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A. M. CLOGSTON
MICROWAVE MODE SUPPRESSORS

2,948,870

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FIG. 1

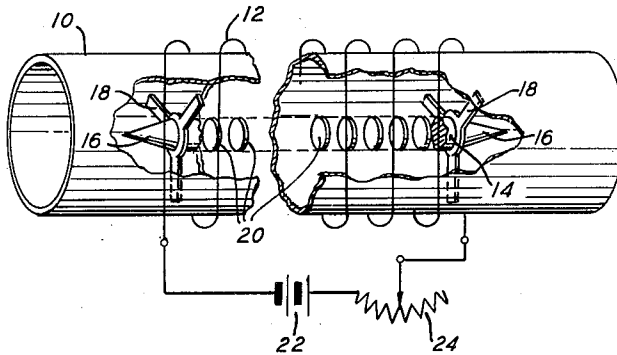


FIG. 2

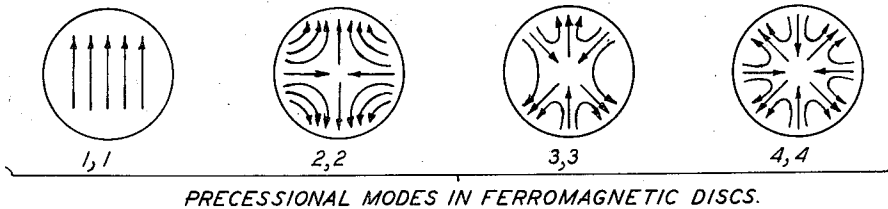


FIG. 3

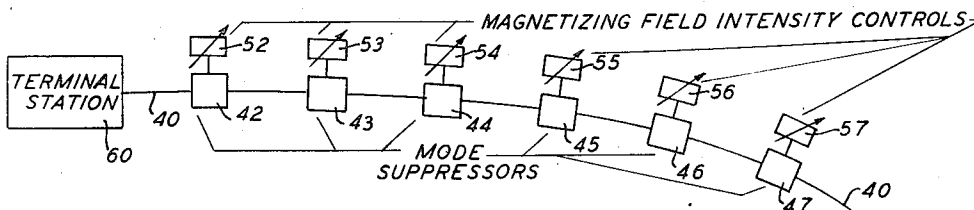
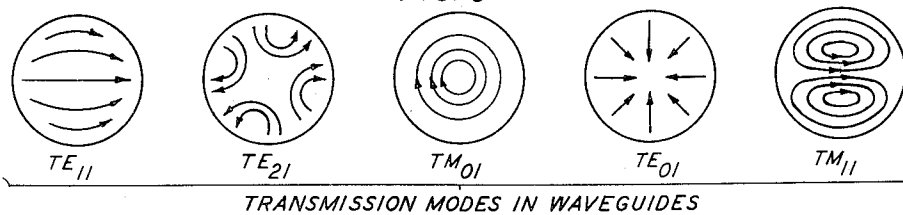


FIG. 4

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MICROWAVE MODE SUPPRESSORS

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4 Claims. (Cl. 333-98)

This invention relates to microwave mode suppressors. More particularly, it relates to mode suppressors which when inserted in a wave guide freely pass a desired mode of wave transmission but selectively suppress unwanted modes of microwaves generated in the wave guide during transmission of the desired mode wave through the wave guide.

In the transmission of microwave energy through a wave guide a particular definite mode of wave propagation is usually selected as being the most efficient or otherwise most desirable mode for transmitting energy through the particular wave guide employed and is referred to by those skilled in the art as the "wanted," "desired" or "preferred" mode of wave propagation for that wave guide. Unfortunately, in the majority of instances, the "desired" or "preferred" mode wave tends to generate other less efficient modes, variously referred to as "spurious" or "undesired" or "unwanted" modes of wave propagation while being transmitted through the wave guide, particularly if the guide includes imperfections such as dents or even small scratches in its conductive wall and especially where the guide must include bends and curved portions to conform to the prescribed transmission path. If nothing is done to suppress such "spurious" or "unwanted" modes at appropriate intervals along the wave guide a very substantial portion of the energy of the desired mode wave will be transferred to the less efficient or "unwanted" modes. This in turn will result in the loss or useless dissipation of much of the original energy before it reaches the output end of the wave guide. While many devices and arrangements have been resorted to by those skilled in the art to suppress "spurious" or "unwanted" modes of wave propagation in wave guides, all such prior art artifices leave considerable latitude for improvement in efficacy, flexibility, economy, adaptability, and convenience.

