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GYROMAGNETIC WAVEGUIDE POWER LIMITER HAVING EASY
AXIS OF FERROXPLANAR MATERIAL ALIGNED
WITH MAGNETIC BIASING FIELD
Filed Sept. 24, 1962

3,131,366

FIG. 1

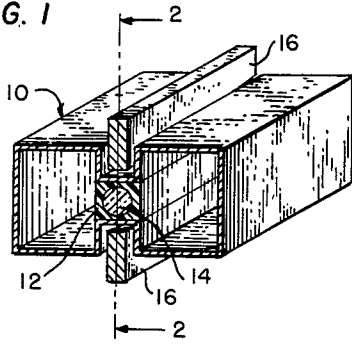


FIG. 2

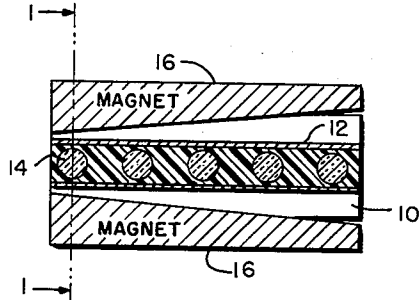


FIG. 3

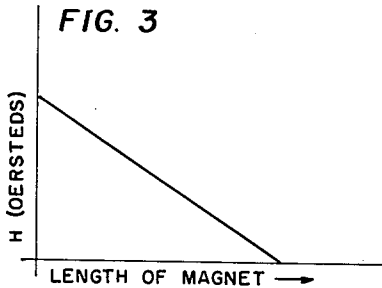


FIG. 4

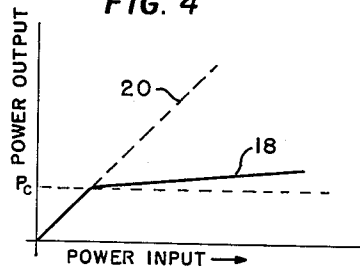
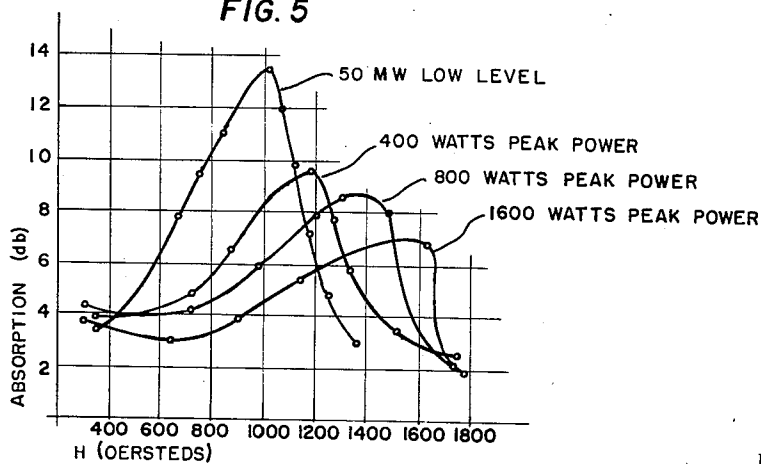


FIG. 5



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**GYROMAGNETIC WAVEGUIDE POWER LIMITER
HAVING EASY AXIS OF FERROXPLANAR MA-
TERIAL ALIGNED WITH MAGNETIC BIASING
FIELD**

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5 Claims. (Cl. 333—24.2)

(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government for governmental purposes without the payment of any royalty thereon.

This invention relates to wave transmission systems utilizing gyromagnetic elements, and more particularly to gyromagnetic elements for use in such systems as power limiters.

It is well known that gyromagnetic mediums such as ferrites are characterized by certain unpaired electron spins which respond to a transmitted microwave signal by precessing gyroscopically about the line of an applied magnetic field. When the frequency of the applied signal is equal to the natural precession frequency of the electron spins, a resonant condition exists under which the electron spins are able to absorb large amounts of energy from the signal and thereby greatly attenuate the signal. Assuming a given resonant D.-C. magnetic field, it is characteristic of such ferrites that the signal attenuation is very low below a critical power P_c , but beyond this point the attenuation increases linearly due to the resonance effects and, as a result, the power output remains substantially constant for input power levels beyond the critical power level P_c . Power limiting action is thereby achieved. However, for conventional isotropic ferrites, a relatively larger magnetic biasing field is necessary and concomitant large bulky magnets are usually required.

Recently two groups of ferrites that have very large anisotropy fields were discovered and one of these is known as the ferroxplanar group. This group of ferrites has a hexagonal crystal structure with the easy plane of magnetization perpendicular to the C axis, i.e., planar anisotropic, and are hereinafter referred to as planar ferrites. One such planar ferrite material is a crystal having the chemical composition $\text{BaZn}_2\text{Fe}_{16}\text{O}_{27}$ which is described in application Serial Number 200,000 for Method of Growing Single Crystals, filed June 4, 1962. This type planar ferrite is characterized by a large anisotropic field which tends to keep the magnetization in the easy plane and thereby reduce the D.-C. field required for ferromagnetic resonance. When such planar ferrites are utilized in ferromagnetic resonance applications at microwave frequencies, it has been found that the magnetic field required for resonance is greatly reduced when the easy plane of magnetization is aligned parallel to the applied D.-C. magnetic field. The planar ferrite, like the conventional ferrite, is capable of absorbing the energy from an RF oscillating field whose magnetic vector is perpendicular to the axis of the D.-C. magnetic field.

