III. Tests with a Doublet of Pure YIG Disks

Another test with a pure YIG doublet was subsequently tried, using continuously variable spacing and a [111] orientation of the axes. This resulted in a smooth variation in resonant field with relative orientation of the two disks. The frequency range was extended to 3000 MHz, since higher frequencies are to undoped material what lower frequencies are to Ga YIG. A differential gaussmeter was used to show that the individual disks were initially very similar in $4\pi M_s N_z$ at a number of fixed frequencies. Since the procedure here involved inserting and removing the disks one at a time, in a bandstop-filter structure, orientations relative to the applied magnetizing field were probably not perfectly reproduced. Nevertheless, the measurements were repeatable within ± 3 Oe at 1200 MHz and above.

Resonances of this doublet were strong, and all data were clear cut and reproducible. In the octave 1500–3000 MHz, the variation of the effective $4\pi M_s N_z = H_{dc} - f_0/2.8$ with spacing was examined in detail and found to decrease by several tens of oersteds as the second disk was brought in from relatively far away to almost touching. This observation is consistent with theory. Most of the change occurs for spacings in the range 0.006 to 0.040 inch, for 0.150-inch diameter by 0.005-inch-thick disks. Figure 2 shows a few representative plots, at selected frequencies, of relative resonant field against disk spacing. The vertical limit marks represent a combination of experimental error and a "hysteresis" effect that will be explained soon by reference to Fig. 3.

Unfortunately, the observed change in effective $4\pi M_s N_z$ was neither constant nor even proportional to H_{dc} as the frequency varied. Actually, it dropped from about 45 Oe out of 2270 Oe at 1900 MHz, to about 25 Oe out of 2690 Oe at 3000 MHz. Thus, if we were to plot the resonant field against frequency for several disk spacings, all on one graph, then these several curves would not be parallel, though at the higher fields or frequencies they become more nearly parallel. This result means that if two unequal "inner" disks on opposite sides of a bandpass filter are "equalized" at one frequency by introducing two more "outer" disks at whatever spacing is appropriate to each side, they would not remain equalized at another frequency, and the filter would not be "tracking." As yet, no theory is available to apply to the aforementioned observed details; so far one can only predict approximately for the end-points, that is, for infinite and zero spacing.

An unusual phenomenon, observed at the lower frequencies, is exemplified in Fig. 3 for frequencies of 800 MHz and 1200 MHz. Below about 1500 MHz ($H_{dc} \approx 2100$ Oe) the resonant field for a given frequency and spacing is lower when the disks are approaching one another than when separating. This effect, which disappeared at higher fields and frequencies and therefore probably arises from some incomplete saturation condition, was always distinct and reproducible.

IV. Conclusions

Until doublets per se can be studied further, they cannot be used as adjustable resonators in bandpass filters. Instead, equality of $4\pi M_s N_z$ may have to depend on selecting pairs of "matched" disks from a large batch of disks.

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Bandstop Filter Formulas[1]

This correspondence summarizes a few simple formulas for single-resonator bandstop filters. We have found the formulas useful mainly in the tuning procedure or to determine the individual resonator Qs of multi-resonator bandstop filters [1]–[5]. These equations arose and were developed at the Stanford Research Institute during various applications; the exact formulas have not been published before.

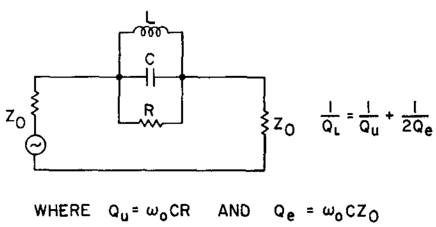

Fig. 1. Single-resonator bandstop filter.

Consider the single-resonator bandstop filter shown in Fig. 1, with the unloaded Q, Q_u, and external Q, Q_e, as defined in the figure. The source and load impedances (Z_0) are assumed to be equal. Let

$(L_A)_{max}$ = maximum attenuation in dB of bandstop filter (with single resonator).

V_{max} = maximum input VSWR of bandstop filter (with single resonator).

w_{x-dB} = fractional bandwidth between x-dB points on a guide wavelength basis. (The suffix 1 is used to emphasize that this is the bandwidth of a single cavity of possibly a multi-cavity filter in which the other cavities have been decoupled.)

$$A = \text{antilog}_{10}\left[\frac{(L_A)_{max}}{20}\right] = 10^{(L_A)_{max}/20}.$$

The resonator normalized slope parameter[1] is

$$\frac{b}{Y_0} = \frac{1}{2}\frac{Q_u}{A-1}.$$

Then,

$$A = \tfrac{1}{2}(V_{max} + 1)$$

$$\frac{Q_u}{Q_e} = 2(A-1) = V_{max} - 1$$

$$Q_u = \frac{1}{w_{3-db}}\sqrt{A^2 - 2}.$$

More generally,

$$Q_u = \frac{1}{w_{LA-dB}}\sqrt{\frac{A^2 - 10^{L_A/10}}{10^{L_A/10} - 1}}$$

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[1] These formulas resulted from research contracts for the U. S. Army Electronics Laboratories, Fort Monmouth, N. J.

References

[1] L. Young, G. L. Matthaei, and E. M. T. Jones, "Microwave band-stop filters with narrow stop bands," *IRE Trans. on Microwave Theory and Techniques*, vol. MTT-10, pp. 416–427, November 1962.

[2] B. M. Schiffman and G. L. Matthaei, "Exact design of band-stop microwave filters," *IEEE Trans. on Microwave Theory and Techniques*, vol. MTT-12, pp. 6–15, January 1964.

[3] E. G. Cristal, "Addendum to an exact method for synthesis of microwave bandstop filters," *IEEE Trans. on Microwave Theory and Techniques (Correspondence)*, vol. MTT-12, pp. 369–382, May 1964.

[4] J. J. Taub and R. L. Sleven, "Design of band-stop filters in the presence of dissipation," *IEEE Trans. on Microwave Theory and Techniques*, vol. MTT-13, pp. 589–616, September 1965.

[5] G. L. Matthaei, "Magnetically tunable bandstop filters," *IEEE Trans. on Microwave Theory and Techniques*, vol. MTT-13, pp. 203–212, March 1965.

Design Data for UHF Circulators

Introduction

Davies and Cohen [1] have described detailed calculations based upon the theoretical investigations of Bosma [2] into stripline circulator operation. The calculations yielded design curves for various modes of circulation but were applicable only for a particular relationship between center conductor width and ferrite radius. This correspondence describes an extension of their calculations to a wide range of stripline geometries, permitting greater freedom in circulator design.

Design Curves

The circulator geometry is depicted in Fig. 1, with the radius of the center conducting plane R being taken equal to the ferrite radius. Curves have been obtained as solutions of Bosma's circulation equations with the aid of a digital computer, using a technique which separates the required data from the singularities associated with solutions.

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