8.3: OPERATION OF A MICROWAVE GARNET LIMITER

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It is now possible to design a class of low level, milliwatt range ferrimagnetic microwave limiters which exhibit distinctive characteristics and important advantages over previously reported ferrimagnetic limiters[1-4]. The limiter characteristically consists of a microwave transmission cavity containing as a nonlinear element a large single crystal spherical sample of yttrium iron garnet (YIG) biased to the subsidiary absorption[5,6] by a dc magnetic field perpendicular to the rf magnetic field. Garnet losses increase with power above the subsidiary absorption threshold and result in a nonlinear decline in cavity Q which limits the output power. Large filling factors are needed for a significant limiting range and the large YIG single crystals now available make this limiter practical. At a given frequency the limiting threshold can be varied with the bias magnetic field, in contrast to gyromagnetic coupler limiters[1-4].

The important circuit properties of a microwave limiter are:

(a) threshold limiting power
(b) limiting characteristic above the threshold
(c) insertion loss below the threshold

The threshold output power (P_{oc}) is proportional to H^2_{crit}. From Suhl's[5] theory for the subsidiary absorption, h_{crit} is proportional to the effective spin wave linewidth ΔH_k. Single crystal YIG was chosen because ΔH_k can be quite small, resulting in a low threshold power. At 4080 Mc/s with a TE_{101} cavity of 0.400" height, and a Q_L of 200, limiting levels as low as 2 mw were observed. P_{oc} can be raised to the 100 mw range by decreasing the bias magnetic field.

From circuit theory and an application of perturbation theory, an expression for the limiting characteristic can be obtained

$$p_i = p_o \left[1 + \frac{Q_e}{4} T_o^{\frac{1}{2}} \quad F \chi''(p_o) \right]^2 , \qquad (1)$$

where p_o and p_i are the available and output powers normalized to their critical values. T_o is the transmission coefficient below threshold and F, the filling factor, is proportional to the ratio of sample to cavity volumes. For a fixed value of p_o it is seen that a large value of p_i will result if a large filling factor is used, which illustrates the need for large samples. Measurements of the imaginary part of the garnet susceptibility χ'' at 4000 Mc/s as well as X-band measurements by Hartwick, et al[7] indicate that Suhl's theory[5] does not predict the magnitude or form of the observed results. In the calculations the measured values of $\chi''(p_o)$ were used. By choosing the threshold power and the insertion loss below the threshold the cavity parameters for a given cavity mode and H_{dc} are determined.

Equation (1) can then be used to determine the theoretical limiting response. Figure 1 shows the theoretical and measured response using the previously mentioned cavity parameters and a 0.260" YIG sphere. The limiting threshold was 14 dbm and the insertion loss below the threshold was 0.5 db. The discrepancies can be attributed to inhomogeneities in the rf magnetic fields within the sample. The limiting characteristics can be improved by an increase in the external Q (Q_e) but at the expense of the insertion loss below the threshold. Also shown on this figure is the result of cascading two such limiters with a quarter wavelength section.

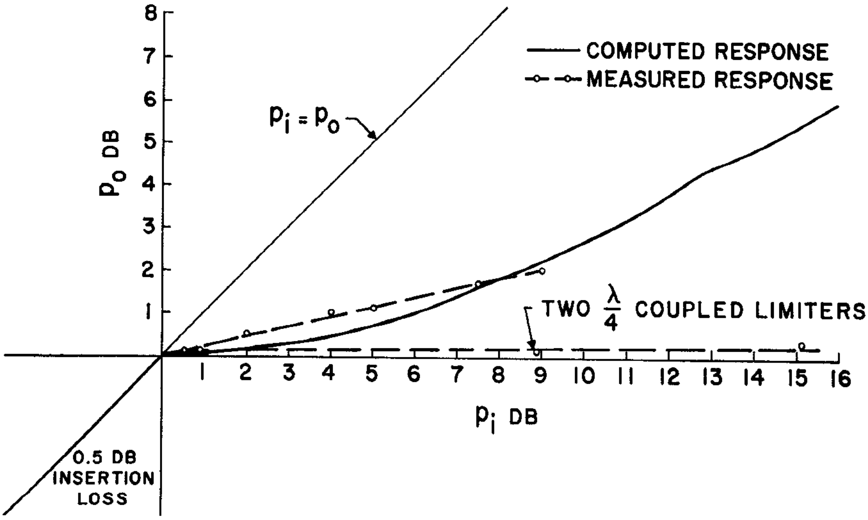

Fig. 1. Theoretical and experimental response of the subsidiary absorption limiter.

