MAGNETOSTATIC WAVE NOTCH FILTER

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ABSTRACT

The application of epitaxial YIG resonators is reported in a tunable notch filter design of center frequency 9 GHz. Tuning from 8 to 10 GHz was accomplished via a miniature electromagnet of volume about 1 cm^3. This volume gives the filter application in phased arrays of simultaneous transmit/receive antenna modules.

INTRODUCTION

Future aircraft and other platforms will use shared aperture antennas. This will increase interference in broadband receivers because of radars, jammers, communication and navigation equipment. Two high level signals can produce intermodulation products in low noise amplifiers (LNAs) which will significantly degrade a systems dynamic range. A single larger input to a broadband electronic support measure/electronic warfare (ESM/EW) receiver can saturate the input LNA and prevent signal detection and analysis over a multi-octave band. Time gating of the receiver and sensitivity control to combat this significantly reduce the effectiveness of high probability-of-intercept receivers. This situation is exacerbated in a high signal density environment in which high duty cycle radars and jammers are in operation.

Tunable notch filtering is effective in rejecting all types of radio frequency interference since it eliminates the problem before the receiver input while minimizing degradation in the overall system performance. Band-stop filtering using yttrium iron garnet (YIG) spheres is a mature technology and filters with up to eight stages are available commercially. They are tunable over multi-octave frequency bands from 0.5 GHz to 26 GHz and higher. However, they are too large for use in each transmit/receive (T/R) module of an X-Ku band active aperture antenna.

We report here the application of epitaxial YIG resonators in a tunable notch filter design. The center frequency was 9 GHz and tuning was accomplished by the use of a miniature electromagnet from 8 GHz to 10 GHz. The electromagnet volume on the order of 1 cm^3 is small enough to give this filter potential application in phased arrays of simultaneous T/R antenna modules - see figure 1. Additionally, the application of epitaxial YIG resonators is

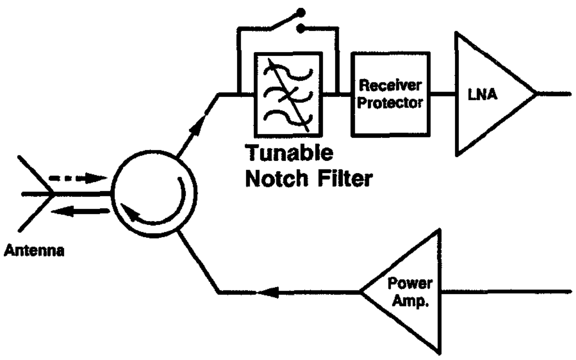

Figure 1. Circuit location of an epitaxial tunable YIG notch filter in a simultaneous transmit/receive antenna module.

anticipated to result in devices with reduced loss, increased frequency range, improved reproducibility and lower cost. These advantages result from the planar nature of the YIG films which allows the use of planar coupling structures and photolithography to define the resonators.

DESIGN AND PERFORMANCE

A drawing of the notch filter and its associated electromagnet is shown in figure 2. Initially a finite element analysis of the electromagnet was performed to determine approximate limits on the degree of miniaturization possible consistent with the requirements of 5000 Oersted magnetic bias field in an air gap volume large enough to accommodate the YIG disc resonators and associated microstrip circuit. The permanent magnet material required for providing the fixed 5000 Oe. bias field was Nd-Fe-B. However, a later combination of a permanent magnet from this material and one from Sm-Co material provided a composite magnet structure whose temperature coefficient of magnetic field matched that of the YIG resonators. In the geometry of figure 2, for forward volume magnetostatic waves, this gave a temperature compensated notch filter.

