Nov. 17, 1959 E. STRUMWASSER 2,913,687

DIELECTRIC SUPPORT FOR FERRITES IN WAVEGUIDE DEVICES

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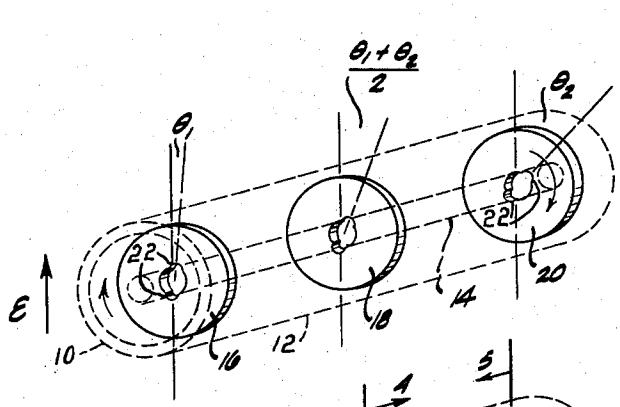


FIG. 1.

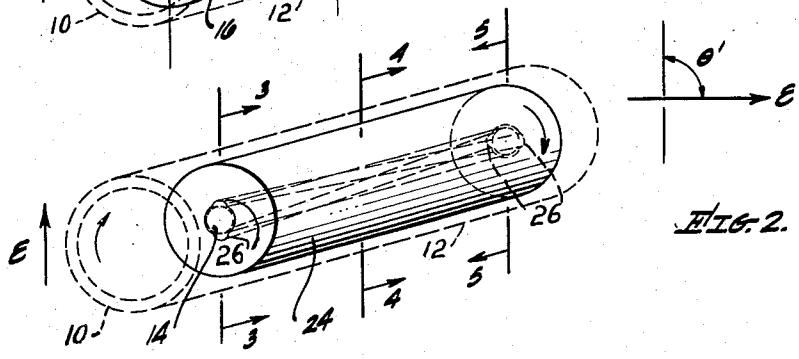


FIG. 2.

FIG. 3.

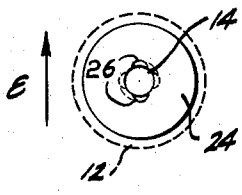


FIG. 4.

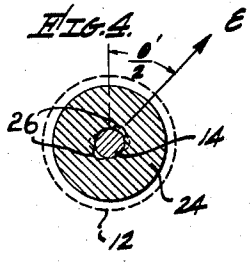
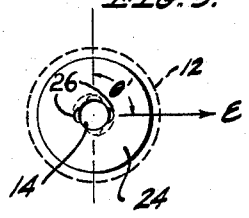


FIG. 5.



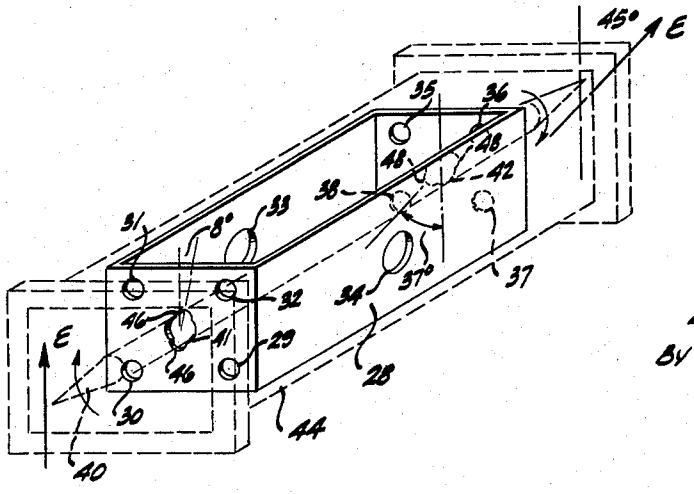


FIG. 6.

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DIELECTRIC SUPPORT FOR FERRITES IN WAVEGUIDE DEVICES

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6 Claims. (Cl. 333—98)

This invention relates to high power ferrite microwave devices, and more particularly to a supporting component for the ferrite element in such devices.

