COLLINEARLY EXCITED EDGE COUPLED RESONATORS

K. W. Reed, A. K. Reddy, and W. A. Davis

The Center for Advanced Electron Devices
The University of Texas at Arlington

Arlington, Texas

ABSTRACT

A magnetostatic surface wave resonator using adjacent microstrip transducers edge coupled to a rectangular YIG film cavity has been built and evaluated. Loaded Qs higher than 1000 were obtained with resonant insertion losses as low as 8 dB. Sidelobe suppression exceeded 12 dB, yielding a usable tunability spanning 3 to 5 GHz.

INTRODUCTION

Magnetically tunable magnetostatic wave (MSW) based filters are useful as feedback elements in frequency agile microwave (1 - 20 GHz) oscillators. High Q (>1000) MSW filters designed for this application have been under continuous investigation for the past 8 years. The two principal approaches used are transducer arrays and Fabry-Perot type cavity structures using reflective gratings of metal stripes, etched grooves, or ion implanted zones [1,2,3,4,5,6]. These techniques have yielded resonators with loaded Qs ranging from 300 to 1000 and typical insertion losses of 10 to 30 dB. Sidelobe rejection greater than 25 dB for the transducer arrays and 10 dB for the resonator structures are typical.

Edge coupled magnetostatic surface wave (MSSW) resonators have recently been introduced by Huijer and Ishak [7] of Hewlett Packard as an alternative to the earlier designs. In addition to fabrication simplicity, this new technique performs competitively with the existing technology, exhibiting resonant insertion losses as low as 5 dB spurious suppression exceeding 10 dB, and loaded Qs from 900 to 4000 over a 6 GHz tuning range.

A variation on the Huijer-Ishak resonator has been investigated at UTA, allowing for some added design flexibility and lower cavity bypass leakage.

EXPERIMENTAL DEVICE

The principle difference between the collinearly excited edge coupled resonator and the Huijer-Ishak device is that both the input and output microstrip coupling structures are in line and on the same side of the planar cavity (Figure 1).

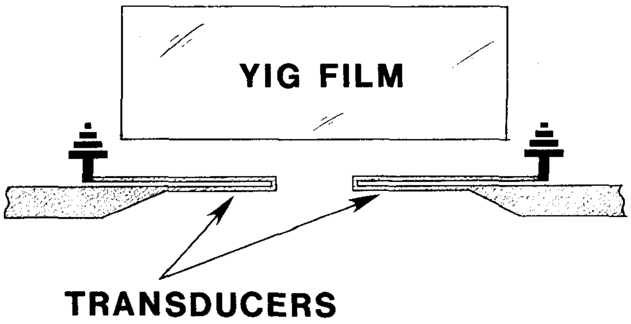

Figure 1. Collinearly excited resonator.

The experimental device consisted of an 18 um undoped rectangular YIG film flipped over onto the excitation structure and biased for MSSW propagation. Gold microstrips were used on a 250 um thick substrate, mounted on a brass ground block. Coupler filaments were 30 um wide (100 Ohms) electrically short (3 mm) microstrip loops grounded at one end to approximate uniform currents. Input and output couplers were arranged collinearly with the tips of the loops separated by 3 mm.

THEORY

Coupling to the output is thought to be via evanescent fields transverse to the cavity direction. It has been proposed that the steering angle characteristic of the MSSW mode in the presence of crystaline anisotropy would allow MSSWs propagating off the cavity axis to reach the ouput by executing multiple cavity transits. A coupling mechanism of this type would result in relatively high insertion losses and higher resonant Qs in response to the longer path lengths. In as much as Qs and insertion losses obtained for the collinearly excited devices are comparable to the results reported for the bilateral configuration, experiments tend to oppose this multi-transit theory. Experiments are currently in progress to verify the evenescent coupling theory.

The resonance condition occurs when energy reflected from the opposite edge of the planar cavity arrives at the leading edge in phase with the excitation signal, resulting in large evenescent fields in

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the gap between the input and output couplers. To first order, the condition for resonance as given by Chang [8] is,

$$\mathrm{Re}\{\tilde{k}_+ + \tilde{k}_-\}\ell = 2\pi n \qquad (1)$$

where, n is the positive integral mode number, and k_+ and k_- are the propagation constants for the forward and reverse going waves. A more complex theory would include the effects of width modes as reported by Chang [8] and the effective path length associated with the phase shift accompaning reflection off the edges of the crystal. Since the electronic spins abruptly dissapear at the edge of the crystal, an approximate null in the magnetostatic H-field would occur there, corresponding to an inversion in that field on reflection. A similar inversion would occur upon reflection from the edge at the excitation port, making the difference in phase between the energy being launched from the input coupler and the forward going energy in the cavity equal to the phase length of the cavity.

