A LOW-LOSS MAGNETOSTATIC WAVE FILTER USING PARALLEL STRIP TRANSDUCER

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ABSTRACT

A new configuration for magnetostatic forward volume wave (MSFVW) filter has been proposed. Parallel strip transducers and metal disks on yttrium iron garnet (YIG) film were adopted. Expressions developed for the radiation impedance of transducers makes the design of these medium band-width filters possible. Insertion loss of 6 dB was achieved in the 0.7-5.2 GHz band, and 4 dB in the 2.8-3.9 GHz band.

INTRODUCTION

Magnetostatic wave filters which operated in the X-band and the S-band showed a very wide frequency tuning range and high out-of-band spurious response[1, 2]. A study on magnetostatic wave resonators was recently reported. These resonators used metal disks loaded on YIG film[3]. The magnetostatic wave filters using these resonators show great promise for applications in broadband single conversion receivers because of their demonstrated high dynamic range and freedom to operate at any microwave frequency. The insertion loss of the filter using these resonators was, however, 16 dB because of its small coupling coefficient between wire antennas and YIG film.

We applied parallel strip transducers to the MSFVW filter using metal disks loaded on YIG film in order to increase the coupling cefficient. We calculated radiation impedance with the Fourier transform relation which has been applied to magnetostatic surface wave (MSSW) transducers, and we made the design of medium band-width filters possible. Expressions developed for the radiation impedance of transducers also explain the experimental dependence of YIG film thickness on 3 dB band-width of MSFVW filter.

In this paper a new configuration for a MSFVW filter which achieves insertion loss of 6 dB in the 0.7-5.2 GHz band and 4 dB in the 2.8-3.9 GHz band is discussed. This is the lowest loss performance in any magnetostatic filter that has been reported.

CONSTRUCTION

A cross-section of the magnetostatic wave filter is shown in Figure 1. The

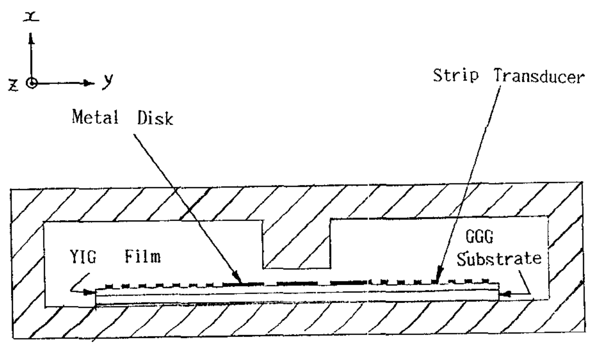

Figure 1. Cross Section of MSFVW Filter

filter consists of YIG film grown by liquid-phase epitaxy on a gadolinium gallium garnet (GGG) substrate, and has parallel strip transducer and metal disks. The center frequency of the filter is determined by the strength of the magnetic bias field, which is applied normal to the YIG film to excite MSFVW. The number of strips is three to seven, and the coupling coefficient between transducers having more strips and YIG film is large.

Metal disks loaded on the YIG film work as magnetostatic wave resonators and have the effect of supressing out-of-band spurious response. The Q-factor of the magnetostatic wave resonators is 500-2000 in the S-band. We laid three magnetostatic resonators, and constructed the MSFVW filter.

Figure 2 is a photograph showing the interior of the filter. The brass housing enclosing the YIG filter element was designed to minimize the microwave feed-thru between input and output ports. Measurements of this feed-thru showed it to be -75 dB. The parallel transducers and disks are made of 0.05 mm thick silver film which decreased conduction loss. Input and output terminals are SMA connectors.

THEORY

Radiation resistance of magnetostatic surface-wave (MSSW) was calculated considering transducer spatial current distribution and the results enable one to predict transducer frequency response a specified weighting of transducer element width, length, and spacing [4]. We applied this theory to calculate radiation resistance of the MSFVW. The reactance component of radiation impedance was calculated with Hilbert transformation [5].

