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HEAT TRANSFER MEMBER FOR COAXIAL WAVEGUIDE DEVICE

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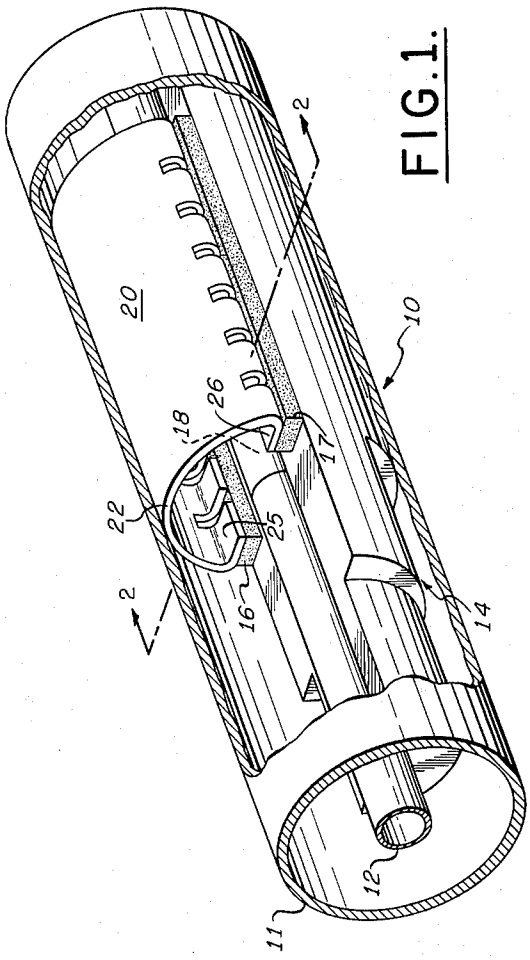


FIG. 1.

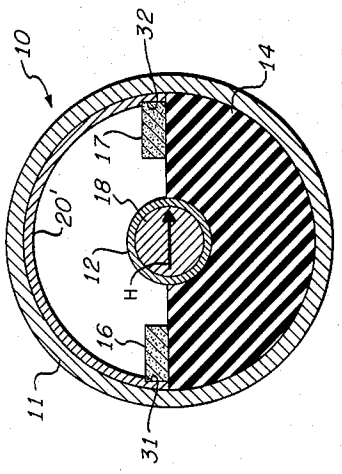


FIG. 3.

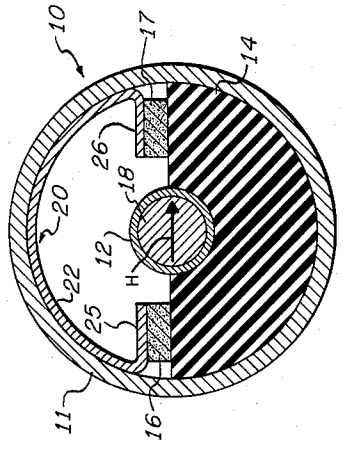


FIG. 2.

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HEAT TRANSFER MEMBER FOR COAXIAL WAVEGUIDE DEVICE

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This invention relates to a means for cooling an element of gyromagnetic material employed in a TEM mode waveguide device.

The present invention is particularly useful in coaxial line isolators and phase shifters of a type described in U.S. Patents 3,078,425, issued February 19, 1963, in the name of B. J. Duncan, and 3,072,867, issued January 8, 1963, in the name of W. C. Heithaus, and both assigned to applicant's assignee. These devices, particularly the isolators, often are limited in their power handling capabilities because the R.F. energy dissipated in the gyromagnetic material, ferrites and garnets for example, causes the material to heat up. It is well known that the gyromagnetic material begins to lose its gyromagnetic properties as its temperature approaches the Curie temperature of the material. This means that for a given isolation ratio the power handling capabilities of the device will be limited, or if the device must operate at a higher power level a sacrifice will have to be made in the isolation ratio. Various attempts have been made to overcome the heat problem associated with high average power gyromagnetic devices. One approach has been in the development of gyromagnetic materials having higher temperature capabilities and the other approach has been in the nature of physical structures and/or arrangements to provide efficient heat transfer paths between the gyromagnetic material and the outside surface of the waveguide device. Arrangements to improve heat transfer out of the gyromagnetic material may involve circulation of a fluid coolant near or in contact with the material, or the material may be placed against a conductor of the coaxial line. However, these procedures are in many cases impractical, either because the additional size or weight or cost are intolerable, or because the electrical properties desired in the particular application cannot be obtained with such structures. For example, the optimum front to back loss ratio in a coaxial isolator is quite often obtained when the gyromagnetic material is positioned between the outer and inner conductor and in contact with neither one. Furthermore, the material shapes which have demagnetizing factors yielding optimum temperature stability are not shapes which have a broad flat surface which can be conveniently placed against one of the conductors for good heat dissipation. A gyromagnetic material with a rectangular cross section with its broad dimension parallel to the magnetic field is usually best for temperature stability. The same shape is usually desirable in devices where a small magnet must be used, as in Patent 3,072,867, mentioned above.