It is accordingly a principal object of the present invention to overcome the deficiencies of prior art mode suppressing devices and arrangements.

In the copending applications of L. R. Walker, Serial No. 571,227, which matured into Patent 2,810,882 granted October 22, 1957, and J. F. Dillon, Jr., Serial No. 571,226, being filed concurrently, on March 13, 1956, with the present application and assigned to applicant's assignee, it is shown that elements or bits of various shapes of ferromagnetic material of low conductivity, preferably cut from a single crystal of the material the major surfaces of each such element also preferably being parallel to the (100) plane (Miller crystallographic indices) of the single crystal from which it is cut, will in the presence of a unidirectional magnetizing field of any of a number of particular intensities and a microwave frequency field of any of a number of frequencies and particular configurations in the vicinity of the ferromagnetic element, said microwave field being directed normally with respect to the unidirectional field, exhibit marked ferromagnetic resonance absorption characteristics. As emphasized in the above-mentioned copending

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application of J. F. Dillon, Jr., the preferred element shape, in order to realize a plurality of spaced, sharply defined, resonance absorption lines, is a small, thin, disc having, by way of example, a diameter of one-tenth of an inch and a thickness of five mils or less, the element being cut from a single crystal preferably with the major surfaces of the disc parallel to the (100) plane of the crystal from which it is cut. The element must furthermore be of a ferrite or ferromagnetic material having a resistivity of at least ten ohm-centimeters. Elements of other shapes such as rectangular or triangular plates should have comparable dimensions and particularly the ratio of the maximum dimension of the plate to its thickness should be large, for example, in the order of twenty to one. Spherical specimens cut from a single crystal of ferrite having high resistivity have absorption peaks several times wider than for discs of comparable diameter and, at most, have only a few minor subsidiary resonant peaks so that they will, in general, find only a relatively limited field of usefulness.

As the Dillon application further points out, a small number of small thin plates cut from a single ferrite crystal can advantageously be substituted for the much larger, single cylindrical polycrystalline member of ferrite employed widely in the prior art, since the thin plates will produce an equivalent rotational effect for a much smaller aggregate mass. Thus the use of small thin plates, as taught solely in the Dillon application, requires much less material, occupies much less space, and introduces much less dissipation, as well as providing substantially superior results to those obtainable by employing large, thick, chunky polycrystalline elements as taught in the prior art.

A convenient and versatile control of these characteristics, commonly referred to by those skilled in the art as gyromagnetic characteristics, is afforded by controlling the intensity of the unidirectional magnetizing field and the shape of the absorbing elements. Control of the intensity of the magnetizing field can usually be effected by employing an electromagnet energized by a direct current source and a potentiometer in the circuit connecting the source to the electromagnet as illustrated, for example, in the above-mentioned copending applications, and in Fig. 1 of the drawings accompanying the present application.

A principal object of the invention, accordingly, is to facilitate the suppression of unwanted modes of propagation in microwave frequency transmission lines.

Another object is to improve the control of mode suppression in microwave frequency transmission lines.

Other and further objects, features and advantages of the present invention will become apparent during the course of the following description and from the appended claims.

The principles of the invention will be more readily perceived in connection with the detailed description of a specific illustrative embodiment of the invention given hereinafter and from the accompanying drawings, in which:

Fig. 1 illustrates a structure employed in a specific embodiment of the principles of the invention;

Fig. 2 illustrates the precessional modes of ferromagnetic discs such as those employed in the device of Fig. 1;

Fig. 3 illustrates the electromagnetic field in a circular wave guide for several modes of propagation of microwaves in a wave guide; and

Fig. 4 represents a transmission system employing a plurality of mode suppressors of the invention.

In more detail, in Fig. 1, a structure employed in a specific illustrative embodiment of the invention adapted for use in round wave guide transmission lines is illustrated. Section 10 of round wave guide has centrally po-

sitioned therein along its longitudinal axis, a cylindrical member 14 of dielectric material, such as titanium dioxide, tapered at each end as illustrated for end portions 16 of member 14. Member 14 is supported by spiders 18 of polystyrene foam so that the longitudinal axis of member 14 is coincident with the axis of wave guide section 10.

