MAGNETOSTATIC FORWARD VOLUME WAVE STRAIGHT EDGE RESONATORS

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ABSTRACT

The preformance of Magnetostatic Forward Volume Wave Straight Edge Resonators (MSFVW-SER) is presented. The resonator uses a rectangular YIG film to propagate Magnetostatic forward volume waves where the straight edges serve as reflectors. The interference of width mode resonances with the main resonance reported in the MSSW-SER is not observed in the MSFVW-SER. As a result, high-Q tunable microwave resonators with a tuning range from 1-20 GHz, insertion loss less than 8 dB and spurious rejection better than 10 dB have been designed and fabricated.

INTRODUCTION

During the early investigation of Mangnetostatic Wave devices it was found that resonances occur in rectangular slabs of YIG [1]. Recently, our laboratory reported on MSSW resonators using rectangular YIG films where the straight edges serve as reflectors for MSSWs. These devices are tunable between 2 and 16 GHz and exhibit low insertion loss (≤10 dB) with high spurious rejection (≥10 dB) [2-4]. However, it was noticed that the high order width mode resonances of of the MSSW-SER interfere with the main resonance at different tuning frequencies and cause splitting of the main resonance. Moveover, below 4.2 GHz, the power handling of the MSSW-SER is poor because of coincident limiting effect in pure YIG films. Another disadvantage of the MSSW-SER is that of large power dissipation in the bias electromagnet. Because the bias magnetic field is applied in the plane of the YIG film, perpendicular to the propagation direction, a large magnet gap is required, setting an upper frequency limit for practical magnet sizes. In this paper, the performance of the MSFVW-SER, which eliminated all the above disadvantages, is presented. As a result, high-Q tunable microwave resonators with tuning range from 1 to 20 GHz, insertion loss below 10 dB, and spurious rejection better than 10 dB could easily be designed.

DISCRIPTION OF THE RESONATOR

A typical configuration for the MSFVW-SER, is shown in Figure 1. It consists of a ferrimagnetic resonant cavity, placed on a thin film transducer structure. The resonant cavity is made of a piece of YIG film epitaxially grown on a GGG substrate and cut into a rectangle by a wafer saw. The transducers are short circuit microstrips patterned in gold on a dielectric substrate (such as sapphire or quartz). The applied magnetic field is perdicular to the surface of the YIG film for the excitation of MSFVWs in the YIG film by one or two transducers. These isotropic waves propagate inside the volume of the YIG film and are reflected back between the straight edges. A circulating wave pattern results that is resonant if the following condition is met:

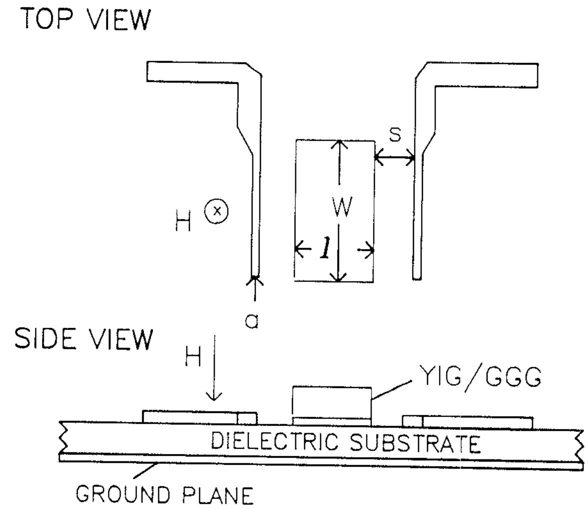

Fig.1 Magnetostatic Forward Wave Straight Edge Resonator - A schematic.

$$K_n l = n\pi \qquad , n = 1, 2, 3..... \tag{1}$$

where K_n is the wave number for the MSFVWs and l is the distance between the straight edges of the YIG film.

