same size and shape. Any magnetic material, such as Alnico may be used for this purpose so long as it can be magnetized sufficiently to provide the necessary bias to the ferromagnetic strips. In practice, however, it has been found that the grain oriented barium ferrite magnets exhibit high coercive forces which make them more desirable for these devices. It is to be noted that for this application, the magnet 18 is polarized with its poles running along opposite sides of its cylindrical surface rather than being located at the ends. Also, the poles are aligned so as to direct magnetic flux through the ferromagnetic strips 15 and 16 in a direction transverse to the flow of microwave energy. An electrically conductive film 19 is either painted or plated on the surfaces of the magnet 18. This provides an electrical continuation of the center conductor 12 of the coaxial line. This film of course would be unnecessary in the case where a permanent magnet material is chosen which has a surface conductivity approaching that of copper or silver.

A length of the outer conductor 11, also in the vicinity of ferromagnetic strips, is removed and replaced by a tubular section 20 of the same dimensions. This section is made of a low magnetic reluctance material such as iron, and provides an effective return path for magnetic flux. This makes more efficient use of the available flux with consequent reduction in the required magnet size. Furthermore, the complete enclosure of the system by this material provides a magnetic shield which protects the system from the effects of stray external magnetic fields. An electrically conductive film 21 is either painted or plated on the inside surface of the low re-

luctance outer section 20 in order to provide an electrical continuation of the outer conductor of the line.

During operation of the device, microwave energy originating at a generator 13 travels toward a utilization means 14 via the coaxial line 10 in a TEM mode configuration. Upon encountering the dielectric insert 17 the microwave magnetic field is distorted in such a manner as to cause a circularly polarized component to be generated. The sense of circular polarization, however, is such that propagation of energy toward utilization means 14 will be relatively unaffected by the ferromagnetic strips 15 and 16. Should any of this energy be reflected by discontinuities between the strips and the load, it will impinge upon the isolator from the opposite direction. The sense of circular polarization now will appear reversed to the ferromagnetic strips and resonant attenuation will occur, thus preventing this reflected energy from reaching the generator 13.

The magnetic flux which provides the necessary bias for the ferromagnetic strips 15 and 16 originates from the permanent magnet 18, which forms the center conductor. The flux flows first through the upper strip 15 into the low-reluctance section 20 of the outer tubular conductor 11, it then travels around the conductor, through the lower strip 16, and again into the magnetic source 18. The electrically conductive films 19 and 21 on the permanent magnet and the low-reluctance magnetic outer conductor provide an electrical continuation of the coaxial line, while allowing easy passage of magnetic flux from the magnetic components to the ferromagnetic strips.

While the invention has been described in its preferred embodiments it is to be understood that the words which have been used are words of description rather than of limitation and that changes within the purview of the appended claims may be made without departing from the true scope and spirit of the invention in its broader aspects.

What is claimed is:

1. A transverse electromagnetic wave transmission line device comprising,
 - first and second longitudinally extending spaced-apart and conductively separated electrical conductors for guiding electromagnetic waves in a transverse electromagnetic mode along a path defined by said conductors,
 - an element of magnetic polarizable gyromagnetic material that exhibits gyromagnetic effects to electromagnetic waves propagating along said conductors, said gyromagnetic element being positioned between said conductors in the propagating path of said waves, and
 - a permanent magnet entirely enclosed within and sep-

arated from the propagating path of said waves by one of said conductors,

said permanent magnet being positioned in its enclosing conductor in the region adjacent said gyromagnetic element and being magnetized transversely to said conductor to immerse said gyromagnetic element in a transverse magnetic field.

2. The combination as claimed in claim 1 and further including,

a member of low magnetic reluctance material adjacent the other one of said conductors and exterior to the propagating path of said waves,

said member of low reluctance material substantially enclosing said conductors, thereby providing a low reluctance flux return path for the magnetic flux produced by said permanent magnet.

3. A coaxial transmission line nonreciprocal device comprising,

a section of coaxial transmission line having longitudinally extending inner and outer conductors conductively separated from each other for propagating electromagnetic waves in a transverse electromagnetic mode,

mode distorting means disposed between said conductors and incompletely filling the cross-sectional area therebetween for distorting said transverse electromagnetic mode to produce circularly polarized components of said electromagnetic waves,

at least one element of magnetic polarizable gyromagnetic material that exhibits gyromagnetic effects to waves propagating through said line,

said gyromagnetic element being positioned between said conductors in the region of circular polarization of waves propagating through said line,

a permanent magnet located entirely within said inner conductor in the region occupied by said element of gyromagnetic material and magnetized transversely to said transmission line for transversely magnetizing said gyromagnetic element, and

a tubular element of a low magnetic reluctance material surrounding said outer conductor for providing a low reluctance magnetic flux return path for the magnetic flux produced by said permanent magnet.

4. The combination claimed in claim 3 wherein said permanent magnet is a longitudinally extending bar magnet magnetized transversely to its longitudinal dimension.

No references cited.