Embedded in member 14, so as to be concentrically aligned on the coincident longitudinal axes of members 14 and 10, are a plurality of discoidal members, which are, for example, preferably of one of the types shown in Figs. 1, 2 and 3 of the drawings accompanying the above-mentioned copending application of J. F. Dillon, Jr., and described in detail in said application. In other words, members 20 can, preferably, be thin plane discs, discs with a hole through the center or discs of lenticular cross-sectional shape, cut from a single crystal of a ferromagnetic material having appreciable resistivity, the specific properties of which are described in detail in Dillon's application. The number of discoidal members 20 should be used is, obviously, dependent upon the amount of unwanted mode energy that should be absorbed in any specific instance, and in general may vary from one or more to a dozen or more. For this reason, breaks are shown in the center of wave guide 10 and member 14.

A magnetizing coil 12 is wound around the portion of wave guide 10 in which element 14 is situated and is energized by direct current source 22 connected to coil 12 through potentiometer 24 to control the intensity of the resulting magnetizing field. The magnetizing field is, of course, directed along the longitudinal axis of member 14.

The operation of the device of Fig. 1 will be more readily perceived by considering, in connection therewith, the precessional mode diagrams of Fig. 2 for discs and the transmission mode diagrams of Fig. 3 for wave guides.

Fig. 2 illustrates the first four of a large number of modes of precessional vibration which can occur in discs 20 of Fig. 1 under specific combinations of unidirectional magnetizing field intensity and microwave field configuration in the vicinity of the disc. Reference may again be had to the above-mentioned copending application of J. F. Dillon, Jr., for an exposition of the number, variety and distributions of ferromagnetic resonance absorption peaks which may be present under particular combinations of the magnetic fields for the three types of discoidal members suggested.

The precessional modes, as illustrated in Fig. 2, are alternately "odd" and "even" and of increasing degrees of complexity.

The wave guide transmission modes of Fig. 3 are, of course, by now classical and well known and understood by those skilled in the art so that a detailed description thereof in this application is not deemed necessary.

By inspection of Figs. 2 and 3 it is apparent that the following relations exist:

Wave Guide Mode	Precessional Modes
TE ₁₁ will tend to excite.....	(1, 1); (3, 3); etc.
TE ₂₁ will tend to excite.....	(2, 2); (4, 4); etc.
TE ₀₁ will tend to excite.....	none.
TM ₀₁ will tend to excite.....	none.
TM ₁₁ will tend to excite.....	(1, 1); (3, 3); etc.

By way of specific example, by adjusting the intensity of the unidirectional magnetizing field, the (1, 1) precessional mode of the discs can be brought to its point of substantially maximum ferromagnetic resonance absorption and the wave guide transmission modes TE₁₁ and TM₁₁ would then be selectively absorbed.

As a further specific example, if the unidirectional magnetizing field is adjusted to bring the (2, 2) precessional mode of the discs to its point of substantially maximum

resonance absorption, the wave guide transmission mode TE₂₁ will be selectively absorbed.

In both examples given above, the wave guide TE₀₁ or TM₀₁ transmission mode would not be absorbed.

As explained in Dillon's above-mentioned application, the embedding of the discs in a dielectric member with pointed ends is designed to reduced impedance mismatches in the guide. The inclusion of ferrite particles of high resistivity embedded in the tapered portions 16 of member 14 would tend to further improve the impedance match.

Obviously, the devices of the invention can be readily adapted for use in rectangular wave guides in which case rectangular thin plate members conforming more or less to the cross-sectional shape of the wave guide can be substituted for discs 20 and dielectric member 14 of Fig. 1. As a matter of fact, spheres or even irregularly shaped bits of ferromagnetic material of low conductivity can be substituted for the discs of Fig. 1, in either round or rectangular wave guides, and a substantial degree of ferromagnetic resonance absorption can be realized. To the present time, however, thin plates have been found to exhibit the phenomena to a greater degree than other shapes. In general, the relatively much larger polycrystalline ferromagnetic elements of the prior art cannot be made mode selective since they tend at their points of ferromagnetic resonance absorption to strongly absorb all propagation or transmission modes passing through the wave guides in which they are placed.