The resonant condition described by equation (1) is only valid for a rectangular YIG film with infinite width (W=∞). For a YIG film with finite width (Fig. 1), the resonant condition needs to be modified to include the effect of width modes excitation. Adam and Bajpai [5] have analyzed width modes is YIG-MSFVW delay line configurations and reported the dispersion equations for different high order width modes of a YIG film with finite width W. Figure 2 shows the variation of wavenumber $K_{n,m}$ with frequency for width modes $m = 1, 2, 3$ in a YIG film of finite width W. From this set of dispersion curves, the resonant frequency for each width mode follows the following equations:

$$K_{n,m} l = n\pi \qquad , n, m = 1, 2, 3....... \tag{2}$$

The frequency response of this rectangular SER with a given dimension of l and W is a family of resonant modes corresponding to a different value of n and m for a fixed external magnetic field. For each principal resonance ($n = 1, 2, 3......, m = 1$) , different odd ($m = 1, 3, 5,......$) width mode resonances or even ($m = 2, 4, 6........$) width mode resonances are excited depending on the current distribution on the short-circuited

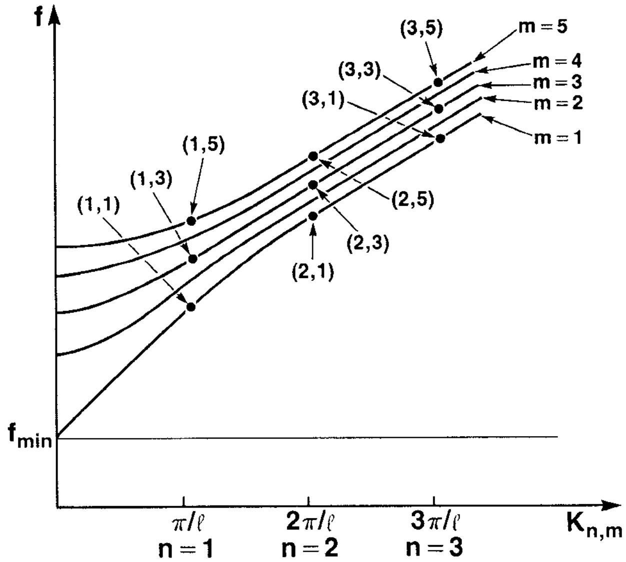

Fig.2 Dispersion curves for MSFVW-SER width mode resonators.

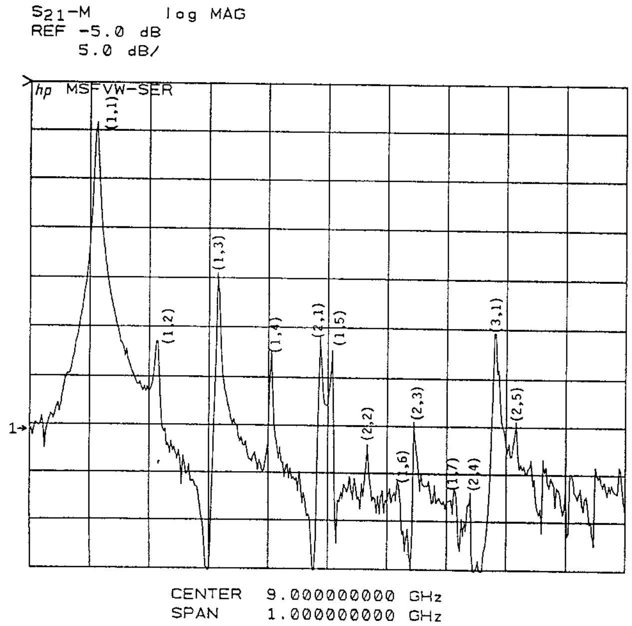

Fig.3 Typical frequency response of a MSFVW-SER.

microstrip transducers. If W is equal to the length of the microstrip transducer , then at low frequencies the current distribution on the transducer is almost constant because W is small with respect to the value of $\frac{\lambda_{em}}{4}$, where λ_{em} is the electromagnetic wavelength. With this constant current distribution on the microstrip, only the odd order ($m = 1,3,5....$) width mode resonances are excited. As the tuning frequency increases, the value of the $\frac{\lambda_{em}}{4}$ decreases such that it will become equal to W. At this high tuning frequencies, the current distribution becomes nonuniform and both even and odd mode resonances can be excited.