In ferrite microwave devices such as isolators, attenuators, and modulators in which the ferrite member is supported within a section of waveguide by supports fabricated of a dielectric plastic material such as polytetrafluoroethylene (Teflon), no special problems are encountered regarding arcing between the dielectric and ferrite when the microwave power being handled is of the order of a few watts. However, such a configuration is susceptible to voltage breakdown between the ferrite and the dielectric support when the power being transferred through the device is of the order of hundreds of kilowatts. This arcing occurs primarily at the points of maximum electric field and results from the finite air gap between dielectric and ferrite due to imperfect mechanical contact between support and ferrite, or because the materials near the contact area are distorted by localized heating.

It is, therefore, an object of this invention to substantially eliminate arcing between the ferrite member and its dielectric support in a ferrite microwave device.

Briefly, this is achieved by cutting away a portion of the dielectric support from the ferrite in that area in which the electric field gradient is maximum, thereby creating a greater air gap and less tendency for arcing between the ferrite and the dielectric in the area of greatest electric field gradient.

The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and advantages thereof, will be better understood from the following description considered in connection with the accompanying drawing in which several embodiments of the invention are illustrated by way of example. It is to be expressly understood, however, that the drawing is for the purpose of illustration and description only, and is not intended as a definition of the limits of the invention.

In the drawing:

Fig. 1 is a perspective view of one embodiment of the dielectric supports for a ferrite member in accordance with this invention;

Fig. 2 is a perspective view of a second embodiment of the invention;

Fig. 3 is an end view of the support of Fig. 2 at the input end of a ferrite waveguide device;

Fig. 4 is a cross-section through the dielectric support of Fig. 2 at the line 4 of Fig. 2;

Fig. 5 is an end view of the support of Fig. 2 at the output end of the waveguide device; and

Fig. 6 is a perspective view of a dielectric support in accordance with this invention in a practical embodiment of a waveguide ferrite device.

Referring now to the drawing, in which like numbers represent like elements in the different figures, it will be assumed for purposes of illustration and description

that it is desired to pass energy from left to right through the waveguide ferrite device. In the cause of simplicity, certain structural details have been omitted from the figures. For example, secured to each end of each divice is a suitable waveguide flange for coupling the device to other equipment. Also omitted from the drawing is the conventional means external to the waveguide for providing a longitudinal magnetic field through the ferrite along its length.

Referring specifically to Fig. 1, vertically polarized microwave energy is impressed upon opening **10** of circular waveguide section **12** from a microwave source in a manner well known in the art. Ferrite cylinder **14** is symmetrically supported along the length of waveguide **12** by annular dielectric discs **16**, **18** and **20** which are in turn transversely supported at intervals along the length of waveguide **12**. The number of discs is determined by the structural requirements of supporting the ferrite; and their exact position along the ferrite is determined by optimum impedance match considerations. In Fig. 1 a three disc support configuration is assumed. A suitable external longitudinal magnetic field causes the vertical plane of polarization to be Faraday rotated as the energy traverses along ferrite cylinder **14** so that the plane of polarization when the energy passes dielectric disc **20** is at an angle θ_2 with respect to the vertical. Thus, the plane of polarization of the energy rotates in a clockwise direction, as indicated by the arrows in Fig. 1.

The center holes in annular discs **16**, **18** and **20** are of substantially the same diameter as ferrite cylinder **14** which is supported by said center holes.

According to this example, disc **16** has "cutouts" **22** which are approximately circular with centers on a line at the angle θ_1 passing through the center of disc **16**; and in this example their diameters are approximately half that of ferrite cylinder **14** and their centers are approximately on the circumference of the center hole in disc **16**. The exact size and geometry of the cutouts are determined by the consideration of sufficiently decreasing the gradient in the area where arcing would otherwise occur while disturbing the symmetry of the device as little as possible; because the greater the assymmetry seen by the reflected energy, the greater the ellipticity given to the reflected energy as it passes back through the ferrite device. The structure of discs **18** and **20** is substantially identical to that of disc **16**. Disc **18** is placed half way along the length of ferrite cylinder **14** and is rotated about the cylinder at the angle

$$\frac{\theta_1+\theta_2}{2}$$

Disc **20** is placed at the output side of ferrite cylinder **14** and is rotated about the ferrite cylinder to the angle θ_2.

