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MICROWAVE POWER LIMITER UTILIZING A PLANAR FERRITE SPHERE

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FIG. 1

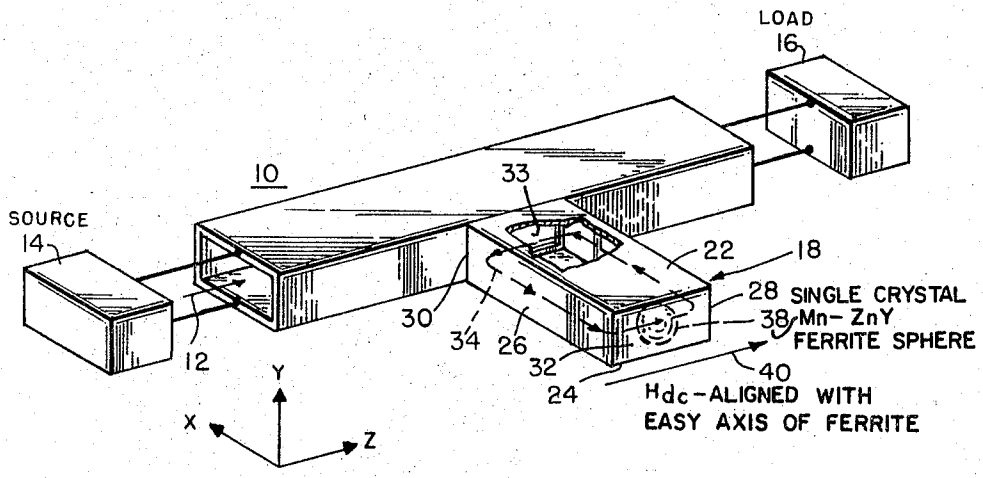
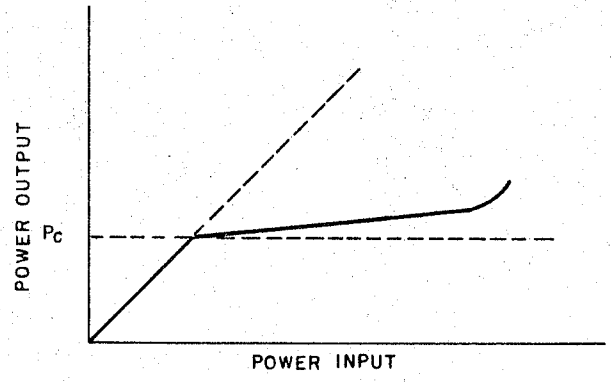


FIG. 2



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MICROWAVE POWER LIMITER UTILIZING A PLANAR FERRITE SPHERE

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4 Claims. (Cl. 333—24.2)

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 limiters which provide protection for receivers in such systems.

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. 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. One such planar ferrite is a crystal having the chemical composition $Ba_2Zn_{2-x}Mn_xFe_{12}O_{22}$, where x is a numerical value between 0 and 1.5, and which is described in copending application Ser. No. 380,103 for Method of Growing Single Crystals Containing Manganese, filed July 2, 1964. These type crystals are known as Mn-ZnY single crystals where Y designates a crystal structure having the general chemical composition $Ba_2Me_2^{II}Fe_{12}O_{22}$ as defined on page 185 of "Ferrites" by Smit and Wijn (1959). These crystals are characterized by a large planar anisotropy field (9600 oersteds) which causes the spin precession to be highly elliptical. This natural elliptical precession endows Mn-ZnY single crystals with a very high parallel susceptibility as compared with other single crystal material, and provides a decrease in the critical power level required for limiting action. Also, the anisotropy field greatly reduces the direct current magnetic field requirements for an operational limiter.

It is an object of the present invention to provide an improved planar ferrite power limiter for operation at microwave frequencies.

It is another object of the present 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.

In accordance with the present invention there is provided a power limiter which includes a first and second rectangular waveguide joined together in a T-configuration, the first waveguide having input and output ports through which a microwave signal propagates. Also included is a coupling means between the input and output ports for coupling microwave signal energy from the first waveguide to the second waveguide. The second waveguide is provided with an end wall which is electrically spaced from the coupling means by $\lambda_g/2$ where λ_g is the wavelength of the propagated microwave signal. Included further is a planar ferrite sphere located at said end wall and oriented such that the easy plane of magnetization thereof is parallel to the direction of the magnetic field produced by the coupled microwave energy, and an external unidirectional magnetic field applied parallel to the easy plane of magnetization of the ferrite sphere.

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 cut away, of a power limiter embodying the present invention; and

FIG. 2 is an explanatory curve to illustrate the power output versus the power input characteristic of the power limiter shown in FIG. 1.