It is an object of the present invention to provide a control for the level of power flow in a microwave transmission system by means of planar ferrite.

It is a further object of the invention to provide a ferrite power limiter for operation at microwave frequencies which produces a large shift in the resonant field as the power level is increased.

It is still another object of the invention to provide a ferrite power limiter for operation at microwave frequencies wherein power limiting may be achieved over a relatively wide range of power variations.

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In accordance with the present invention there is provided a waveguide microwave power limiter which includes a plurality of longitudinally spaced planar ferrite elements, preferably spherically shaped, and a D.-C. magnetic biasing field which is tapered along the longitudinal dimension of the waveguide to provide a gradient in the polarization magnitude along the spaced planar ferrite spheres. The spaced planar ferrite spheres are arranged such that the respective easy plane of magnetization of each sphere is oriented parallel to the direction of the D.-C. magnetic field.

For a better understanding of the invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawing in which:

FIG. 1 is a perspective view, partially in section, of one principal embodiment of the invention;
FIG. 1; and

FIG. 2 is a sectional view taken along the lines 2—2 of FIGS. 3—5 are explanatory curves.

The present invention is based on the principle that, for a given frequency, a large shift occurs in the resonant field of a planar ferrite as the incident power level is increased. This relationship is clearly shown in the curve of FIG. 5.

Referring now to FIGS. 1 and 2 of the drawing, at 10 there is shown a ridge waveguide having the narrow or ridged section 12 filled with a high dielectric material, stycast for example, in which there is imbedded a plurality of longitudinally spaced single-crystal planar ferrite spheres 14 having preferably the chemical formula in the above-mentioned application. A tapered, D.-C. magnetic field is arranged along the longitudinal dimension of the ridged section 12 by means of a permanent magnet 16 or any other suitable means well known in the art, to provide a gradient in the polarization magnitude longitudinally along the spaced planar ferrite spheres. It is to be understood, of course, that the gradations in the magnitude of the biasing field may be supplied by any one of other well known methods including an electrical solenoid or an electrically energized magnet. The spaced planar ferrite spheres 14 are arranged such that the respective easy plane of magnetization of each sphere is oriented parallel to the direction of the D.-C. magnetic field formed by the magnet 16. The planar ferrite spheres are preferably spaced apart $\frac{1}{4}\lambda$ of the operating or center frequency, or any odd-multiple of a $\frac{1}{4}\lambda$ of the operating frequency. The total number of spheres required is a function of the power stability of the input source applied to the input of the waveguide 10. The microwave energy, of course, extends longitudinally through the ridge waveguide 10 in the conventional manner. A typical variation of the applied D.-C. magnetic field with respect to the longitudinal dimension of the waveguide 10 is shown in FIG. 3. The gradient in the polarization magnitude longitudinally along the gyromagnetic elements 14 allows the power limiter to operate effectively with random variations of the incident power level and frequency. At each ferromagnetic resonance, there is a specific critical incident power beyond which any further increase in incident power produces little or no increase in output power. This is illustrated in FIG. 4, where the solid curve 18 represents the output power as the input power increases and the dashed curve 20 represents the power output in the absence of a power limiter. It will be seen that the power output increases only very slightly over the critical power P_c for large increases in the power input. The gradations in the magnitude of the biasing field will permit power limiting action over a range of incident power variations at a prescribed given frequency. In actual operation, the bias value may be set

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arbitrarily at the power level desired to initiate or begin limiting action. In such an arrangement a current controlled solenoid may be utilized.

Although the invention has been described in connection with a ridge waveguide structure, it is to be understood that the invention is not to be limited thereto. Various other waveguide structures may be used in applying the principles of the invention without departing from the spirit and scope of the invention.

What is claimed is:

1. A device for limiting the power level of microwave energy comprising a waveguide section, a plurality of planar ferrite elements spaced along the longitudinal dimension of said waveguide section, and means for magnetically biasing said planar ferrite elements such that the biasing magnetic field is tapered along said longitudinal dimension, said planar ferrite elements being arranged such that the respective easy plane of magnetization of each planar ferrite element is oriented parallel to the direction of said biasing field.

2. The device in accordance with claim 1 wherein said planar elements are spherically shaped and said waveguide section comprises a ridge waveguide.

3. The device in accordance with claim 2 wherein said planar ferrite spheres are spaced longitudinally along the ridged portion of said ridge waveguide.

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4. The device in accordance with claim 3 wherein said planar ferrite spheres are imbedded in a relatively high dielectric material.

5. A device for limiting the power level of microwave energy at a prescribed operating frequency comprising, a waveguide section, a plurality of spherically shaped planar ferrite elements spaced along the longitudinal dimension of said waveguide section, said planar ferrite spherical elements being spaced apart at odd multiples of $\frac{1}{4}\lambda$ of said operating frequency, and means for magnetically biasing said planar ferrite spherical elements such that the biasing magnetic field is tapered along said longitudinal dimension, said planar ferrite spherical elements being arranged such that the respective easy plane of magnetization of each planar ferrite spherical element is oriented parallel to the direction of said magnetic biasing field.

References Cited in the file of this patent

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777,341 Great Britain ----- Mar. 22, 1955

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Weiss: "The Behavior of Ferroxdure at Microwave Frequencies," IRE Convention Record, part 8, 1955, pages 95-99.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,131,366

April 28, 1964

Samuel Dixon, Jr.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 25, for "procession" read -- precession --; column 3, line 18, for "place" read -- plane --.

Signed and sealed this 13th day of October 1964.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents