BAND STOP FILTER USING LPE-YIG FILMS

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Abstract

Current injection into flat ribbon strips adjacent to YIG films provides rapid linear tuning and low insertion loss band-stop filters on a planar structure. Results show promise for high frequency hopping devices over a fairly wide bandwidth.

Introduction

Epitaxial magnetic garnets for microwave device applications have received great interest in recent years.[1] Microwave filters utilizing Yttrium Iron Garnet (YIG) films as resonator chips in microstrip circuits can provide a planar technology for future microwave devices [2,3]. We present here a simple technique for linear tuning and fast switching, of low insertion loss band stop filters, by varying the local H field in the neighborhood of a film on microstrip. We used YIG disks**, with 2mm diameter and 10 μm thickness, grown on (111) GGG substrates, in our work. We also investigated the influences on Ferrimagnetic Resonant (FMR) frequency of first-order crystalline anisotropy and growth induced anisotropy.[4] Here we compensate for these anisotropies and wall effects by the techniques described herein.

Single Pole Filter

Shown in the insert of Fig. (1) is a microstrip line with characteristic impedance 50Ω. At the film junction, the microstrip line is replaced by a narrow copper wire, with width of approximately 1.5mm, running over the YIG film. A swept RF field between $f_1 = 3.26$ GHz and $f_2 = 3.36$ GHz is fed to the microstrip line through an OSM connector. FMR is observed at a field intensity of 600 oe applied parallel to the disk face, as shown by solid line in Fig. (1). No attempt at impedance matching was made. Off band insertion loss less than 2 dB was readily achieved. Fine tuning is accomplished by changing the local field H_1 generated by a 2 mm wide current strip crossed over the microstrip line and YIG film. With a pulsed D-C current applied to current strip, frequency hopping is observed as shown in Fig. (1). The magnitude of the frequency shift depends on the direction and strength of the local H_1 field. A standard calculation[5] for the magnetostatic field produced by a current strip, at a distance X below a strip of width $\bar{W}$ gives for the field,

$$|H_1| = \frac{I}{\pi \bar{W}} \tan^{-1}\left(\frac{\bar{W}}{2X}\right)$$

Tuning characteristics, in the neighborhood of applied field H_o, can easily be derived, i.e.

$$\Delta\omega = \gamma\left(\frac{H_o + 2\pi M}{\sqrt{H_o(H_o + 4\pi M)}}\right)\left(\frac{1}{\pi \bar{W}} \tan^{-1}\left(\frac{\bar{W}}{2X}\right)\right) I$$

with $4\pi M$ the saturation magnetization for the film of interest. Fig. (2) shows the good agreement achieved between experimental and theoretical results for X = .13mm, H = 600 oe, $4\pi M$ = 1750 oe and $\bar{W}$ = 2mm. We have demonstrated here that linear frequency tuning in the neighborhood of resonant frequency is available if a surface current can be generated near the YIG film.

Fast switching is another merit of the present configuration. With it, switching speeds greater than 10 MHz/μs are easily achieved. This is comparable to the speed of commercially available fast switching filters which utilize specially designed magnetic circuits and drivers (e.g. W.J. 5162D) to obtain the fast switching. This 10 MHz/μsec value is within an order of magnitude of the limit established by $\Delta t \Delta f$ (= 10 MHz) > 1. With improved design perhaps a 100 MHz/μsec switching speed would be a reasonable limit to expect.

Switching speed is measured by feeding pulsed CW, with 13μs pulse duration, into the microstrip line. The frequency is tuned until maximum absorption is observed as represented by level A in Fig. (3). A synchronized pulsed D-C current with 5μs pulse duration is then applied to the current strip. Shifting of the resonant frequency of the filter due to the perturbing H_1 field is observed as level B in Fig. (3).

Two Pole Filter

Efficient tuning for multipole filters can also be realized by using the present technique. Two identical resonator chips, with dimensions as described before, are separated by $\lambda/4$ as shown in Fig. (4a). In the absence of a bias field, the input RF is as shown in Fig. (4b). With a bias magnetic field of about 600 oe parallel to the disk faces, resonant spikes are observed, as shown in Fig. (4c). These two well separated and distorted peaks were tuned so as to form the band-stop filter of Fig. (4d). Current was passed through the strip shown in Fig. (4a).

One filter was tuned up and the other tuned down in frequency, simultaneously and synchronously. Critical tuning for the present configuration was achieved with I = 1.2 Amps. We have demonstrated here the potential of compensating anisotropy fields and wall effect by the changing local H_1 field produced by surface current. For a two pole band-stop filter of this configuration, off band insertion loss is found to be 4.3 dB without impedance matching. We believe that by varying the dielectric loading and dielectric thickness around the YIG film, reduction in insertion loss to less than 1 dB/pole is possible.[2] For the

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present configuration, we found that

$$(\Delta f)_{3dB} = 9.3 \text{ MHz}$$

$$(\Delta f)_{10dB} = 2.5 \text{ MHz}$$

$$L_{max} \simeq 16 \text{ dB}$$

and that spurious modes are typically > 14 dB down, for the two pole filter. (The notation used here is similar to that used by Matthaei[6].)

With improved IC design techniques; reliable, attractive, planar multipole YIG filters can easily be achieved. Here we have demonstrated a simple technique for frequency tuning, however, it may play a very important role in microwave integrated circuit devices.

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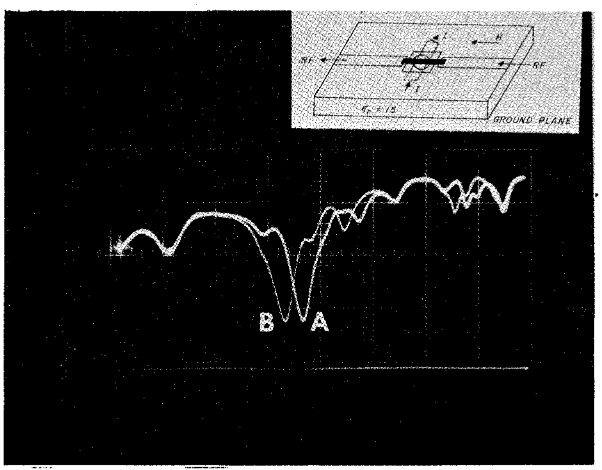

Fig. 1(a) - Microstrip circuit configuration.
(b) - Single resonator FMR. Solid line corresponds to I=0 with f_A=3310.5 MHz, dotted line corresponds to I=.4 Amp, f_B=3306.2 MHz

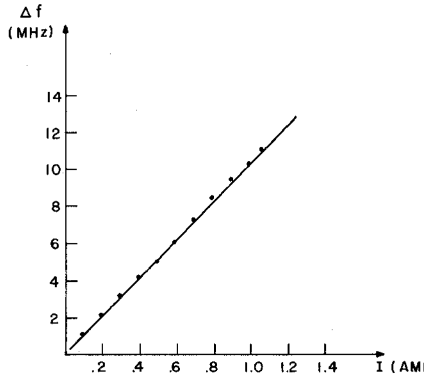

Fig.2 - Frequency shift against D-C current.
_______ theoretical curve with X=.13mm
. . . . . experimental results.

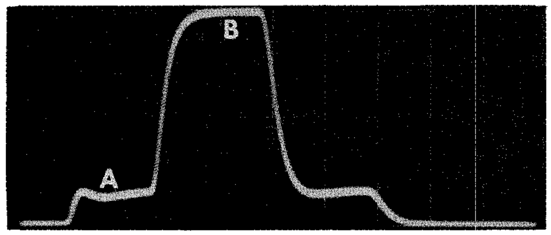

Fig. 3- Switching time measurement in between f_A = 3310.5 MHz and f_B = 3306.2 MHz. Time scale is 2μs/Div.

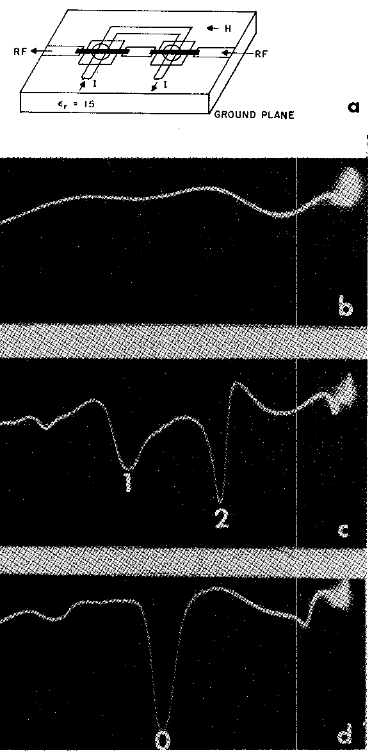

Fig. 4(a)-Microstrip circuit for electronically tunable two pole band-stop filter.
(b)-rf input with H=0, I=0.
(c)-H=600 oe. I=0. f_1=3288.5MHz, f_2=3310.5MHz
(d)-H=600 oe. I=1.2Amps. f_0=3298MHz