Thus the cutouts are coincident with a line passing through the center of the ferrite and parallel to the plane of polarization so as to provide an air gap between ferrite and dielectric in the area of high gradient of the electric field.

Referring to Fig. 2 in which an embodiment is shown which utilizes "solid" cylinder **24** of dielectric to support ferrite cylinder **14**. Dielectric cylinder **24** with a cylindrical bore along its axis of the same diameter as ferrite cylinder **14** which is supported therein is, in this example, the same length as ferrite cylinder **14**. Dielectric cylinder **24** along its length substantially fills circular waveguide section **12** and is supported therein. "Cutouts" **26** in this embodiment are spiral grooves of substantially the same cross-section as cutouts **22** of Fig. 1. The groove cutouts spiral continuously and at a constant pitch along the length of the dielectric cylinder in a manner such that the cross-section of the cutouts

is rotated at an angle θ' at the output end of dielectric cylinder **24**. Thus, for a 90° rotation of the plane of polarization of energy, it may be seen (in Figs. 3 to 5) that the cutout portions **26** lie parallel to the electric vector E along the path of the microwave energy. At what may be considered the input end, before rotation, the plane of polarization may be considered to be vertical, with the device in the relative position of Figs. 2 and 3. Halfway along the dielectric cylinder **14**, both the electric vector and the cutouts **26** are inclined at an angle

$$\frac{\theta'}{2}$$

with respect to the vertical. After full rotation, as shown in Fig. 5, the electric vector E is displaced at an angle θ' from the vertical but still bisects the cutouts **26**.

Referring to Fig. 6, a practical embodiment is shown which is adapted for use in a high power, force cooled microwave isolator. In this embodiment the dielectric "box" support **28** has perforated holes **29** through **38** to allow the flow of a suitable coolant past ferrite cylinder **40**. Holes **41** and **42** are of the same diameter as ferrite cylinder **40** and support cylinder **40** which passes through the holes. Square waveguide section **44** supports dielectric box support **28**, the inside height and width dimensions of waveguide section **44** being substantially equal to the height and width dimensions of dielectric box support **28**. Ferrite cylinder **40** has pointed ends which extend beyond the input and output ends of dielectric support **28**. The plane of polarization at the input end of ferrite cylinder **40** is vertical, is caused to be rotated 8° to the right at the input end of box **28**, 37° at the output end of box **28**, and 45° at the output end of ferrite cylinder **40**. Cutouts **46**, geometrically similar to cutouts **22** of Fig. 1, are accordingly rotated 8° as shown in Fig. 6. Likewise cutouts **48** are geometrically similar to cutouts **22**, but are rotated 37° as shown.

Thus, in all the embodiments of the invention shown, the respective cutouts are adapted to provide a larger gap between the dielectric support and the ferrite cylinder in that area in which the electric field gradient is highest; and this area is determined by the direction of the plane of polarization which in these waveguide ferrite devices is caused to rotate as the traveling energy passes along the length of the device.

For purposes of explanation of operation of the embodiments of Fig. 1 and Fig. 2, it will be assumed that circular waveguide section **12** is being excited in the conventional TE_{11} mode and further that the energy incident upon input opening **10** is vertically polarized. Thus, it is clear that when the energy impinges upon the input end of ferrite cylinder **14** the areas of maximum electric field gradient will be in a plane passing through the center of the ferrite cylinder and parallel to the electric field vector where cutouts **22** are situated. The ferrite cylinder is supported by that portion of the center hole of dielectric disc **16** which has not been altered by the cutouts **22**. Thus, there is a larger gap betwen dielectric and ferrite in the area of high field gradient; and undesired arcing is thereby prevented. When the microwave energy reaches dielectric support **16** the plane of polarization has already rotated to angle θ_1 and the cutout is rotated to the same angle. The Faraday rotation of the plane of polarization is in a conventional manner effected by an externally caused longitudinal field along the ferrite cylinder. When the microwave energy reaches dielectric supporting disc **18**, the plane of polarization of the energy has been rotated to an angle