Typically the coupling gap is large (~1 mm) compared to the film thickness (15-25 um) yielding equal excitation of MSSWs in both the top and bottom surfaces of the film. Thus the single ferrite cavity is equivalent to two resonant cavities connected in parallel.

TRANSMISSION MEASUREMENTS

The measured insertion loss of the resonator is shown in Figure 2 where the magnetic field was adjusted to give a center frequency of 3.9 GHz. The loss at the main resonance is 8 dB with a 3 dB width of 3.3 MHz that represents a loaded Q of 1180.

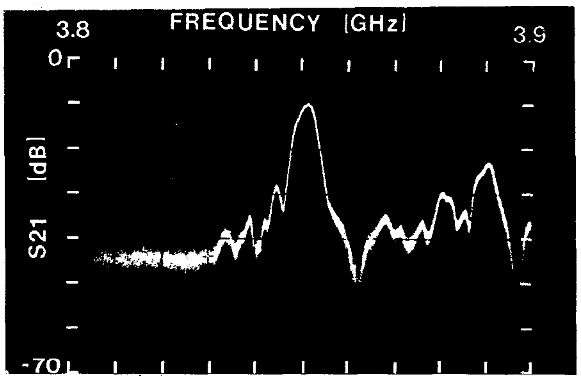

Figure 2. Narrow band S21 response.

The broadband S21 response shows lower cavity bypass leakage (Figure 3) than is characteristic of earlier Fabry-Parot resonators. This should enhance the noise characteristic when used with tunable oscillators. By varying the magnetic bias field, the tuning profile given in Figure 4 is obtained. The main resonance exceeded the maximum sidelobe level throughout the band over a 2 GHz range. This represents the single mode oscillator tunability.

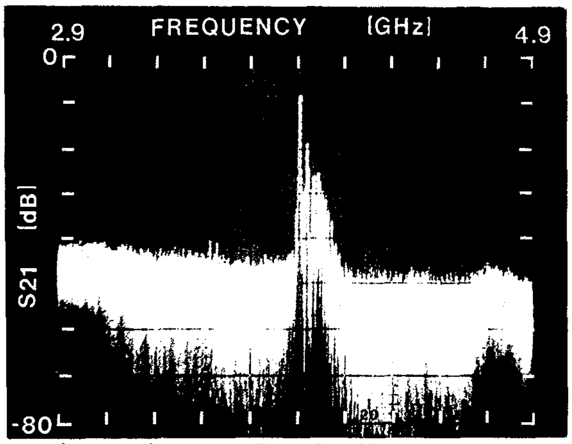

Figure 3. Broadband S21 response.

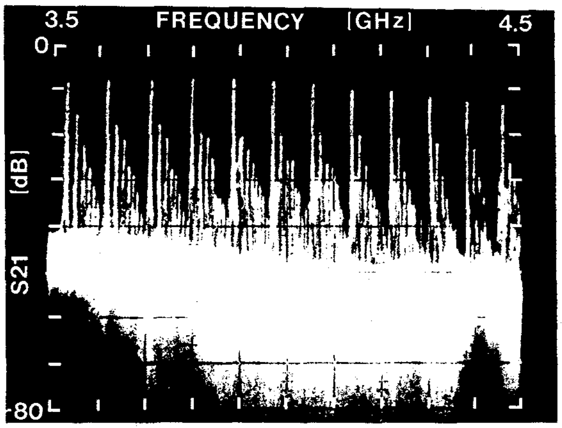

Figure 4. Tunability of S21 (600-1150 Oe)

Automatic network anaylzer measurements were made over a set of narrow band ranges. The reference plane for both the reflection and transmission measurements was chosen at the point where the microstrip transmission line came in close proximity to the YIG cavity. These reference planes were obtained using TDR techniques on the network analyzer using the MAMA program. Shown in Figure 5 is the response of the resonator when it was tuned to 4.8 GHz. The Q at this point is 1278 and the quality factor reflecting the usefulness of the resonator in a tunable oscillator is

$$R = -20\log(\Delta f) - L \qquad (2)$$

where, Δf is the 3 dB frequency bandwidth in GHz and L is the insertion loss. At this frequency R = 38.3 and it ranges from 36 to 40 over the tunable band of the resonator.