In the coaxial line device utilizing the present invention, the gyromagnetic material is most often in one of the shapes described above, where the shape provides good temperature stability and requires a small magnet but is not readily cooled by contact with a conductor of the line. The gyromagnetic material is most often supported on a dielectric material that serves to distort the magnetic field of the wave propagating in the line. Any heat generated in the material must travel to the dielectric, then through the dielectric to reach the outer conductor of the coaxial line. The heat is then lost to the surrounding environment from the outer conductor. Because the dielectric mode distorting material typically will have very poor

thermal conductivity, the heat transfer paths from the gyromagnetic material to the outer conductor of the coaxial line are poor, with the result that the temperature of the gyromagnetic material rises considerably higher than the temperature of the outer conductor. In some instances the temperature differential between the outer conductor and the gyromagnetic material may be as much as 100° C. or more.

It therefore is an object of this invention to provide an efficient heat transfer path between an internally positioned element and a conductor of a coaxial line device.

It is another object of this invention to provide a simple and economical device to increase the power handling capabilities of a coaxial line device utilizing gyromagnetic material.

A further object of this invention is to provide an insertable heat transfer device that may be utilized readily with existing coaxial line devices to cool gyromagnetic materials located therein, and thus to improve the power handling capabilities of said existing device.

It is another object of this invention to provide an insertable heat transfer member for use in a non-reciprocal coaxial line device.

It is a further object of this invention to provide means for cooling an element of gyromagnetic material disposed between the conductors of a TEM mode transmission line waveguide device.

Another object of this invention is to provide an efficient heat transfer path in a TEM mode transmission device utilizing gyromagnetic material without the addition of physical apparatus or structure to the exterior of the device.

In accordance with the present invention, structurally simple and thermally efficient heat transfer paths are provided between internally positioned elements of gyromagnetic material and the outer conductor of a coaxial transmission line by a heat transfer member that has a rounded portion comformable to the inner surface of said outer conductor and having transversely-extending portions that make good surface contacts with the gyromagnetic elements. The heat transfer member is made of a radially-thin material having good thermal conduction properties, low magnetic permeability, and high mechanical resilience, whereby it is rigidly held in position between the outer conductor of the line and the gyromagnetic elements.

The present invention will be described by referring to the accompanying drawings wherein:

FIG. 1 is a perspective view, partially cut away, illustrating the heat transfer device of the present invention assembled in a coaxial line device;

FIG. 2 is a cross-sectional view taken at section 2—2 of FIG. 1; and

FIG. 3 is a cross-sectional view illustrating an alternative embodiment of the present invention.

Referring now in detail to FIG. 1, the coaxial line device **10** may be an isolator of the type previously referred to and includes outer conductor **11** and inner conductor **12**. A member of dielectric material **14** having a cross-sectional shape in the form of a sector of an annulus is disposed between outer conductor **11** and inner conductor **12** and serves as the magnetic field mode distorting means to induce circularly polarized components of the R.F. magnetic field propagating between conductors **11** and **12**. Disposed on the top surfaces of the dielectric member **14** are two longitudinally-extending elements **16** and **17** of a material that possesses gyromagnetic properties in the presence of the R.F. electromagnetic waves propagating through the device. This material may be one of the ferrimagnetic materials that now are well known to the art. Elements **16** and **17** are mag-

