Substrate Integrated Waveguide Frequency Reconfigurable Filter Controlled by Magnetic Field

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Abstract— In this work, a novel upper and lower sideband tunable SIW bandpass ferrite filter is presented. With the application of an external magnetic bias on the ferrite slabs, the lower sideband of the filter can be adjusted from 8.8 GHz to 10.7 GHz and the upper sideband can be tuned from 9.3 GHz to 12.0 GHz. Compared to previously reported frequency tunable SIW filters, the proposed filter offers a relatively wide tuning range and flexibly reconfigurable abilities while dramatically reducing the complexity of external control circuit.

1. INTRODUCTION

Frequency tunable/reconfigurable filters have special significance in future smart and miniaturized wireless systems [1, 2]. The currently popular substrate integrated waveguide (SIW) technique [3] combines the best and complementary features of both planar transmission lines and non-planar waveguides. Thus it is found very appropriate in microwave and millimeter-wave tunable filter applications. Researchers try to realize some SIW reconfigurable filters by use of PIN diodes [4, 5] and varactors [6, 7]. Unlike those conventional planar transmission lines, such as the microstrip line, the SIW is a uniconductor guided-wave structure and has the same electric potential for each metallic surface. Therefore, some difficulties exist in electronically tunable SIW designs. Besides, complex DC bias circuits may lead to unwanted leakage and interference. Tuning operation characteristics of SIW components by magnetic field is another possible way of avoiding these problems.

In this paper, a tunable bandpass filter is designed with YIG ferrite employed in. Both lower sideband and upper sideband of the filter can be adjusted separately. This ferrite-loaded SIW filter can be considered as two sub-components. Design principles of these two sub-components are based on isolator and switch respectively. Up to now most reconfigurable SIW bandpass filters are achieved by resonant cavity [8–11]. In [12] circulators/isolators are used as tunable bandpass filter. However no publication is found to use isolator and switch to achieve reconfigurable bandpass filter.

2. FILTER IMPLEMENTATION

This ferrite bandpass filter is proposed of a reconfigurable highpass filter, which is based upon ferrite switches, and a tunable broadband isolator can be viewed as a bandstop filter. In this section, these two sub-components are designed respectively. At last, the SIW frequency reconfigurable filter is proposed. The substrate used is 0.508 mm thick Rogers6010 substrate. Its permittivity and loss tangent are 10.2 and 0.0023, respectively. YIG ferrite is employed in this design. Its saturation magnetization value is 1850 Gs, relative dielectric constant is 14.5, and 3 dB line width is 20 Oe. All ferrite slabs used in this design is as thick as the substrate.

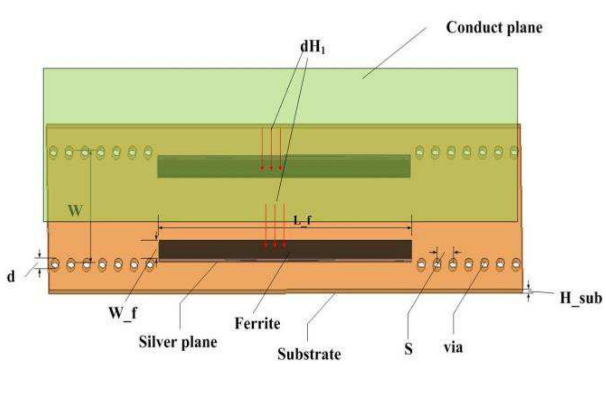


Figure 1: Structure of the highpass filter.

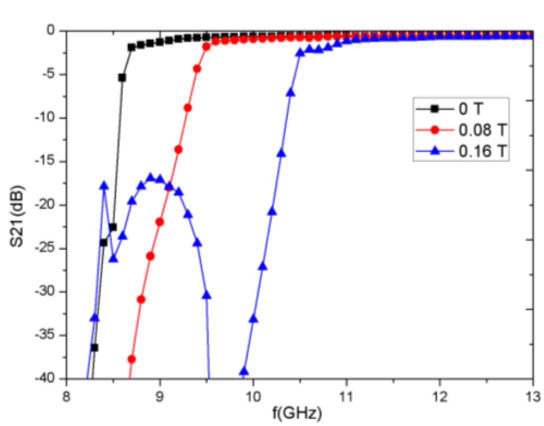


Figure 2: S_{21} in different dH_1.