With reference to Figure 1, we calculated the far-field total power carried by a MSFVW propagation in the y-direction away from a transducer. The total power P is

$$P = R_e\left(\frac{1}{2}\int_{-\infty}^{\infty} H_x^* E_z \, dx\right) \qquad (1)$$

and radiation resistance R_m is expressed as follows.

$$R_m = 2P/I_0^2 \qquad (2)$$

where transducer current I_0 is

$$I_0 = \int_{-a/2}^{a/2} J_z(y)\, dy \qquad (3)$$

And then, the imaginary part of the radiation impedance is obtained from the following equation.

$$X_m(\omega) = \frac{R_m(\omega)}{\pi}\, \ell n \left\{\frac{(1-\omega/\omega_2)(\omega/\omega_1+1)}{(1+\omega/\omega_2)(\omega/\omega_1-1)}\right\} + \frac{2\omega}{\pi\omega_1}\int_{1}^{\omega_2/\omega_1} \frac{R_m(x\omega_1)-R_m(\omega_1)}{x^2-(\omega/\omega_1)^2}\, dx \qquad (4)$$

where

$$\omega_1 = \gamma Hi, \quad \omega_2 = \gamma\sqrt{Hi\,(Hi+4\pi M)} \qquad (5)$$

The insertion loss of the MSFVW filter is eventually derived from (2) and (4).

$$I.L. = 20\log_{10}\left\{\frac{(R_g + R_m\ell/2)^2 + (X_m\ell/2)^2}{2R_g R_m \ell}\right\} + 76.4\,T\,\Delta H \qquad (6)$$

where ℓ is transducer length, T is delay time, and ΔH is full magnetic line width.

EXPERIMENTAL RESULTS

We made the MSFVW filter using parallel strip transducers and metal disks loaded

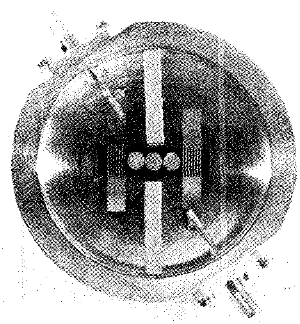

Figure 2 Photograph of MSFVW Filter

on YIG film. The dimension of the YIG film is 20 mm × 5 mm, and the number of strips is seven. The width of a single strip is 0.2 mm and the width of a spacing is 0.3 mm. The diameter of the three metal disks is 3 mm.

Figure 3 gives a typical MSFVW filter response. This medium-band MSFVW filter consists of 43 μm thick YIG film. It can be seen that insertion loss is less than 4 dB. The 3 dB band-width is 25 MHz, passband shape shows that the third travelling echo (TTE) level is supressed. The time domain response of the medium-band MSFVW filter is given in Figure 4, which shows the first signal pulse at 45 nsec followed by a second pulse at 90 nsec and TTE pulse at 130 nsec. Measurements of spurious signals in the time domain show TTE pulse to be -20 dB. Further work is necessary to reduce these undesired time domain signals to less than -35 dB. Group delay characteristics of the MSFVW filter with frequency is shown in Figure 5. It is approximately constant at 40 nsec across the 3 db band-width.

A multi-trace plot for the MSFVW filter is shown in Figure 6 in the 0.5-6 GHz frequency range. Insertion loss of 6 dB is achieved in the 0.7-5.2 GHz band and 3.5 dB in the 2.8-3.9 GHz band. Very low loss performance is therefore obtained in a wide frequency range.