Referring now to FIG. 1 of the drawing, there is shown at **10** a rectangular waveguide section adapted to propagate high power microwave energy in the conventional rectangular mode in the Z-direction as indicated by the arrow **12**. Connected to one end of waveguide **10** is a source **14** of microwave energy having a relatively high power level as, for example, a high power transmitter. Connected to the other end of guide **10** is a load **16** to which it is desired to introduce microwave signals at, but not exceeding, one given power level. Attached to one side wall of waveguide section **10** is a resonant rectangular waveguide cavity section **18**. Resonant cavity section **18** comprises a section of rectangular waveguide having broad walls **22** and **24**, narrow side walls **26** and **28** and end walls **30** and **32**, with end wall **30** being affixed to the side wall of waveguide section **10** and an integral part thereof. A mutual couplying slot **33** is provided in end wall **30** so that electromagnetic energy is coupled from waveguide section **10** into resonator **18** and the length of resonator **18** is made one-half wavelength of the operating frequency. The microwave energy coupling from waveguide **10** to resonator **18** is such that a very intense magnetic field is established very close to the end wall **32** of resonator **18** as indicated by the dashed line **34**. Attached to end wall **32** substantially at the center thereof within resonator **18** is a sphere **38** of the above-mentioned planar single crystal Mn-ZnY ferrite with the easy plane of magnetization of the planar Mn-ZnY sphere **38** oriented parallel to the direction of the RF magnetic field **38** resulting from the propagated microwave energy as hereinabove described. A unidirectional magnetic biasing field H_{dc}, indicated by the arrow **40** is applied parallel to the direction of the RF magnetic field close to end wall **32** and in the easy plane of magnetization of the planar Mn-ZnY sphere **18**. If, as shown in FIG. 1, the electromagnetic wave propagated energy is in the Z-direction, and with the wave front in the x–y plane, then the R.F. magnetic field, the easy plane of magnetization and the applied unidirectional magnetic biasing field will be parallel to the Z-direction. With such an arrangement the natural elliptical precession motion of the Mn-ZnY sphere

18 induces an oscillatory magnetic moment parallel to the Z-direction. With the RF magnetic field being of a frequency equal to that of the oscillatory Z-magnetic moment, the precesssional motion is further excited, provided of course, that the RF field is of sufficient magnitude so that energy is pumped into the spin system faster than it is lost due to relaxation processes.

In operation, at low power levels, there is no interaction between the RF energy and the Mn-ZnY sphere 18 so that the cavity reflects a short at the plane of the coupling iris 33. Thus, at relatively low input power, the electromagnetic wave energy propagates with very little loss. At the limiting power level P_c (FIG. 2), absorption of energy occurs in the Mn-ZnY sphere 18 due to the excitation of the spin waves. Thus, it will be seen that the power output remains substantially constant at level P_c for large increases in the power input.

While there has been described what is at present considered to be the preferred embodiment of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is therefore aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A power limiter comprising

a first and second rectangular waveguide joined together in a T-configuration, said first waveguide having input and output ports through which a microwave signal propagates,

coupling means between said ports for coupling said microwave signal energy from said first waveguide to said second waveguide,

said second waveguide having an end wall electrically spaced from said coupling means by $\lambda_g/2$ where λ_g is the wavelength of said signal,

a planar ferrite sphere located at said end wall and oriented such that the easy plane of magnetization of said sphere is parallel to the direction of the magnetic field produced by the coupled microwave energy,

and an external unidirectional magnetic field applied parallel to said easy plane of magnetization of said ferrite sphere.

2. The power limiter in accordance with claim 1 wherein said ferrite sphere comprises an Mn-ZnY planar ferrite.

3. A power limiter comprising

a first rectangular waveguide having opposing narrow and broad walls and adapted to propagate a microwave signal in the TE_{10} mode,

a secon drectangular waveguide orthogonally positioned with respect to a narrow wall of said first waveguide, and terminated by an end wall spaced $\lambda_g/2$ wavelength therefrom, where λ_g is the wavelength of said microwave signal,

means for coupling said microwave signal from said first waveguide to said second waveguide whereby there is established a RF magnetic field parallel to and adjacent said end wall, and in the direction of propagation of said microwave signal,

a planar ferrite sphere within said second waveguide and attached to said end wall, said sphere being oriented such that the easy plane of magnetization of said sphere is parallel to said RF magnetic field at said end wall,

and an external unidirectional magnetic field applied parallel to said easy plane of magnetization and said RF magnetic field.

4. The power limiter in accordance with claim 3 wherein said ferrite sphere comprises an Mn-ZnY planar ferrite.

References Cited by the Examiner

UNITED STATES PATENTS

2,946,753	7/1960	Jonker et al.	252—62.5
3,113,278	12/1963	Okwit	333—24.2
3,131,366	4/1964	Dixon	333—24.2

OTHER REFERENCES

Philips Techanical Review, vol. 18, 1956/57, No. 6, Nov. 30, 1956, pp. 145–154.

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