A Magnetically Tunable Planar Band-stop Filter Using Ferrite Layer

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Abstract **- A tunable metamaterial band-stop filter using magnetic material is presented in this paper with numerical results. Our filter is based on a 50 Ohms microstrip feed line, three metamaterial resonators and YIG layer. The feed is supplied with a variable magnetic bias in the range of 0-200KA/m, the central frequency of the filter varies from 10.10 GHz to 12.05GHz (up to 16% tuning) according to the applied magnetic bias, while achieving a maximum rejected bandwidth of 1.2 GHz.**

Index Terms -Microstrip filters, Metamaterial resonators, Tunable filters, YIG.

I. INTRODUCTION

Your goal is In recent years, tunable band-stop filters have been very useful to delete signal interference in receivers of frequency-tuned communications systems [1,2]. Several methods have been used to realize the tunability, micro electromecanical systems (MEMS) [3], BST varactor [4] and ferroelectric films [5]. Metamaterial resonators have been used in microwave filters, authors in [6,7] proposed the SRR (Split Ring Resonator) and CSRR (Complementary Split Ring Resonator) resonators.

In this work, the aim is to investigate in the design of a metamaterial microstrip band-stop filter with tunable properties. The proposed device is realized in microstrip technology with a YIG (Yttrium Iron Garnet) layer and metamaterial resonators (single-turn square planar resonator). The band-stop filter is simulated using the full wave commercial software HFSS. The obtained simulation results allow confirming the validity of the proposed tunable microstrip band-stop filter.

II. DESIGN AND RESULTS WITH ALUMINA SUBSTRATE

Figure 1 shows the proposed metamaterial band-stop filter, it is composed of three single-turn square resonators and an adapted microstrip line. The metamaterial unit cell resonator used in this work was studied in Ref [8]. The proposed filter is in the microstrip technology based on Alumina substrate (Al_2O_3).

The resonators are located near the strip line to satisfy the excitation condition. They have the same dimensions and the same distance between them. The simplified electric equivalent circuit and the dimensions of the resonator are well detailed in [2].The used substrate have a relative permittivity close to 10, and thickness h=0.635mm.

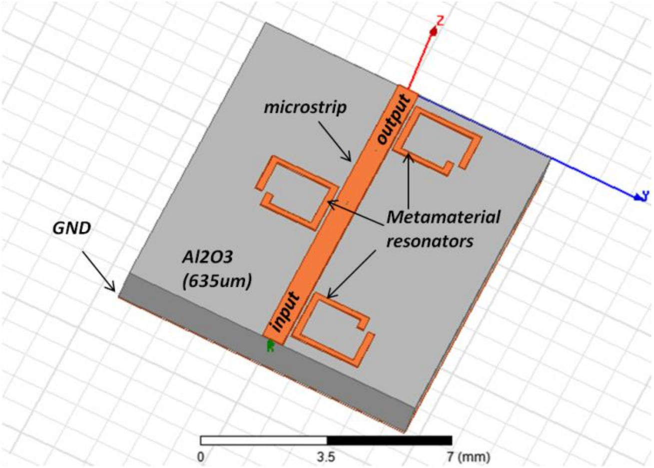

Fig. 1 Metamaterial microstrip band-stop filter.

The transmission coefficient of the proposed band-stop filter is presented in figure 2. The device has been analysed numerically using 3D finite element method based on the HFSS software.

The band-stop is centred around 9.80 GHz with a transmission level close to -20.09dB and a rejected band of 600MHz. This rejected band is three times wider than the rejected band obtained using a single resonator [2].

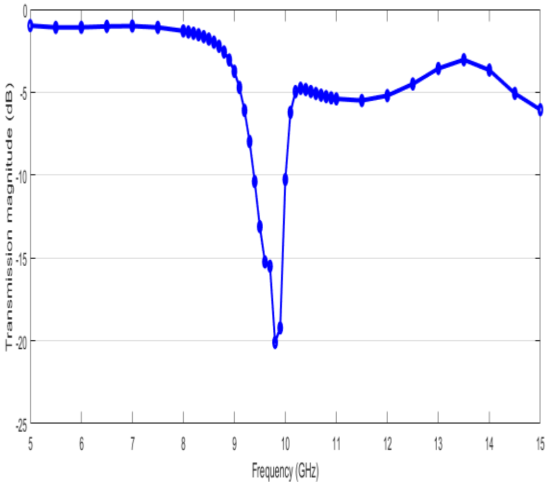

Fig. 2 Simulated transmission coefficient of the proposed band-stop filter.

III. DESIGN AND RESULTS WITH YIG SUBSTRATE

In this part, by introducing Yttrium Iron Garnet (YIG) ferrite substrate into the previous structure (Figure 3), we propose and numerically demonstrate a magnetically tunable metamaterial microstrip band-stop filter.

The commercially available YIG has attractive microwave properties such as low loss tangent (tan $\delta \leq 2/10^{-4}$) at microwave frequencies and high dielectric strength. It has a relative dielectric permittivity close to 15, the saturation magnetization equal to 1780Gauss and a ferromagnetic resonance line with ΔH=20Oe. We suppose that the YIG is saturated and the internal bias field is uniform.