netically biased, or polarized, in a direction transverse to the longitudinal axis of device **10** by means of a transversely magnetized permanent magnet **18** that is located within center conductor **12** in the region of the line occupied by elements of gyromagnetic material **16** and **17**, as disclosed in the above-mentioned Patent 3,072,867. The device as described thus far has found use as a phase shifter, and as a resonance isolator. When used as an isolator for example, gyromagnetic elements **16** and **17** absorb electromagnetic energy propagating in one direction in the coaxial waveguide. When the electromagnetic energy is propagating at a sufficiently high power level, the absorbtion of energy causes elements **16** and **17** to heat up considerably, and because dielectric member **14** and the air space on the opposite side thereof are relatively poor thermal conductors, elements **16** and **17** cannot readily dissipate their absorbed heat. It has been found that the positioning of gyromagnetic elements **16** and **17** for optimum interaction with electromagnetic waves often is some place intermediate the surfaces of conductors **11** and **12**. The dimensions of the ferrite material usually are rather critical so that it is not possible to extend the radial dimensions of the ferrite member to permit it to contact one of the conductors without radically degrading the performance of the device. In accordance with this invention the heat transfer member **20** is positioned within the device **10** so as to provide an efficient heat transfer path to the outer conductor **11**. Heat transfer member **20** extends longitudinally along the line in the area occupied by gyromagnetic elements **16** and **17** and is comprised of transverse cross-sectional regions that includes a rounded portion **22** that is conformable to the curvature of the inner surface of outer conductor **11**. Heat transfer member **20** further includes axially-extending edged portions **25** and **26** that are bent around to extend transversely inwardly so as to be adapted to contact gyromagnetic elements **16** and **17**. Heat transfer member **20** is comprised of a radially-thin material that has high thermal conductivity for good heat transfer, low magnetic permeability so as not to materially affect the magnetic field, and a high mechanical resilience so as to have the characteristics of a spring. Beryllium copper has been successfully used as the material for heat transfer member **20**. The radius of curvature of the curved portion **22** may be made slightly longer than the radius of curvature of the inner surface of outer conductor **11** so that heat transfer member **20** must be slightly radially-compressed when inserted within the device. The resilient properties of member **20** then assures good mechanical rigidity and excellent heat transfer paths between gyromagnetic elements **16** and **17** and the outer conductor **11**. To assure these features, the axially-extending edged portions **25** and **26** conform to the contacting surfaces of gyromagnetic elements **16** and **17**, which in the device of FIG. 1 requires that said edged portions be substantially flat in order to contact the flat top surface of the slabs of gyromagnetic material. As illustrated in FIG. 1, these axially-extending edged portions may be serrated or notched in order to provide spring fingers that firmly contact the gyromagnetic elements **16** and **17**. These spring fingers assure good surface contact with gyromagnetic elements **16** and **17** and thus maintain large contact areas for transferring heat from the gyromagnetic elements **16** and **17**.

The radial spacing between the axially-extending edged portions **25** and **26** and center conductor **12** should be sufficient to prevent power breakdowns from occurring across the gaps that are formed therebetween. With this precaution in mind, the axially-extending edged portions **25** and **26** should be made to cover as much of the top surface of elements **16** and **17** as possible. The thickness of the material of the heat transfer member **20** should be sufficient to provide an efficient heat transfer path, but should not be so thick as to make the fingers inflexible or to constitute significant electrical discontinuities within the coaxial waveguide. In a device constructed substantially as illustrated in FIG. 1, a ⅞ inch outside diameter coaxial waveguide operated successfully with a heat transfer member **20** comprised of beryllium copper having a thickness of .015 inch. If the device of FIG. 1 is to be used in an environment of very high physical shock, heat transfer member **20** may be held securely in its desired axial position by having it fit snugly between the coaxial line connectors at the two ends of line **10**, or it may be held in axial position by means of low loss dielectric beads or pins.

In order to improve the surface contacts between heat transfer member **20** and the inner surface of outer conductor **11** and with the top surfaces of gyromagnetic elements **16** and **17**, a material such as a suspension of beryllium oxide powder in silicone grease may be deposited on the outer surface of heat transfer member **20** prior to its insertion in the coaxial line device **10**. In situations wherein the standing wave ratio of the device must be maintained at an extremely low value, the spring fingers of heat transfer member **20** may be tapered in length at the two end regions so as to improve the impedance match of the heat transfer member to the coaxial line.

Heat transfer member **20** provides the advantage that no additional external apparatus or structure is required, and therefore no sacrifice is required in the compactness and small size of the device, this being an extremely attractive feature of the internal magnet coaxial line device.

Another extremely attractive feature of the heat transfer member of this invention is that it also may be manufactured and supplied as a completely independent item which may be inserted into existing coaxial line devices employing gyromagnetic materials. The fact that the heat transfer member is made of a thin resilient material and is held in place by means of its resilient properties greatly add to its usefulness since the only operation required to incorporate it into a new or existing device is to insert it into position.