$$\frac{\theta_1+\theta_2}{2}$$

In order to prevent arcing at this support, disc **18** is rotated to the same angle

$$\frac{\theta_1+\theta_2}{2}$$

When the microwave energy reaches disc **20** at the output end of ferrite cylinder **14** the plane of polarization of the energy has been rotated to the angle θ_2 and dielectric supporting disc **20** is accordingly rotated so that the cutouts are coincident with the areas which would otherwise have a high electric field gradient. As the microwave energy passes beyond disc **20**, it is further "rotated" to the angle θ in the remainder of the ferrite.

The operation of the embodiment of Fig. 2 is substantially the same as that of Fig. 1 except that the dielectric cylinder **24** continuously supports ferrite cylinder **14** along its length instead of by spaced dielectric discs. In this embodiment the spiral groove cutouts **26** are adapted to provide a larger gap at all points along the ferrite cylinder at which a high field gradient would otherwise occur. In this embodiment the total angle of Faraday rotation is θ', and therefore the total angle of the spiral of cutouts **26** is θ'.

In the practical embodiment of Fig. 6 it will again be assumed that the energy incident upon the input of waveguide section **44** is vertically polarized. For purposes of impedance matching, ferrite cylinder **40** is pointed at each end. In this practical embodiment the total angle of Faraday rotation is 45° so that energy reflected from a load at the output end of waveguide section **44** will be rotated another 45° as it passes back through the device so that any reflected energy appearing at the input end of waveguide section **44** will be of orthogonal polarization to the normal input polarization. Since it is desired to support the ferrite cylinder at points along its greatest diameter, the ferrite rod with its pointed ends is made to extend beyond each end of the dielectric box support **28**. Thus, some amount of Faraday rotation of the plane of polarization of the incident microwave energy will have already occurred when the energy reaches the input end of dielectric box support **28**, and the cutouts therein are accordingly rotated by the angle equal to that amount of Faraday rotation of the microwave energy at that point. In a practical embodiment that angle is 8°. Likewise, the amount of Faraday rotation which has occurred in the ferrite when the energy has reached the output end of support **28** is not the full 45° but rather 37°, and the cutouts **48** are accordingly placed at an angle of 37°. The remaining 8° of rotation of the angle of polarization of the microwave energy occurs after the microwave energy has left the output end of support **28** and before the energy leaves the output pointed end of ferrite cylinder **40**.

In the practical embodiment of Fig. 6 power levels of up to 300 kilowatts have been transmitted through the device into a variable phase 2:1 mismatch, and no arcing occurred between the ferrite and dielectric supports.

Other advantages provided by this invention are the ease and simplicity of adapting the new dielectric supports to existing waveguide ferrite devices and thereby increasing their power handling capacity. A further advantage is that in a force cooled waveguide ferrite device, the cutouts permit the coolant to flow past portions of the ferrite which would normally be in contact with dielectric supporting material and thereby permit better and more uniform cooling thus preventing localized differential heating effects from damaging the ferrite material and resulting in a further increase in power handling capacity.

What is claimed is:

1. In a unidirectional waveguide device employing a pencil shaped ferrite element for rotating the plane of polarization of microwave energy conducted through the waveguide device, the ferrite element being substantially smaller in cross section than the waveguide, means sup-

porting the ferrite element in the waveguide device, said means comprising: a solid dielectric element supporting and partially encompassing the ferrite element and being in contact therewith along that portion of the surface of said ferrite element across which there is appreciably no change in electric field intensity, portions of said dielectric supporting element being cut out and the surface spaced apart from that portion of the surface of said ferrite element across which there exists the greatest field intensity and at which there would otherwise exist an excessive electric field gradient.