From the solution of Equation (2), one can see that the high order width mode resonances ($n = 1,2,3,...; m = 2,3,4,...$) for the MSFVW-SER occur at the high frequency side of the principal resonances ($n = 1,2,3,..; m = 1$). In contract, the high order width mode resonances for the MSSW-SER [2] occur at the low frequency side of the principal resonances. Because of this difference and the difference between the tuning characteristics of MSSWs and MSFVWs, one can predict that the high order width mode resonances for MSFVW-SER will not interfere with the main resonance at all tuning frequencies.

EXPERIMENTAL RESULTS AND DISCUSSION

Figure 3 shows a typical frequency response of a rectangular MSFVW-SER. The spurious resonant modes occurred at the high frequency side of the main resonance $(1,1)$ and high order principal resonances $\{(2,1),(3,1),..\}$ are the width mode resonances :

$$\{(1,2),(1,3),(1,4),(1,5),.;(2,2),(2,3),.;(3,2),(3,3),.\}.$$

The symbols (n,m) are used for the classification of these resonances. In this particular configuration both the odd and the even order width mode resonances are excited. However, the odd order width mode resonances are stronger than the even order width mode resonances because of the nonuniform current distribution on the microstrip transducers.

Experimental measurements confirmed the property that the higher order width mode resonances do not interfere with the main resonance at all tuning frequencies. The insertion loss, return loss ,loaded Q and spurious rejection of the main resonance for MSFVW-SER can be adjusted by suitably spacing away the transducers or by adjusting the dimensions of the resonator. Through a careful choice of YIG and transducer parameters, a 1 to 20 GHz tunable MSFVW-SER was designed, fabricated and tested. Figure 4 shows the transmission and reflection responses of this resonator at 5,15 and 20 GHz, respectively. Figures 5 and 6 (a,b) show the tuning characteristics, the insertion loss of the main resonance and the spurious rejection of this resonator. As shown in these results, the insertion loss of the main resonance is between 4 to 6 dB from 2.5 to 15 GHz, 6 to 8 dB from 1.5 to 2.5 GHz and 15 to 20 GHz, and 8 to 12 dB from 1 to 1.5 GHz. The spouious rejection is always better than 10 dB over the entire tuning range. The loaded Q of the resonator is between 375 to 1000 from 1 to 7 GHz and 1000 to 2300 from 7 to 20 GHz. The upper tuning frequency could be extend to over 20 GHz by selecting different YIG and transducer parameters.

The 1 dB power compression point of this device was measured to be -7 dBm, 0 dBm , $\geq$ 5 dBm at 1, 4.5 and above 7 GHz, respectively. In a recent paper [6], we have discussed the phase noise characteristics of the MSFVW-SER using YIG films of different linewidths and different incident power levels. It is noticed that the phase noise characteristics of MSFVW-SER degrades at incident power levels closer or above the 1 dB compression point. The reader is referred reference [6] for more details about phase noise in the MSW devices. The power and phase noise performance of the MSFVW-SER can be improved by using a higher linewidth YIG film. However, the insertion loss and the loaded Q of the device will be degraded.