The insertion phase for both the forward and reverse directions (S21 and S12) is shown in Figure 6. Clearly the

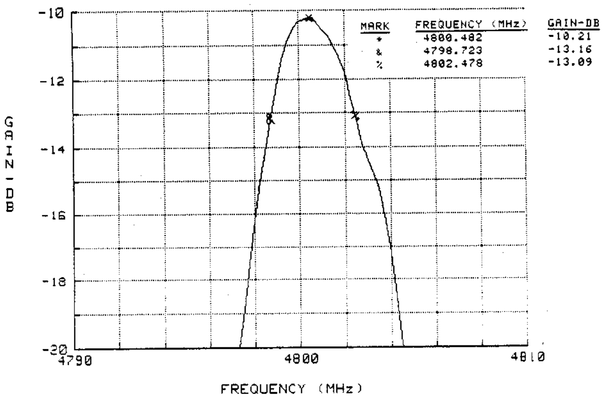

Figure 5. Insertion loss

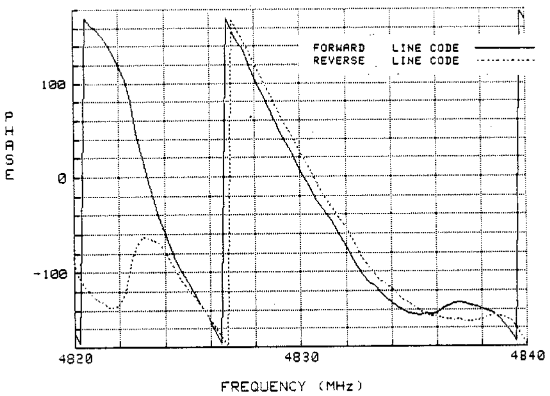

Figure 6. Insertion phase.

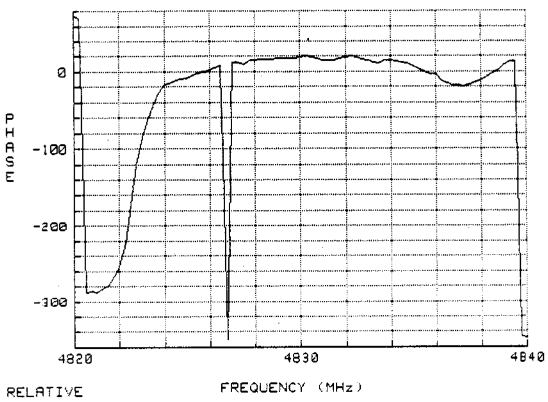

Figure 7. Phase difference.

difference in phase in the two directions as shown in Figure 7 is either 0 or 360 degrees over the band of frequencies where the network analyzer dynamic range is not exceeded. The collinear resonator is a bilateral tunable filter and cannot be modeled with a single gyrator as was done by Carter [9] for two concentric mutually orthogonal coupling loops surrounding a ferrite ellipsoid. Since the collinear resonator is bilateral, a simple equivalent circuit consisting of R's, L's, and C's can be used. Such a circuit is shown in Figure 8. The measured

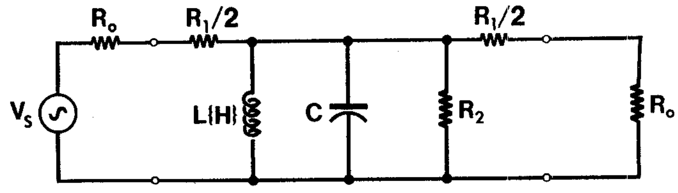

Figure 8. Equivalent circuit.

parameters, Q and minimum insertion loss, are all that are needed to completely determine the equivalent circuit for the insertion loss characteristic.

The transducer power loss for an attenuator is

$$\alpha^2 = \frac{\text{Power delivered to the load}}{\text{Power available from the source}} \tag{3}$$

For a given attenuation the resistors are [10]

$$R_2 = \frac{2R_0}{1 - \alpha^2} \tag{4}$$

$$R_1 = \frac{2R_0(1 - \alpha)}{1 + \alpha} \quad . \tag{5}$$

The loaded Q is found from the equivalent circuit.

$$Q = \omega_o C[(R_0 + R_1/2)/2 \,||\, R_2] \tag{6}$$

$$Q = \omega_o C \frac{2\ R_0 \alpha}{(1 + \alpha)^2} \tag{7}$$

Hence, knowing Q and α, the capacitance C is found and thus

$$L = 1/\omega_o^2 C \ . \tag{8}$$

At 4.8 GHz, R_1 = 25.975 Ohms, R_2 = 35.136 Ohms, C = 2.322 nF, and L = 0.4736 pH. The comparison between the equivalent circuit and the measured response (Figure 9) shows that good correlation is obtained