2.1. Highpass Filter

In this part a highpass filter is employed to form the lower sideband of the reconfigurable bandpass filter. According to [13, 14] proper SIW dimension is chosen firstly. As shown in Fig. 1, the actual SIW width (W) is 6.1 mm, the distance between adjacent metallic vias (S) is 1.2 mm, and the diameter of vias (d) is 0.6 mm. After Full-wave EM simulations were performed with the help of *ANSYS* HFSS, $L\_f = 16$ mm and $W\_f = 1$ mm are obtained.

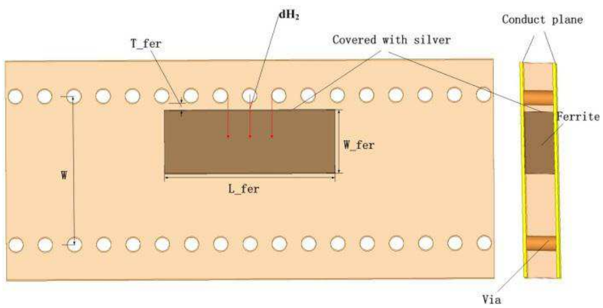


Figure 3: Configuration of the isolator.

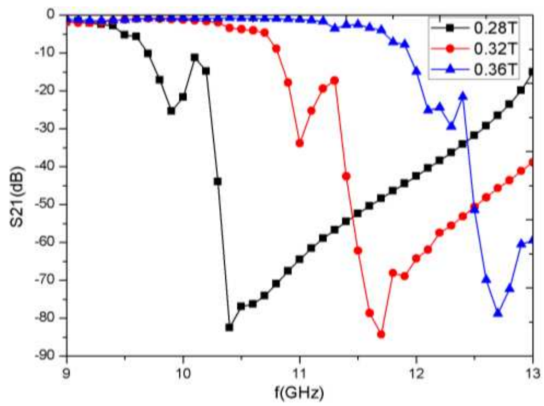


Figure 4: S_{21} response when dH_2 changes.

With the application of an external magnetic bias (dH_1) on the ferrite slabs, the cutoff frequency of the SIW is changed [15], thereby making the highpass filter tunable. Fig. 2 shows the highpass filter can be adjusted from 8.8 GHz to 10.7 GHz with about 1.5 dB insertion.

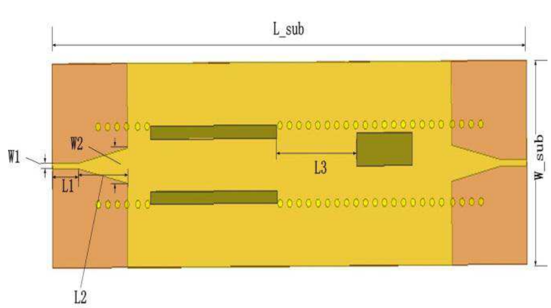
2.2. Isolator

The second component, which is associated with a wide ferrite slab in a SIW with the magnetic field perpendicular to the direction of propagation, employs the edge-mode effect [16] to achieve the bandstop phenomenon and then form the upper sideband of the SIW filter. As shown in Fig. 3, the wide ferrite slab, one of its surface is covered with silver, is inserted in the substrate. The silver plane acts as a short plane and EM wave will be absorbed in the ferrite slab when external magnetic bias (dH_2) is applied. The dimension of the ferrite is obtained by simulation and parameter optimization by Ansoft HFSS: $T\_fer = 1.25$ mm, $W\_fer = 2$ mm, $L\_fer = 8$ mm.

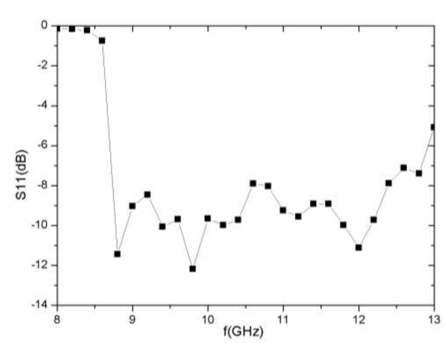
As shown in Fig. 4, the achieved upper sideband of the SIW filter is increased as dH_2 increases from 0.28 T to 0.36 T.

