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COMPACT LOWPASS FILTER WITH HIGH SELECTIVITY USING G-SHAPED DEFECTED MICROSTRIP STRUCTURE

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Abstract—In this paper, a novel G-shaped defected microstrip structure (DMS) is presented. Compared with the conventional DMS, the proposed G-shaped DMS exhibits lower resonant frequency and wider stopband. A lowpass filter with 3 dB cutoff frequency at 3.17 GHz using four pairs of parallel cascaded G-shaped DMS units is designed and fabricated. The measured results show that the transition band is only 0.09 GHz and the stopband over 25 dB attenuation covers 3.4 GHz to 10 GHz. The measured and simulated results are in good agreement.

1. INTRODUCTION

Compact microstrip lowpass filters (LPFs) with wide stopband and high selectivity are desirable to suppress harmonics and spurious signals in modern wireless communication systems [1, 2]. Conventional microstrip filters with stepped-impedance resonator and parallel coupled line occupy large size and have limited stopband [3]. Defected ground structure (DGS), which is a kind of electromagnetic bandgap structure (EBG) offering bandgap properties at some frequency, has been reported to improve the performance of filter and minimize the dimension in recent years [4–9]. However, slots etched on the ground plane in DGS have some problem in actual application such as energy leakage through the ground plane and requiring an Electromagnetic Compatibility (EMC) box [10]. Based on DGS, defected microstrip

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structure (DMS) has been proposed recently. Similar to DGS, DMS disturbs the current distribution across the microstrip and exhibits the properties of slow-wave and bandgap in certain frequency bands. Compared with DGS, DMS is etched in the microstrip without affecting the ground plane. This structure can be integrated more easily with other microwave circuits. Several DMSs with different shapes, such as T-shaped, F-shaped, M-shaped and so on [11–18], have been presented for filter application. In [13], complementary open square ring-DMS (COSR-DMS) is proposed to improve the bandpass filter. In [14], a modified DMS using a F-shaped spurline is applied to design a compact dual-band BPF for GPS/WLAN applications. In [15], a novel bandstop filter with M-shaped slot DMS is designed and fabricated. Most efforts on DMS have been improving the performance of bandpass and bandstop filters [12, 16–18]. However, designs of LPFs with superior selectivity and wide stopband using DMS remain as challenges.

In this paper, a novel G-shaped DMS consisting of one circular and one connecting slot is proposed and a LPF using proposed DMS units with one compensated microstrip line is present. The article is organized as follows: In Section 2, the frequency characteristic and slow-wave property of the proposed G-shaped DMS in the microstrip line are determined. A LPF using a G-shaped DMS array etched in a compensated microstrip line is presented in Section 3. The LPF has been fabricated and measured. Some conclusion remarks are presented in Section 4.

2. CHARACTERISTICS OF G-SHAPED DMS

The geometric structure of the proposed G-shaped DMS unit is shown in Figure 1(a). It consists of one circular ring and one connecting

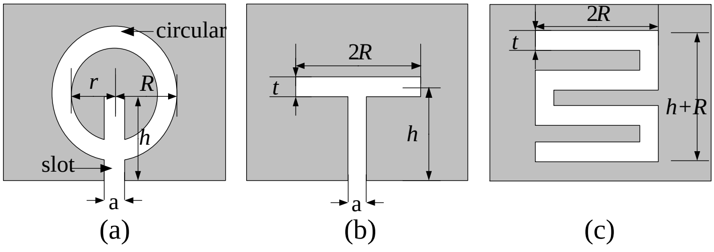

Figure 1. Diagram of proposed G-shaped DMS unit, T-shaped DMS unit, and M-shaped DMS unit.

slot etched in the microstrip line, which seems like the letter G. Figures 1(b) and (c) illustrate the geometric structure of T-shaped DMS [11] and M-shaped DMS [15], occupying the identical defected area, respectively. Dimensions of the proposed structure are as follows: $R = 2\,\text{mm}$, $r = 1.5\,\text{mm}$, $a = 0.2\,\text{mm}$, $h = 4\,\text{mm}$, $t = 0.5\,\text{mm}$. Figure 2 illustrates simulation results of proposed G-shaped DMS, T-shaped DMS [11] and M-shaped DMS [15] on a 1 mm thickness PTFE substrate with a relative dielectric constant of 2.65. Compared with T-shaped DMS and M-shaped DMS, the proposed G-shaped DMS offers the lowest cutoff frequency and the widest stopband rejection characteristic, which assists to reduce the overall size of LPF.