An alternative design of this invention is illustrated in FIG. 3 wherein the heat transfer member **20'** has a cross-sectional configuration that is substantially semicircular. In this embodiment of the invention the two end regions of the heat transfer member **20'** have transversely-extending flattened portions **31** and **32** that are adapted to make good surface contact with the outer flat surfaces of gyromagnetic members **16** and **17**.

As in the embodiment of FIGS. 1 and 2, heat transfer member **20** is made of a high thermal conductivity, low magnetic permeability, and a mechanically resilient material, and is fashioned so as to be held in contact with the gyromagnetic elements and the inner surface of outer conductor **11** by means of a spring action. In effect, heat transfer member **20** "snaps in" to be rigidly positioned as illustrated in FIG. 3.

In both of the illustrated embodiments of the invention the transversely-extending portions of the heat transfer member may be continuous surfaces rather than serrated as illustrated in FIG. 1. In either case they are spring-like in nature and afford large surface areas for the transfer of heat from the gyromagnetic material. This is a material advantage over point or line contacts that would exist if the material were merely positioned against a wall.

The heat transfer member of this invention is not limited to use in devices employing only gyromagnetic material but is useful to transfer heat from any element that is positioned between the conductors of a TEM mode line.

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 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. Means for providing a heat transfer path from an internally located element that is disposed between and thermally isolated from the conductors of a TEM mode transmission line that has at least first and second conductors, said means comprising,

a head transfer member having a transverse cross-sectional shape that includes a first region that conforms to and is in surface contact with a large transverse area of one of said conductors throughout the region of the transmission line occupied by said element,

the transverse cross-sectional shape of said member also including a second region in good thermal contact with said internally located element, thereby to provide a good heat transfer path from said element to said one conductor,

said heat transfer member having high thermal conductivity and being transversely spaced from the other of said conductors to present power breakdown therebetween,

said member being thin throughout its transverse cross-sectional shape so as not to constitute a significant discontinuity in said transmission line.

2. The combination claimed in claim 1 wherein said internally located element is a member of gyromagnetic material that is positioned between said conductors in the magnetic field of TEM mode waves propagating through said transmission line.

3. The combination claimed in claim 1 and further including,

a second internally located element disposed between and thermally isolated from said conductors,

said heat transfer member having a third cross-sectional region in good thermal contact with said second internally located element to provide a good heat transfer path from said second element to said one conductor.

4. Means for providing a heat transfer path from gyromagnetic material in a coaxial line device comprising in combination,

a coaxial transmission line section having concentrically disposed inner and outer conductors,

first and second longitudinally-extending strips of gyromagnetic material rigidly disposed between said conductors on respective opposite sides of said center conductor,

a radially-thin heat transfer member disposed between the inner surface of said outer conductor and respective surfaces of said strips of gyromagnetic material,

said heat transfer member having transverse cross-sectional regions of different shapes and having a longitudinal extent corresponding to that of said gyromagnetic elements,

the first one of said shapes conforming to and being in surface contact with a large angular extent of the inner surface of said outer conductor in the region thereof adjacent said strips of gyromagnetic material, and two of said shaped regions being in good surface contact with respective surfaces of said gyromagnetic elements,

said heat transfer member being of a material having high thermal conductivity, low magnetic permeability, high mechanical resilience, and being positioned within said coaxial transmission line between the gyromagnetic elements and the outer conductor so as to be securely held therebetween by means of its resilient properties.

5. Means for providing a heat transfer path from a gyromagnetic material in a coaxial line device comprising in combination,

a coaxial transmission line section having concentrically disposed inner and outer conductors,

first and second longitudinally-extending strips of gyromagnetic material rigidly disposed between said conductors on respective opposite sides of said center conductor.

a longitudinally-extending heat transfer member having a cross-sectional shape conforming at least in part to a large angular portion of the inner surface of said outer conductor and being of a material having high thermal conductivity, low magnetic permeability, and high mechanical resilience,

said heat transfer member being in contact over its outer conforming surface with said outer conductor and having two axially-extending edge portions formed of inwardly projecting spring fingers in good surface contact with the respective gyromagnetic strips,

said heat transfer member being held securely between said outer conductor and the ferromagnetic strips by means of its resilient properties.