2.3. Tunable Bandpass Filter

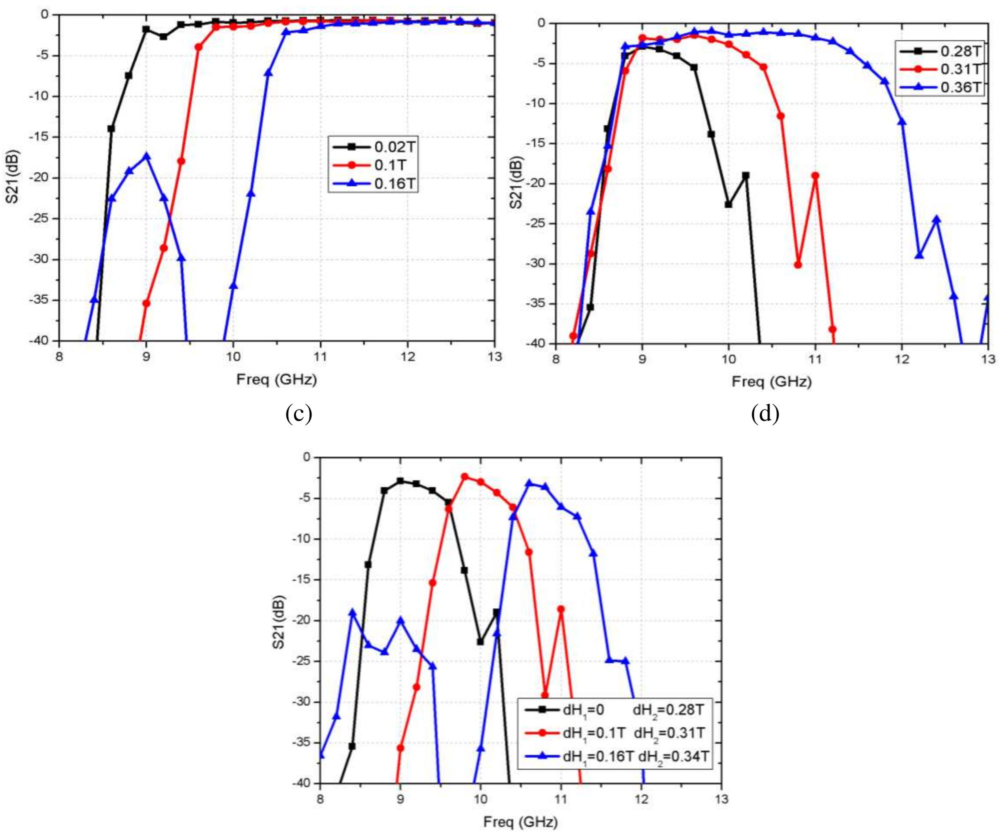
As Fig. 5(a) shows, the isolator and the highpass filter are connected in this section and microstrip to SIW transition structure [17, 18] is added. By HFSS optimization simulation, the following parameter values are obtained: $W_1 = 0.45$ mm, $W_2 = 2.8$ mm, $L_1 = 3.3$ mm, $L_2 = 6.2$ mm, $L_3 = 3.6$ mm, $L\_sub = 64$ mm, $W\_sub = 16$ mm. When $dH_1 = 0$ and $dH_2 = 0.28$ T is applied to the ferrite slabs about 10 dB return loss is achieved as shown in Fig. 5(b). As shown in Fig. 5(c), the lower sideband of the filter can be adjusted from 8.8 GHz to 10.7 GHz. As shown in Fig. 5(d), the upper sideband can be tuned from 9.3 GHz to 12.0 GHz. Furthermore, a filter whose operating



(a)



(b)



(c) (d)

(e)

Figure 5: Geometry and variation of the passband center frequency with the applied magnetization field of the SIW filter: (a) Scheme of the SIW filter; (b) S_{11} response; (c) Variation of lower bandside with dH_1 changes; (d) Variation of lower bandside with dH_2 changes; (e) Variation of the passband with the applied magnetization field's increasing.

band can be adjusted from 8.8 GHz to 12 GHz is achieved with approximately 2.5 dB insertion loss as shown in Fig. 5(e).

3. CONCLUSION

A novel frequency reconfigurable SIW bandpass filter is presented in this paper. The bandpass of the proposed filters can be reconfigured by adjusting the dc-magnetic bias applied to the ferrite slabs located at an SIW structure. With the employment of the ferrite material, the proposed bandpass filter can realize upper sideband and lower sideband's tunable severally while dramatically reducing the complexity of external control circuit compared to traditional electronic control methodologies.

ACKNOWLEDGMENT

This work is supported in part by the China Postdoctoral Science Foundation under grant 2013T608 46 and 2012M511918.

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