A parametric study of the proposed DMS against structure is shown in Figures 3, 4, 5, and 6. In Figure 3, it can be seen when $r = 1.0\,\text{mm}$, $a = 0.2\,\text{mm}$, $h = 2.5\,\text{mm}$ is fixed and the length R increases from 1.2 mm to 1.8 mm with steps of 0.3 mm, this leads to

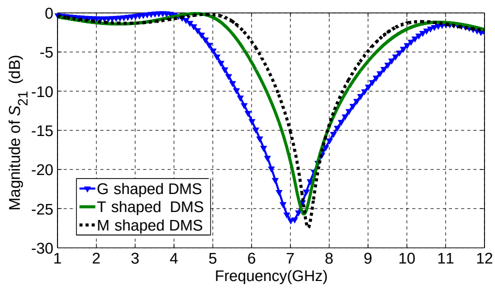

Figure 2. Simulated S-parameters of G-shaped DMS, T-shaped DMS and M-shaped DMS.

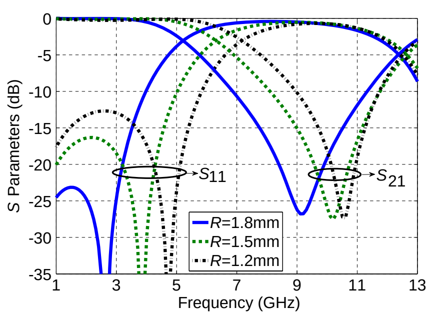

Figure 3. Simulated S-parameters of G-shaped DMS with $R = 1.8\,\text{mm}$, $R = 1.5\,\text{mm}$ and $R = 1.2\,\text{mm}$.

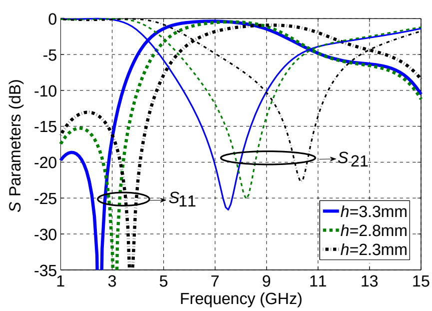

Figure 4. Simulated S-parameters of G-shaped DMS with $h = 3.3\,\text{mm}$, $h = 2.8\,\text{mm}$ and $h = 2.3\,\text{mm}$.

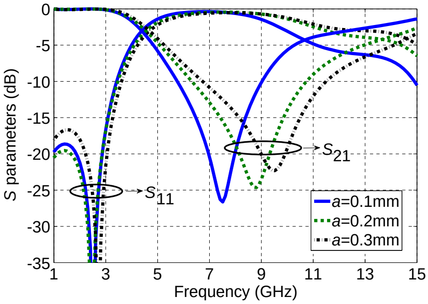

Figure 5. Simulated S-parameters of G-shaped DMS with $a = 0.1\,\mathrm{mm}$, $a = 0.2\,\mathrm{mm}$ and $a = 0.3\,\mathrm{mm}$.

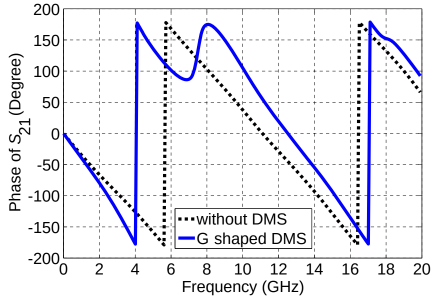

Figure 6. Phase characteristics of the microstrip line with G-shaped DMS and without DMS.

decrease the resonant frequency and increase the stopband width. In Figure 4 when $R = 1.5\,\mathrm{mm}$, $r = 1.0\,\mathrm{mm}$, $a = 0.1\,\mathrm{mm}$ is fixed and the length h of the slot increases from 2.3 mm to 3.3 mm, the resonant frequency decreases from 10.33 GHz to 7.51 GHz. In Figure 5 when $R = 1.5\,\mathrm{mm}$, $r = 1.0\,\mathrm{mm}$, $h = 3.3\,\mathrm{mm}$ is fixed and the width a of the slot increases from 0.1 mm to 0.3 mm, the resonant frequency increases from 7.51 GHz to 9.52 GHz. Therefore, the bandgap properties of the proposed DMS, such as the resonant frequency and the stopband width, can be adjusted by changing the structural parameters of the DMS.

Figure 6 shows the phase characteristics of the microstrip lines with and without DMS. It is to be noted that a jumping phenomenon occurs in phase curve with DMS at the resonant frequency. Compared with the microstrip line without DMS unit, the microstrip line with G-shaped DMS unit exhibits slow-wave behavior below the resonant frequency and exhibits fast-wave behaviors above the resonant frequency. The slow-wave property of DMS increases the electric length and helps to reduce the overall size.