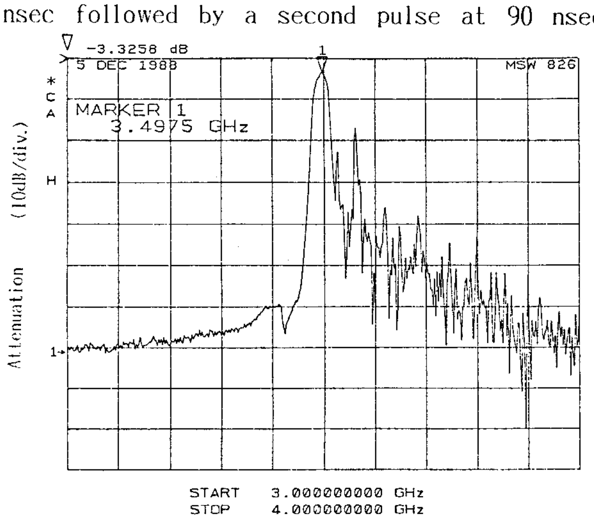

Figure 3 MSFVW Filter Response

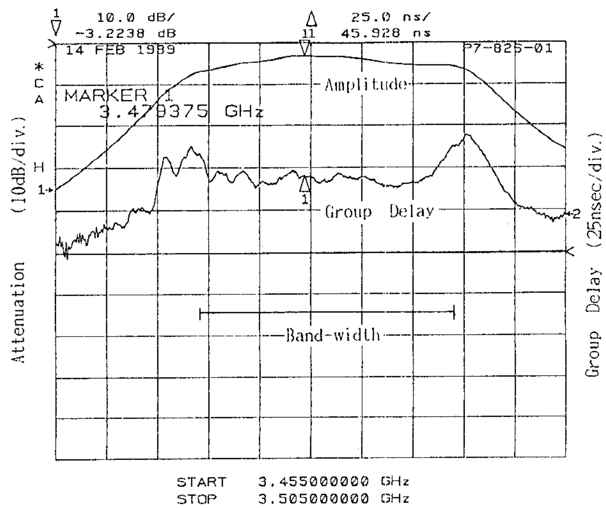

Figure 5 Group Delay of MSFVW Filter

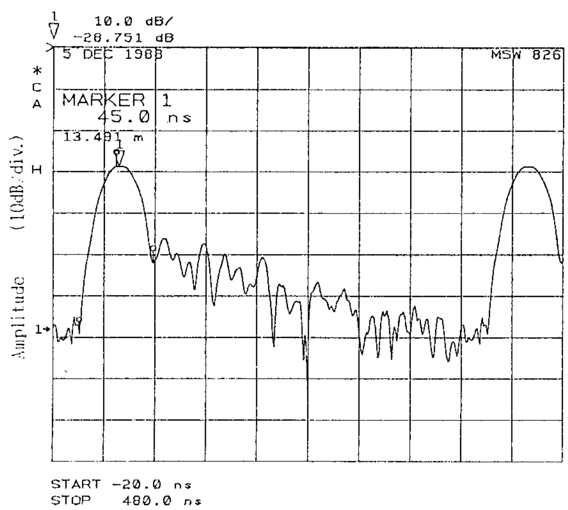

Figure 4 Time Domain Response of MSFVW Filter

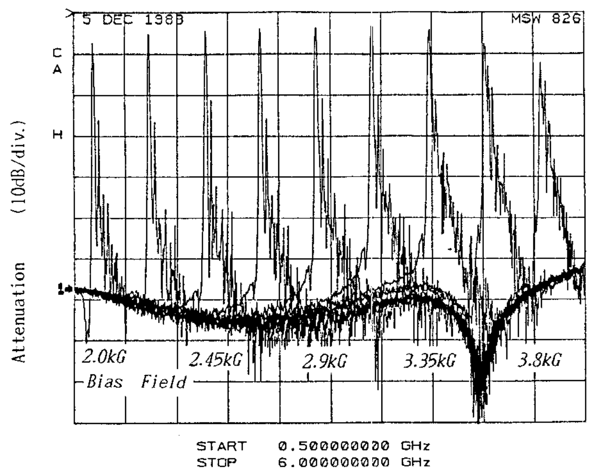

Figure 6 Multi-trace of MSFVW Filter Response

Expressions developed for the radiation impedance of periodic transducers show the dependence of YIG film thickness on 3 db band-width. Figure 7 shows the calculated frequency characteristics of the MSFVW filter using YIG film of 10, 50, and 100 μm. It can be seen that the 3 dB band-width narrows as YIG film thickness decreases. The frequency response of a narrow-band MSFVW filter is shown in Figure 8. The 3 dB band-width is 5 MHz and insertion loss is 5dB. This narrow-band MSFVW filter consists of 11 μm thick YIG film. The calculated frequency characteristics in Figure 7 can explain the frequency response of the expermental dependence of YIG film thickness on the 3 dB band-width of the filter.