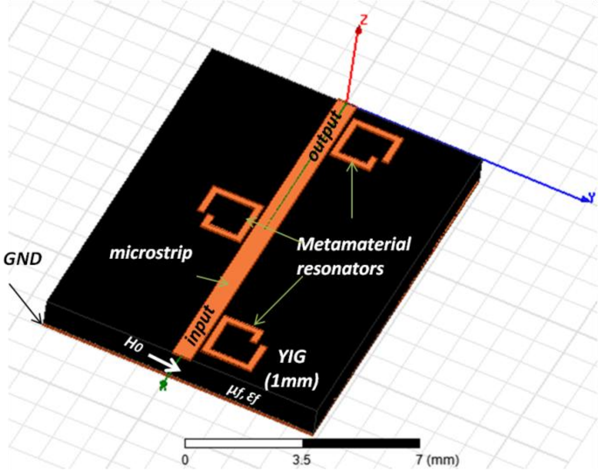

Fig. 3 Metamaterial microstrip band-stop filter over a YIG layer.

Based on the coordinate system shown in preceding figure, and according to the direction of the DC magnetic bias, the tensor permeability has the form of:

$$[\![\overline{\overline{\mu_f}}]\!] = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \mu_f & +jk \\ 0 & -jk & \mu_f \end{bmatrix} \tag{1}$$

Where:

$$\mu_f = 1 + \frac{\omega_0 \omega_M}{\omega_0^2 - \omega^2} \tag{2}$$

$$k = \frac{\omega \omega_M}{\omega_0^2 - \omega^2} \tag{3}$$

$\omega_M = \gamma\mu_0 M_s$, $\omega_0 = \gamma\mu_0 H_0$ and γ is the gyromagnetic ratio of the ferrite. μ_0 is the free space permeability. The damping factor is not taken into account.

Figure.4. shows a comparison of the results obtained for the stopband filter realized on Alumina substrate and the device realized on a YIG layer with a thickness h=1mm and without any bias field applied. We observe a sharper central frequency at 9.90GHz with better transmission levels, better and wider rejected band. The numerical results show a stopband, a central frequency around 10.10GHz with a transmission level of -25.04dB and a rejected band of 800MHz. The central frequency is greater than that the Alumina case. As the permittivity and the thickness are modified, the frequency is modified also.

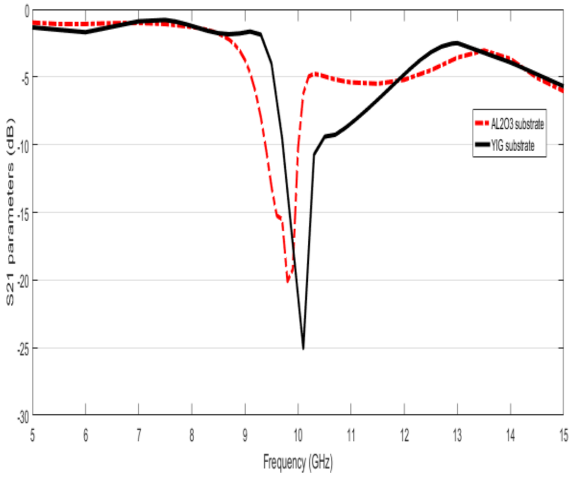

Fig. 4 Comparison of simulation results of the proposed band stop filter with Alumina substrate and the Band stop filter over a YIG substrate with no bias field.

To verify the tunable property of the proposed metamaterial microstrip band-stop filter on YIG substrate, the device has been analysed numerically using full wave simulations for different values of DC magnetic bias. In the case of the applied field of 50KA/m, the central frequency is equal to 10.30GHz, at this frequency, a transmission level is about -21.45dB and a rejected bandwidth equal to 1000MHz. For the second values of the magnetic field (100KA/m), the band-stop filter resonates at 10.70 GHz with a transmission level close to -25.51dB and a rejected bandwidth equal to 1200MHz. In the case of the applied field equal to 200KA/m, the central frequency is shifted to 12.05 GHz with a transmission level equal to -20.96dB and a rejected bandwidth equal to 400MHz.

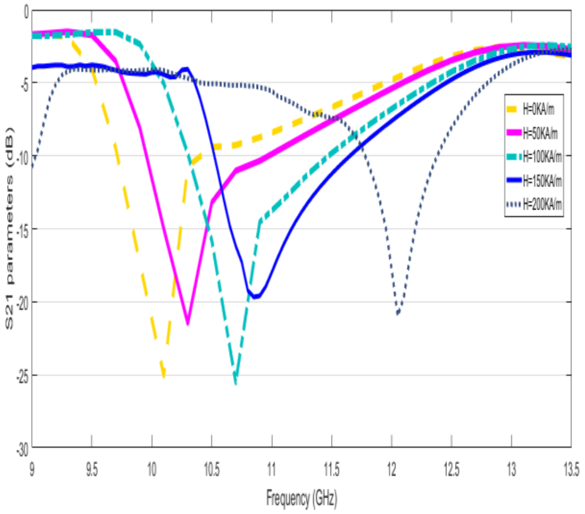

Fig. 5 Simulated results of the proposed metamaterial microstrip band-stop filter for different values of DC magnetic bias.

IV. CONCLUSION

In this paper, a planar metamaterial microstrip band-stop filter was proposed. The design is based on three metamaterials resonators and a 50 ohm microstrip line. The simulated S parameters of the proposed device is given and discussed. It is noted that the proposed filter is electrically small, simple and easy to realize compared to the conventional broadband BSFs.

The devices based on this concept can be very promising for microwave applications in planar technology. It provides a new way to design stop-band filters with small dimensions and simple structure. Moreover, the newly proposed filter is suitable for electrically small antenna applications.

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