As a further alternative, the magnetizing field can, as explained in Dillon's above-mentioned application, be directed parallel to the major surfaces of the thin plates or discs and resonance at much lower magnetizing field intensity can then be realized.

In applying devices of the invention to a wave guide transmission line, they should be spaced at intervals such that the unwanted modes are never permitted to attain troublesome magnitudes. Further, a portion of the devices can, of course, be adjusted to absorb particular specific unwanted wave guide modes and the remainder adjusted to absorb particular specific other unwanted wave guide modes.

A system applying devices of the invention to a simple wave guide transmission system is illustrated in block schematic diagram form in Fig. 4.

In Fig. 4, a wave guide transmission line 40 is shown interconnecting terminal stations 60 and 62. At intervals along wave guide transmission line 40, a plurality of mode suppressors 42 through 47, inclusive, are included in the line and adjusted by magnetizing field intensity controls 52 through 57, inclusive, respectively, to selectively absorb particular specific unwanted wave guide transmission modes at each point.

Numerous and varied other arrangements and devices within the spirit and scope of the principles of the invention will readily occur to those skilled in the art. No attempt has been made, hereinabove, to exhaustively cover all possible arrangements. For example, as discussed in detail in the above-mentioned application of J. F. Dillon, Jr., for a given intensity of the magnetizing field, the absorbing elements may have strong ferromagnetic resonance absorption peaks at as many as ten or more frequencies so that unwanted modes of propagation at a plurality of different frequencies can be simultaneously absorbed by devices of the invention such as that disclosed in Fig. 1, in substantially the manner described above for a single frequency.

What is claimed is:

1. In combination, a wave guide transmission line, means for applying to said line for transmission therealong a preferred mode of electromagnetic wave energy at microwave frequency having a circular symmetric field configuration within the wave guide, said preferred mode tending to degenerate during transmission into at least one other mode having a second configuration of

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magnetic field different from said circular symmetric field configuration, a selective mode suppressor disposed along said line comprising a plurality of thin plates cut from a single crystal of ferromagnetic material of low conductivity, the maximum dimension of each of said plates being not greater than a quarter of the maximum transverse dimension of said wave guide and the thickness of each of said plates being approximately five per cent of the maximum dimension of the plates so that each of said plates is capable of gyromagnetic precession in different modes depending upon the strength of a unidirectional magnetic field applied to said plates, and means for applying a unidirectional magnetic field to said plates of the strength which produces the one of said precessional modes within said plates that corresponds substantially to the configuration of said second magnetic field configuration and is substantially different from said circular symmetric field configuration so that wave energy in said second configuration is substantially absorbed and wave energy in said circular symmetric field configuration is freely passed.

2. In combination, a wave guide transmission line, means for applying to said line for transmission therealong a preferred mode of electromagnetic wave energy at microwave frequency having a first configuration of magnetic field within the wave guide, said preferred mode tending to degenerate during transmission into a plurality of other modes each having configurations of magnetic field different from each other and from said first configuration, a plurality of selective mode suppressors spaced at intervals along said line each comprising a plurality of thin plates cut from a single crystal of ferromagnetic material of low conductivity spaced along the longitudinal axis of said guide, the maximum dimension of each of said plates being not greater than a quarter of the maximum transverse dimension of said wave guide and the thickness of each of said plates being approximately five percent of the maximum dimension of the plates so that each of said plates is capable of gyromagnetic precession in different modes depending upon the strength of a unidirectional magnetic field applied to said plates, and a plurality of means for applying unidirectional magnetic fields of different strengths along the

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different portions of said longitudinal axis of said wave guide upon which said plates are located, respectively, each of said different field strengths being that strength which produces a precessional mode within the plates subject thereto that corresponds substantially to the configuration of the magnetic field of one of said plurality of other modes and that is substantially different from said first configuration so that each mode suppressor is conditioned to strongly absorb energy of a field configuration corresponding to a specific different one of said other modes and freely pass energy of the field configuration of said first mode.

3. The combination of claim 1 in which each ferrite plate is cut from a single crystal of ferrite with its major surfaces parallel to the (100) plane (Miller crystallographic indices) of the single crystal from which it is cut.

4. The combination of claim 2 in which each ferrite plate is cut from a single crystal of ferrite with its major surfaces parallel to the (100) plane (Miller crystallographic indices) of the single crystal from which it is cut.

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