6. Means for providing a heat transfer path from gyromagnetic material in a coaxial line device comprising a combination,

a coaxial transmission line section having concentrically disposed inner and outer conductors,

first and second longitudinally-extending strips of gyromagnetic material rigidly disposed between said conductors on respective opposite sides of said center conductor,

a radially-thin heat transfer member disposed between the surface of one of said conductors and respective surfaces of said strips of gyromagnetic material and being radially spaced from the other one of said conductors,

said heat transfer member having transverse cross-sectional regions of different shapes and having a longitudinal extent corresponding to that of said gyromagnetic elements,

the first one of said shapes corresponding to and being in surface contact with a large angular extent of one of said conductors in the region thereof adjacent said strips of gyromagnetic material, and two of said shaped regions being in good surface contacts with respective surfaces of said gyromagnetic elements,

said heat transfer member being of a material having high thermal conductivity, low magnetic permeability, and high mechanical resilience, and being securely positioned within said coaxial transmission line by means of its resilient properties.

7. An item for use as a heat transfer member in a coaxial line device employing a gyromagnetic material therein, said heat transfer member comprising,

a longitudinally-extending member having a cross-sectional shape that includes a curved portion and transversely-extending flat portions respectively connected to each end of said curved portion,

said heat transfer member being of a material having high thermal conductivity, low magnetic permeability, and high mechanical resilience,

the curved portion of said member being adapted to be in physical and thermal surface contact with the inner surface of the outer conductor of said coaxial transmission line, and the transversely-extending portions of said member being adapted to be in surface contacts, respectively, with elements of gyromagnetic material disposed between said conductors,

the size and shape of said heat transfer member being proportioned so that it will be held firmly due to its resilient properties when positioned within the coaxial transmission line between the gyromagnetic elements and the outer conductor.

8. The combination as claimed in claim 7 wherein,

said transversely-extending portions extend radially-

inwardly and make good surface contacts with flat surfaces of said gyromagnetic element.

9. An item to be inserted into a coaxial line device employing a gyromagnetic magnetic material for serving as a heat transfer member between said gyromagnetic magnetic material and a conductor of said line comprising,

an elongated member adapted to extend along a section of said line and having a transverse cross-sectional configuration that includes first, second, and third portions,

the first portion of said member being adapted to make a large surface contact throughout its length with one of the conductors of said coaxial line, and

the second and third portions of said member being adapted to make surface contacts throughout their lengths with respective longitudinally-extending elements of gyromagnetic material positioned between the conductors of said coaxial line,

said member being adapted to be radially spaced from the other of the conductors of said line by a sufficient distance to prevent power breakdown therebetween,

said member being of a thin material having high thermal conductivity, and high mechanical resilience,

the size and shape of said heat transfer member being proportioned so that it will be held firmly due to its resilient properties when positioned within the coaxial transmission line between the gyromagnetic elements and said contacting conductor.

10. An item for use as a heat transfer member in a coaxial line device employing a gyromagnetic material therein, said heat transfer member comprising,

a longitudinally-extending member having a cross-sectional shape that includes a curved portion and transversely-extending flat portions respectively connected to each end of said curved portion,

said flat portions of said member being adapted to make good surface contact over respective flat surfaces of elongated rods of gyromagnetic material positioned on opposite sides of a center conductor of a coaxial line device, and the curved portion of said heat transfer member being adapted to make good physical and thermal contact with an appreciable angular portion of the inner surface of the outer conductor of the coaxial line,

said heat transfer member being of a material having high thermal conductivity, low magnetic permeability, and high mechanical resilience,

the size and shape of said heat transfer member being proportioned so that it will be held firmly due to its resilient properties when positioned within the coaxial transmission line between the gyromagentic elements and the outer conductor.

11. Means for providing a heat transfer path from gyromagnetic material in a coaxial line device comprising in combination,

a coaxial waveguide section having concentrically disposed inner and outer conductors,

first and second rectangular-shaped strips of gyromagnetic material extending-longitudinally between said conductors,

a heat transfer member extending from a surface area of one of said conductors to repective flat surfaces of said strips of gyromagnetic material and being transversely-spaced from the other one of said conductors,

said heat transfer member having a plurality of transverse cross-sectional regions and extending-longitudinally between said conductors throughout the region occupied by said gyromagnetic material,

the first one of said cross-sectional regions of said member corresponding to and being in surface contact with a large angular extent of one of said conductors in the region thereof adjacent to said strips of gyromagnetic material, and two of said shaped regions being in good surface contace with respective flat surface of said gyromagnetic elements,

said heat transfer member being of a thin material having high thermal conductivity.

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