3. DESIGN OF FILTER WITH PROPOSED DMS

To demonstrate the effectiveness of the proposed DMS unit, cascading four pairs of parallel G-shaped DMS units, a novel lowpass filter has been designed. Figure 7 shows the novel schematic structure of the proposed compact lowpass filter, which consists of a DMS array with one compensated microstrip line. The LPF has two sizes of G-shaped units with different length slots, which are applied to suppress the different bands of frequencies. Four G1 units can suppress the frequency band from the 3.17 GHz to 5.0 GHz, and four

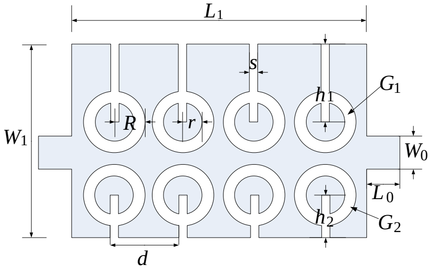

Figure 7. Schematic view of the DMS lowpass filter.

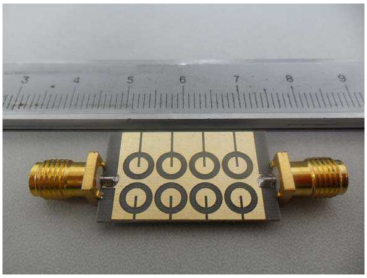

Figure 8. Photograph of fabricated filter.

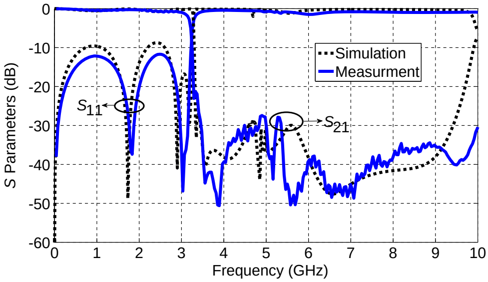

Figure 9. Simulated and Measured S-parameters for proposed DMS filter.

G2 units are used to suppress the frequency band from the 5.0 GHz to 10 GHz. These four pairs of parallel cascaded G-shaped DMS units symmetrically are etched in microstrip line. Because of the mutual influence of the two kinds of DMS, the distance between the G-shaped DMS should be fine-adjusted to make the filter achieve the best performance. After optimization, the optimal values of the parameters are as follows: $L_0 = 2$ mm, $L_1 = 22$ mm, $W_0 = 2.2$ mm, $W_1 = 15$ mm, $R = 2.5$ mm, $r = 1.5$ mm, $d = 5.2$ mm, $s = 0.6$ mm, $h_1 = 6$ mm, $h_2 = 3$ mm. The filter is simulated on a 1 mm thickness PTFE substrate with a relative dielectric constant of 2.65 and loss tangent 0.0027 with an EM-simulator ADS based on the method of moment. The characteristic impedances for microstrip lines at the input/output ports are all 50 Ω.

In Figure 8, the proposed filter is fabricated and measured with the Agilent network analyzer 8720ET. These measured results and simulation results are shown in Figure 9. It can be observed that the simulated and measured results show a good agreement. It can be learned from the measurement results that the filter has a 3 dB cutoff frequency at 3.17 GHz, the insertion loss less than 0.5 dB in the passband from DC to 2 GHz, the return loss better than −10 dB over the most part of the passband and the suppression level better than 25 dB from 3.4 up to 10 GHz. Moreover, the passband can be improved by adding some open stubs at the input and output [19]. The return loss in the stopband region is very close to 0 dB, indicating negligibly radiation loss. The transition band is from 3.17 to 3.26 GHz with −3 to −20 dB, respectively, showing that the filter has good skirt performance. The selectivity of the proposed DMS filter is about 189 dB/GHz. The dimension of the fabricated filter is 22 mm × 15 mm, excluding the input and output ports, as shown in Figure 8.

4. CONCLUSION

A novel, simply G-shaped DMS consisting of one circular ring and one connecting slot has been presented. Simulation results show that the proposed G-shaped DMS unit offers much wider stopband and lower resonant frequency than conventional DMS [11, 15]. To verify the performance, a lowpass filter with 3 dB cutoff frequency at 3.17 GHz using four pairs of parallel cascaded G-shaped DMS structure is designed. The filter has been fabricated and measured. The measured results show that the transition band is only 0.09 GHz and the stopband over 25 dB attenuation covers 3.4 GHz to 10 GHz. With compact size, high selectivity and excellent stopband performance, the proposed LPF is promising for future wireless communication system.

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