Correspondence

Ferrite Shape Considerations for UHF High-Power Isolators*

Ferrite isolators deteriorate at high microwave power levels due to the gyromagnetic saturation phenomena described by Suhl.[1] The onset of this deterioration is particularly detrimental to isolator performance when the main and subsidiary resonances coincide. At microwave frequencies the coincidence effect can generally be avoided if thin transversely magnetized ferrite slabs are used. However, at frequencies below 1 kMc, the finite slab thickness can contribute to main-subsidiary resonance coincidence unless care is taken to choose the proper length and width dimensions of the slab. The following calculations specify the ferrite slab shape needed to avoid this coincidence in UHF ferrite isolators.

The main and subsidiary resonances occur at magnetizing fields H_{res} and H_{sub}, respectively. Coincidence effects are avoided provided that,

$$H_{\text{res}} \geq H_{\text{sub}} \quad (1)$$

where

$$H_{\text{res}} = \left(N_z - \frac{N_x + N_y}{2}\right)4\pi M_s + \sqrt{\left(\frac{N_x - N_y}{2}\right)(4\pi M_s)^2 + \left(\frac{\omega}{\gamma}\right)^2} \quad (2)$$

$$H_{\text{sub}} = \frac{\omega}{2\gamma} + N_z\, 4\pi M_s. \quad (3)$$

By substituting (2) and (3) into (1),

$$\frac{\omega}{\gamma} \geq \frac{4\pi M_s}{3}\left[N_x + N_y + \sqrt{N_x^2 + N_y^2 + 14N_xN_y}\right]. \quad (4)$$

Where

ω = applied angular frequency
γ = the gyromagnetic constant
$4\pi M_s$ = the saturation magnetization
$N_x + N_y + N_z = 1$ are the demagnetizing constants. The z direction is taken as the direction of magnetization.

The demagnetizing constants worked out by Osborn[2] for the general elipsoid are used in calculating the minimum frequency prior to main-subsidiary coincidence for particular ferrite shapes. The results are plotted on Fig. 1 and the ferrite-waveguide geometry is shown in Fig. 2.

Note that the minimum frequency for a particular material and T/L ratio occurs when $W/L = 1$. Now, suppose it is desired to make a YIG 400 Mc high-power isolator with $\frac{1}{8}$ inch thick slabs. The useful width

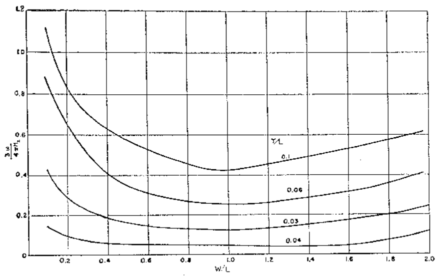

Fig. 1—Critical frequency ratio for the onset of main and subsidiary resonance coincidence as a function of ferrite shape.

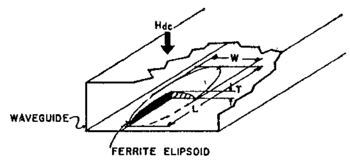

Fig. 2—Ferrite-waveguide geometry.

W is on the order of 3 inches, and the $4\pi M_s \approx 1800$ gauss, $\gamma \approx 2\pi \times 2.8 \times 10^6$ radians per oersted. The value of $3\omega/\gamma 4\pi M_s$ is 0.24, which is entered on the ordinate of Fig. 1. Only those shapes that fall below 0.24 should be considered for the isolator application. Thus, the T/L ratio should be less than 0.06 or $L \geq 2$ inches. If a length of 4.2 inches is chosen, then $T/L = 0.03$, and $W \geq 0.84$ inch.

In conclusion, it has been shown that the ferrite thickness of a ferrite slab causes a contribution to the demagnetizing fields that may produce main-subsidiary resonance coincidence at UHF frequencies. However, an appropriate slab geometry can be specified that eliminates this possibility.

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[2] J. A. Osborn, "Demagnetizing factors of the general ellipsoid," *Phys. Rev.*, vol. 67, pp. 351–357; June, 1945.

Measurement Technique for Narrow Line Width Ferromagnets*

Measurement of the line width of a ferromagnetic resonance curve using the now well-known cavity perturbation technique[1] offers some difficulty in the case of very narrow line width samples. Because of their large magnetic susceptibility, such samples produce a large effective filling factor with respect to the cavity. For example, the filling factor for a small ferromagnetic sample in a nondegenerate rectangular cavity reduces to

$$\eta = \chi\left[h^2V_s/2\int_{V_c} h^2 dv\right] \propto \chi V_s/V_c$$

where χ is the scalar magnetic susceptibility, V_s is the volume of the small sample, V_c is the cavity volume and h is the microwave magnetic field. Since the perturbation equations for cavity frequency shift and Q change are

$$\frac{\Delta\omega}{\omega} = \text{Re}\,(\eta)\,\alpha\,\chi' V_s/V_c$$

$$\Delta\left(\frac{1}{2Q}\right) = I_m(\eta)\,\alpha\,\chi'' V_s/V_c$$

large values of χ must be offset by increasing the size of the test cavity in order to reduce the ratio V_s/V_c if the perturbation is to remain small. When a 0.020 inch yttrium-iron-garnet sphere of the order of 1-oersted line width is to be placed in a simple X-band brass cavity, it is found that a cavity length greater than $50\lambda_g$ may be required to insure a sufficiently small perturbation of the fields in the cavity. The situation may be alleviated somewhat by rotation of H, the dc magnetic field, thereby reducing from 90° the angle between H and h. This procedure, which decouples the sample and effectively reduces V_s, normally precludes controlling the crystalline orientation of the sample under study.

The cavity perturbation method may be avoided if instead the sample is placed in a geometry whereby its magnetic resonance is characterized by reradiation of incident power into a region that is normally isolated when H is moved off-resonance.[2,3] An example of this idea is the cross-guide coupler suggested by Stinson.[3] By detection of the power coupled into the crossed guide, a resonance response curve is easily obtained from which the line width may be measured directly as the width at a certain fraction of the peak value of the curve. A possible disadvantage of this scheme is that the sample is located in a hole common to both guides and may be subject to undesirable nonuniform microwave fields. Furthermore, the mechanism for reradiation by the resonant spin system into the secondary guide may be accompanied by significant radiation damping which would show up as a line broadening in narrow line width samples.

The technique described below has been found satisfactory for line width measurements of fractional linewidth samples in the size range 0.015 inch or larger. As shown in the schematic of Fig. 1, the sample is placed in the transverse, uniform microwave magnetic field at a distance $n\lambda_g/2$ from the short

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