CONCLUSION

A new configuration for an MSFVW filter was reported. We proposed the MSFVW filter using seven parallel strip transducers and three metal disks loaded on YIG film. The radiation impedance of MSFVW filter was calculated using a Fourier transform relation between MSFVW field amplitude and transducer spatial current distribution. We showed, consequently, the dependence of YIG film thickness on the 3 db band-width. The transducer design considering the radiation impedence matching using parallel strips yields the large coupling coefficient with YIG film. Thus, very low insertion loss was achieved in the S-band operation. This is the lowest insertion loss of an MSFVW filter to be reported.

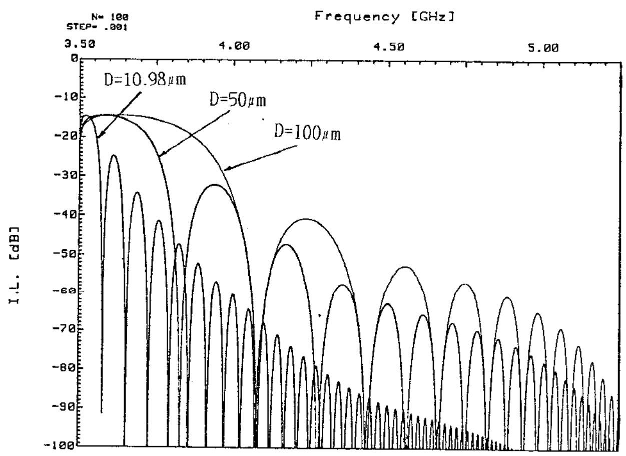

Figure 7 Calculated MSFVW Filter Response

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REFERENCES

[1] Y. J. Ataiiyan, et al., "MSSW Transversal Filters Based on Current Weighting in Narrow (10μm) Transducers", 1986 IEEE MTT-S Digest, pp. 575-578

[2] J. D. Adam, et al., "A 13-channel Magnetostatic Wave Filterbank" 1988 IEEE MTT-S Digest, pp. 879-882

[3] M. Tsutsumi, "A Study on The Magnetostatic Wave Resonators Using The YIG Film" Trans. of IEICE Japan, vol. J70-C No. 8, pp. 1214-1216, Aug. 1987

[4] J. C. Sethares, "Magnetostatic Surface-Wave Transducers", IEEE Trans. Microwave Theory Tech., vol. MTT-27, No. 11, pp. 902-909, Nov. 1979

[5] A. K. Ganguly, et al., "Complex Radiation Impedance of Microstrip-Excited Magnetostatic Surface Wave", IEEE Trans. Microwave Theory Tech., vol. MTT-26, No. 6, pp. 444-447, Jun. 1978

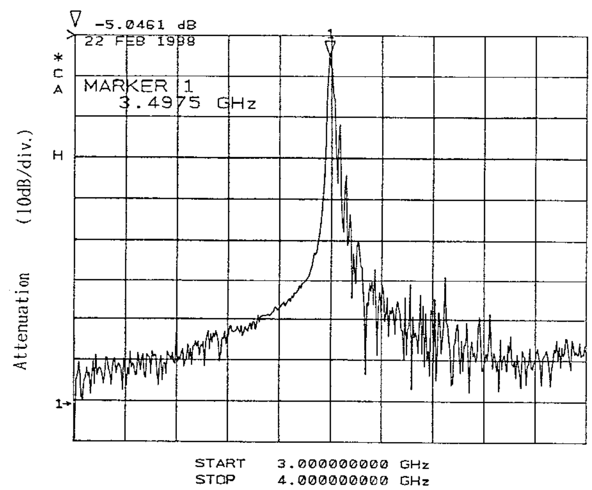

Figure 8 Narrow-Band MSFVW Filter