2. In a waveguide isolator device employing an elongated ferrite element for rotating the plane of polarization of microwave energy conducted through the waveguide device, means supporting the ferrite element in the waveguide device, said means comprising: a plurality of dielectric supporting discs each being transversely supported at different points along the length of the waveguide device and each of said discs substantially filling the cross-section of the interior of said waveguide device, said discs each having central openings to allow passage and support of the elongated ferrite element therethrough, portions of the inner surfaces of said discs thereby being in contact with said ferrite element, the area of said contact being substantially confined to that portion of the surface of said ferrite element across which there is no appreciable electric field intensity, there being cut outs adjacent the central opening in each disc between the ferrite element an each dielectric disc along the associated portion of the surface of said ferrite element across which there would otherwise be a large electric field gradient.

3. In a waveguide isolator device employing a pencil shaped ferrite element having a cross section small compared with that of the waveguide for rotating the plane of polarization of microwave energy conducted through the waveguide device, means supporting the ferrite element in the waveguide device, said means comprising: a solid dielectric cylinder substantially filling said waveguide device, said cylinder having a bore along its axis, said bore providing support for said ferrite element; a pair of cut-away grooves along the length of said bore, said grooves being symmetrically opposite each other along the length of said bore and made coincident at all points along the length of said waveguide device with a line passing through the axis of said device parallel to the electric field vector, the lateral dimensions of said cut-away grooves being determined by optimum considerations between providing rigid support for said ferrite element, providing an airgap sufficient to preclude voltage breakdown in the area near the surface of said ferrite in which there would otherwise be a high electric field gradient, and maintaining the angular symmetry along the centerline of said device.

4. In a high power waveguide microwave isolator device employing an elongated ferrite element having a cross section small compared with that of the waveguide for rotating the plane of polarization of microwave energy conducted through the waveguide microwave isolator device, means supporting the ferrite element in the isolator device comprising: a right parallelepiped dielectric box fabricated of thin slabs of solid dielectric, the exterior dimensions of said box being such that said box substantially fills the interior of said waveguide microwave isolator device; said box including supporting holes centered about the center of the lateral surfaces of said box, said supporting holes being adapted to support the ferrite element along the length of said device, said supporting holes providing contact between dielectric and ferrite along that part of the surface of said ferrite across which there is no appreciable electric field intensity, the supporting holes having cut out portions to define a gap between dielectric and ferrite in that area in which there would otherwise be a large electric field gradient, thus providing support for said ferrite element while precluding voltage breakdown in said area, said box being otherwise perforated in a manner to allow passage of coolant past the surfaces of said ferrite element.

5. In a unidirectional waveguide device employing a ferrite element substantially smaller in cross section than the waveguide device and extending longitudinally along and inside the waveguide device, means for supporting the ferrite element in the waveguide device comprising: a dielectric member within said waveguide device, said dielectric member having an internal aperture therein encompassing said ferrite element with a portion of the surfaces defining said internal aperutre restraining said ferrite element from movement, said dielectric member being in contact with at least portions of the inner walls of said waveguide device, the internal aperture of said dielectric member having cutout portions defining gaps between said dielectric member and said ferrite element in the area of high electric field intensity within said waveguide device.

6. A microwave device comprising: a hollow waveguide for propagating electromagnetic wave energy having an electric field with a principal initial plane of polarization; means including a ferrite element longitudinally disposed within said hollow waveguide for rotating the plane of polarization of microwave energy within said waveguide, the rotation proceeding continuously along the length of the ferrite element; and dielectric support means within said hollow waveguide and at least partially encompassing said ferrite element, said dielectric support means being in contact with the interior walls of said hollow waveguide and in contact with portions of the surface of the ferrite element, there being cut out portions in the dielectric adjacent the ferrite element, the cut out portions extending in a plane parallel to the plane of polarization of the energy within the waveguide at the different points along the length of the ferrite element.

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