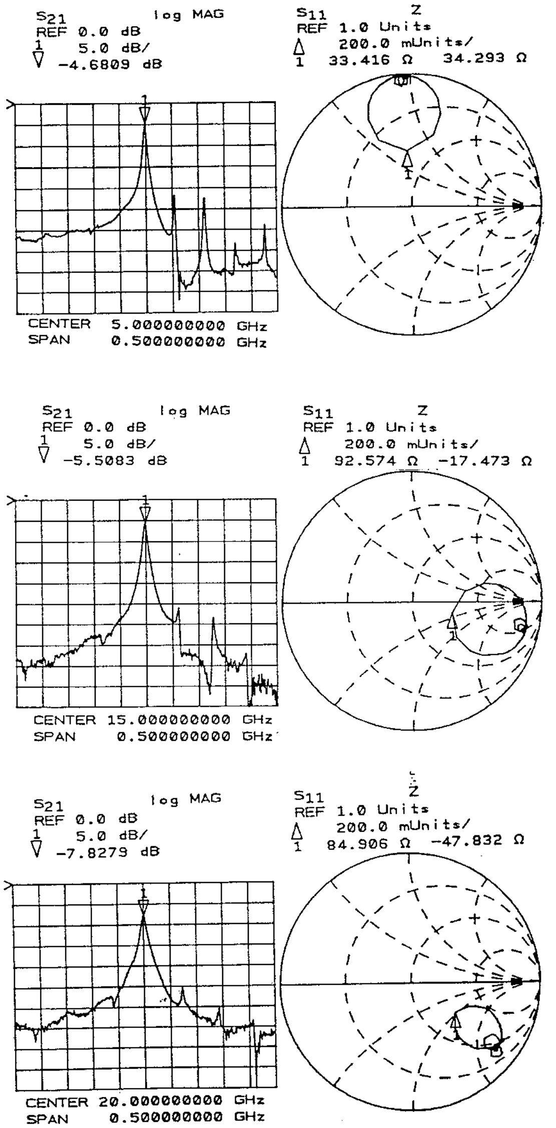

Fig.4 Transmission (left trace) and reflection (right trace) responses of the resonator at 5,15 and 20 GHz.

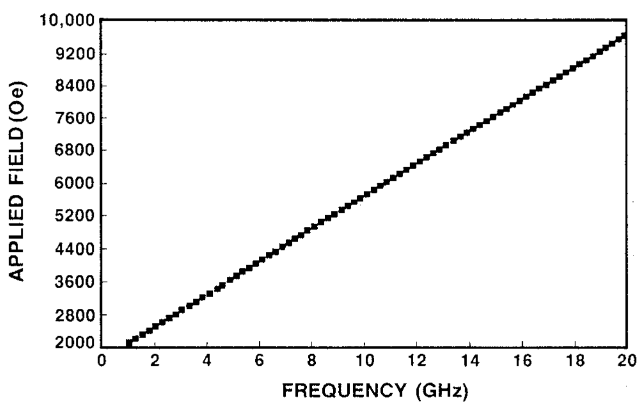

Fig.5 Tuning characterictics of the 1-20 GHz MSFVW-SER.

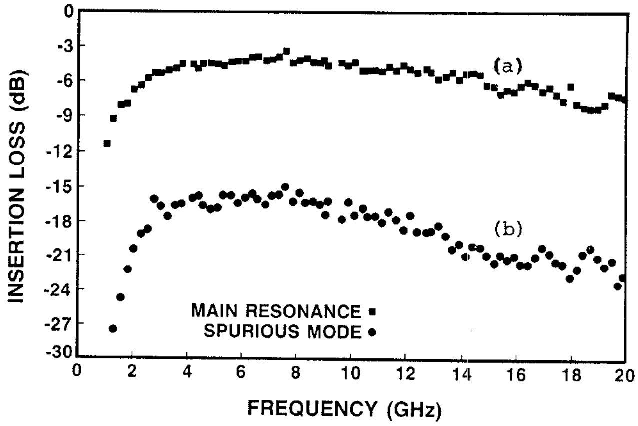

Fig.6 Insertion loss of (a) the main resonance and (b) the worst spurious mode of the 1-20 GHz MSFVW-SER.

The simple structure and the tunability of the MSW-SERs make them attractive for tunable oscillator applications. However, the tuning range of the MSFVW-SER based oscillator is restricted by the external delay of the amplifier feedback loop as reported earlier for the MSSW-SER based oscillator [7] and the MSW delay line based oscillator [8].

ACKNOWLEDGEMENTS

The authors would like to thank Elena Luiz for assembling the test circuits. The YIG films used in this study were purchased from Airtron Corporation.

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