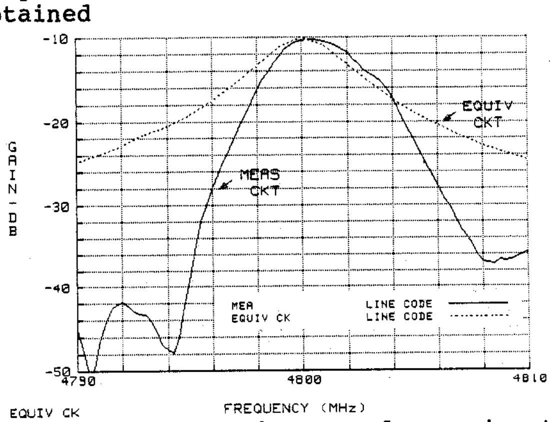

Figure 9. Loss: Theory and experiment.

for the frequency response over a limited band of frequencies. To get higher out of band rejection in the equivalent circuit in order to match the measured data over a wider frequency band, a 3 or 4 pole Butterworth filter would be needed.

REFLECTION MEASUREMENTS

The input impedance of the resonator was measured under several magnetic field levels. At 4.8 GHz, the impedance is shown in Figure 10. The frequency of minimum insertion loss, designated by (1) is 1 MHz away from the notch in the reflection coefficent. Both the reflecion

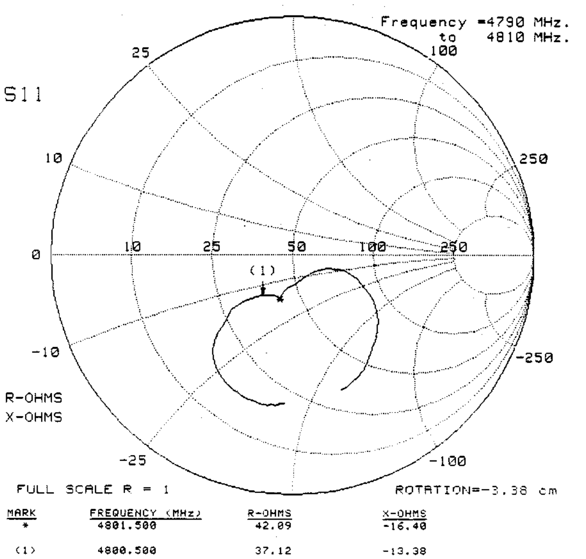

Figure 10. Impedance at 4.8 GHz.

notch and the minimum insertion loss remain 1 MHz apart when the magnetic field changes. Furthermore, as shown in Figure 11, the input impedance shifts from inductive to capacitive as the frequency increases. This appears to be caused by the YIG cavity itself rather than the transducer, since the broadband measurement of the resonator under zero magnetic field bias shows no resonance in the 3 to 4.8 GHz range.

CONCLUSIONS

The collinear edge coupled resonator is a good alternative for magnetically tunable filters. This bilateral filter has the advantage of easy tunability since the distance between the transducer and the YIG cavity may be varied for both the input and output simultaneously without having to change the dimensions of the YIG cavity itself.

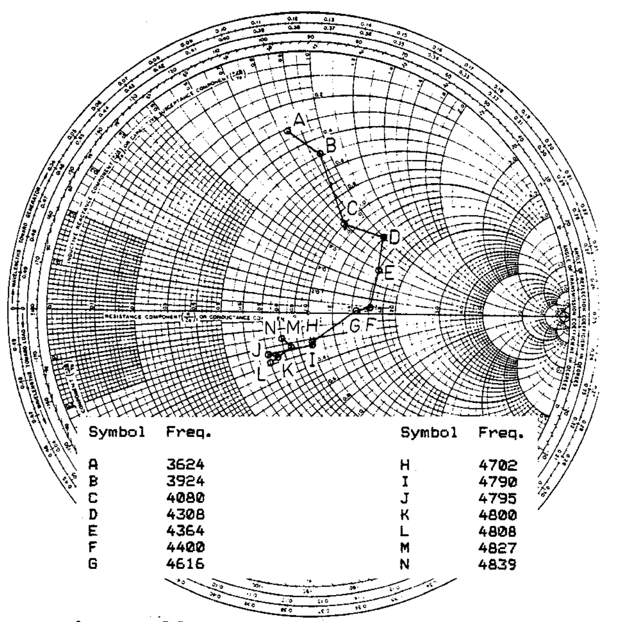

Figure 11. Impedance at resonance.

ACKNOWLEGEMENTS

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