Two separate and important temperature effects have been observed experimentally:

(a) a temperature dependent insertion loss below the threshold (cavity detuning),
(b) a temperature dependent limiting power level.

Cavity detuning is affected by cavity thermal expansion and the temperature variation of the YIG rf magnetic susceptibility. Susceptibility variation is functionally dependent on the temperature coefficients of the biasing magnetic field, H_{dc}, of the component of anisotropy field along the biasing field, H_{anis}, and the saturation magnetization $4\pi M$. Expressions for these detuning effects based upon temperature derivatives of the susceptibility have been obtained which describe the magnitude and functional dependence of each of these contributions.

The temperature dependence of limiting level is described by introducing into Suhl's[5] expressions for the critical rf field, h_{crit}, the temperature dependence of ΔH_k, $4\pi M$, H_{dc}, and H_{anis}. An expression for the temperature derivative of limiting power level is obtained which again describes the magnitude and functional dependence of each of these contributions.

The characteristics of a laboratory limiter are shown in Figure 2 in the temperature range from 55^o to 120^oF. The lower set of curves was obtained with the YIG sphere oriented so that the magnetically easy [111] crystallographic direction is along H_{dc} while the orientation for the upper set of temperature compensated characteristics was along the hard [100] direction. The thermal detuning and limiting level effects are clearly seen. These two extremes of hard and easy orientation represent the cases where the temperature derivative of anisotropy field has been used respectively to cancel and to add to the other sources of temperature variation discussed above. The theoretical expressions developed above to describe these temperature effects predict quantitatively the observed results. They also provide the basis for general optimization procedures in situations which differ in material or performance requirements.

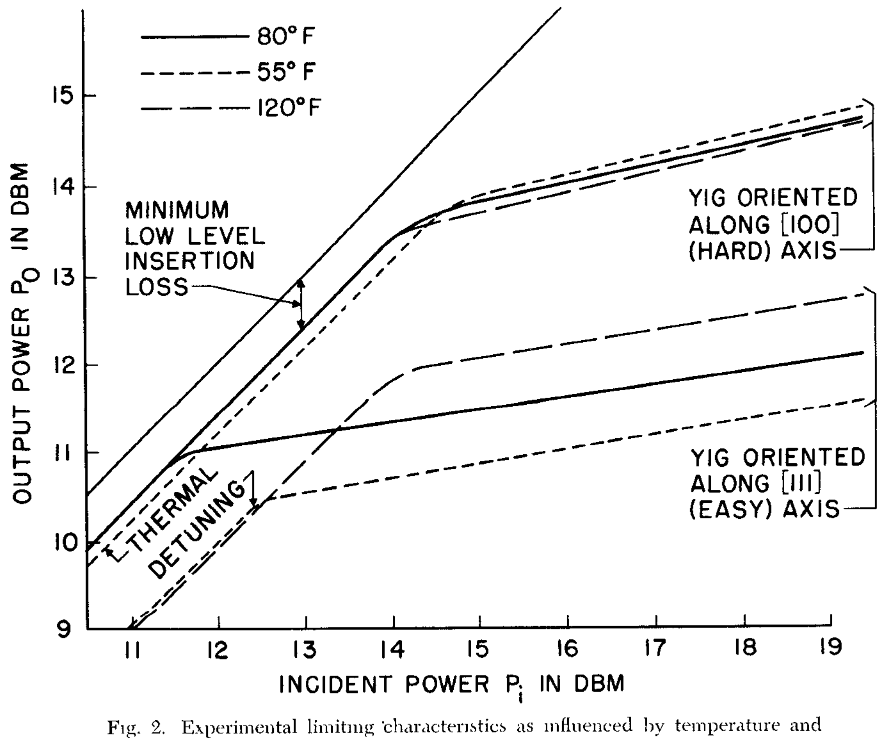

Fig. 2. Experimental limiting characteristics as influenced by temperature and crystallographic orientation.

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