The performance requirements were a 40 dB rejection notch bandwidth of >20 MHz and a 3 dB rejection bandwidth of <100 MHz. Using the standard equations for notch filter design[1] and

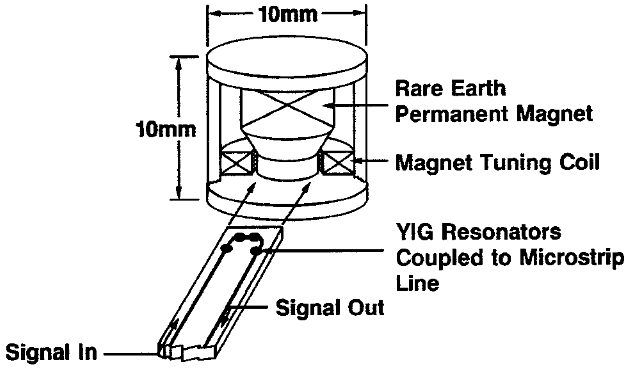

Figure 2. Schematic drawing of the tunable YIG notch filter and its associated miniature electromagnet.

the work of Moll[2] we deduced the equation relating the YIG film thickness to the external Q (Q_E). Using single disc resonators fabricated from a 3" epitaxial YIG wafer we made measurements of S_{21} versus frequency with a network analyzer. This information gave loaded Q, unloaded Q and external Q for a single YIG resonator. A multipole notch filter was then modeled using the interactive software package TOUCHSTONE to determine the least number of poles which would meet the above specifications. The notch filter was modeled as lumped element LCR resonators (whose Q values were given by the above measured data) distributed along a microstrip transmission line. This analysis yielded the requirement for 3 poles and gave the coupling as 1/4 an electromagnetic microstrip wavelength.

A test filter was made from three 1-mm diameter YIG resonators coupled via 50 ohm microstrip line defined on an alumina substrate. The best performance was obtained with gold ribbon placed over the top of each resonator and bonded to the microstrip on each side. Figure 3 shows the transmission response of the filter at three frequency bands positioned at about 8 GHz, 9 GHz, and 10 GHz respectively. The performance meets the notch depth and 40 dB bandwidth specifications but needs further work to meet the 3 dB bandwidth figure of <100 MHz, e.g. a 4 pole design.

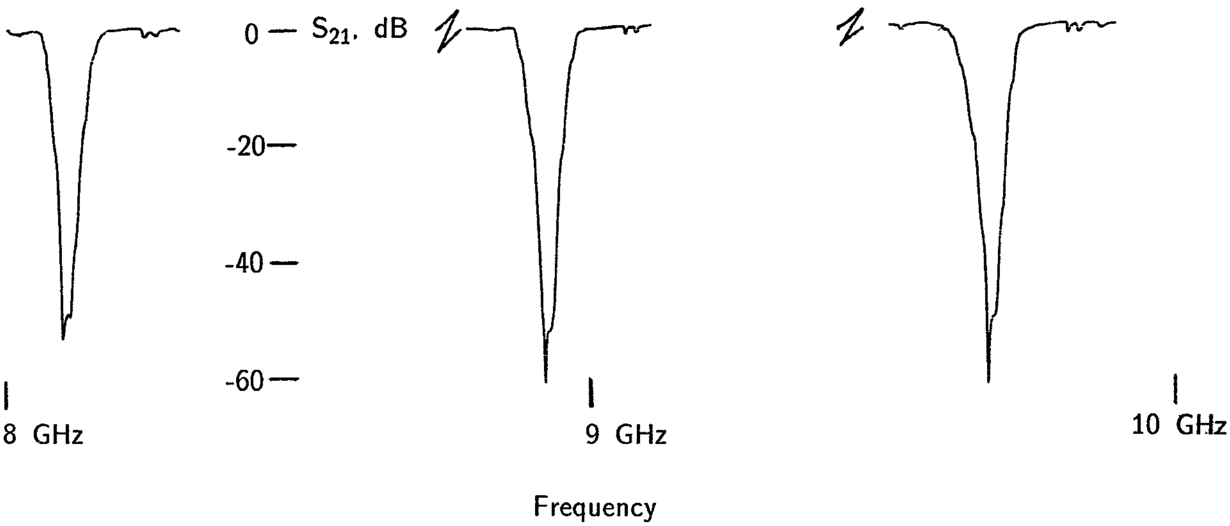

Figure 3. Passband responses of the tunable YIG notch filter respectively positioned at about 8 GHz, 9 GHz, and 10 GHz. The -3 dB bandwidth is 100 MHz, and the -40 dB bandwidth is 25 MHz.

ACKNOWLEDGEMENTS

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2. N. J. Moll, IEEE Trans. MTT-25, 933 (1977).