Miniaturized Dual-Band Bandstop Filter Using Defected Microstrip Structure and Defected Ground Structure

Jun Wang[1], Huansheng Ning[1], Lingfeng Mao[2], and Minquan Li[3]

[1]School of Electronic and Information Engineering, Beihang University, Beijing, 100191, China

[2]School of Urban Rail Transportation, Soochow University, Suzhou, 215006, China

[3]School of Electronics and Information Engineering, Anhui University, Hefei, 230039, China

***Abstract* — A miniaturized dual-band bandstop filter (DBBSF) is proposed by using T-shaped defected microstrip structure (DMS) and U-shaped defected ground structure (DGS). To verify the design concept, the DBBSF is simulated and fabricated. Compared with other published filters, the proposed DBBSF occupies the minimal normalized area. Moreover, the center frequency of the first stopband and the second stopband can be controlled separately due to the negligible mutual coupling between the T-shaped DMS and U-shaped DGS. A two-stage DBBSF is also presented and simulated, which shows maximum stopband rejection up to 49 dB.**

***Index Terms* — Bandstop filter, dual-band, defected ground structure (DGS), defected microstrip structure (DMS), miniaturized filter.**

I. INTRODUCTION

Dual-band bandstop filters (DBBSFs) are very attractive and highly desired in many wireless communication system applications for their effective suppression of the unwanted concurrent interference at two separate frequencies. For instance, the DBBSFs are commonly employed in high-power amplifiers to achieve signal distortion reduction [1]. Compared with a simple cascade of two conventional single-band bandstop filters, DBBSFs shows their compact size, low cost, less passband insertion loss and low group delay [1], [2].

Many effective approaches have been developed to realize the DBBSFs [1-7]. The dual-band rejection can be synthesized by applying frequency-variable transformation to the lowpass prototype [1] or the cul-de-sac configuration [2]. Through the right/left-handed metamaterial transmission lines [3] or the parallel microstrip open stubs of different length [4], the dual-band performance can also be obtained. Recently, much research has been concentrated on the size reduction of DBBSFs, which may be achieved by using two-section stepped-impedance resonators (SIRs) [5], combining split ring resonators and complementary split ring resonator [6], and utilizing a single end-shorted parallel coupled microstrip line and open-ended SIRs [7]. However, the implementation of more compact DBBSFs is still an ongoing challenge.

In this paper, a miniaturized DBBSF is proposed by adopting T-shaped defected microstrip structure (DMS) and U-shaped defected ground structure (DGS). By making full use of the characteristics of the DMS and DGS and the space of signal strip and ground plane, further size reduction and compactness of the DBBSF can be achieved. Firstly, the difference between the presented T-shaped DMS and T-shaped DGS is analyzed. Secondly, the compact DBBSF is designed and realized, where the T-shaped DMS accounts for the first stopband and the U-shaped DGS accounts for the second stopband. And the mutual coupling between these two structures is discussed. Finally, the two-stage DBBSF is constructed and simulated to obtain improved stopband suppression.

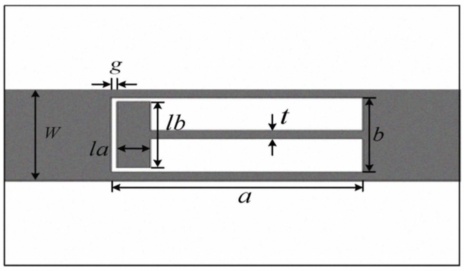

Fig. 1. Geometry of the T-shaped DMS (top view).

II. T-SHAPED DEFECTED MICROSTRIP STRUCTURE

The layout of T-shaped DMS is shown in Fig. 1, where the patterned structure is etched in the signal strip instead of the ground plane in [8] to obtain a lower resonance frequency. For the verification purpose, the T-shaped DMS and the T-shaped DGS are simulated by the full-wave solver Ansoft HFSS with the same following dimensions: $W = 4.5$, $a = 9$, $b = 3.6$, $t = 0.4$, $g = 0.2$, $la = 1.2$, $lb = 3.2$ (all units are in mm). The substrate used in the simulations has relative permittivity of 2.55 and a thickness of 1.5 mm. Fig. 2 shows that the resonance frequency of T-shaped DMS is at 3.24 GHz while the T-shaped DGS is at 3.50 GHz.

The above resonance frequency difference can be explained from the perspective of equivalent parallel RLC circuit [9]. The extracted circuit parameters of T-shaped DMS and T-shaped DGS are 0.560 nH, 4.295 pF, 1801.1 Ω and 0.298 nH, 6.958 pF, 1308.5 Ω respectively. Therefore, the equivalent

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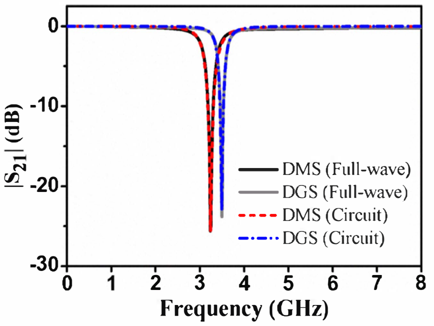

Fig.2 . Full-wave and circuit simulated transmission response of the T-shaped DMS and T-shaped DGS.

inductance will increase quickly when the signal strip is disturbed, leading to the resonance frequency reduction for T-shaped DMS. Meanwhile, since the ground plane is not etched, the T-shaped DMS would be easier to be integrated with other microwave planar devices and has less radiated electromagnetic interference ground noise.

III. MINIATURIZED DUAL-BAND BANDSTOP FILTER

Based on the prominent stopband of T-shaped DMS, a DGS may be added simultaneously to produce another stopband. Thus, a miniaturized DBBSF can be constructed by fully utilizing the space of the signal strip and the ground plane. In our case, the U-shaped DGS is adopted for its high Q factor and compact size [10] and Fig. 3 shows the geometry of the proposed DBBSF.

To validate above design concept, the DBBSF with following dimensions is simulated: $W = 4.5$, $a = 9.0$, $b = 3.6$, $t = 0.6$, $g = 0.25$, $la = 1.2$, $lb = 3.1$, $k = 4.5$, $m = 0.3$, $e = 9.0$, $d = 0$ (all units are in mm). And it is fabricated on Arlon Cuclad 250(tm) substrate with $\varepsilon_r = 2.55$, $\tan\delta = 0.001$ and a thickness of 1.5 mm. Simulated and measured frequency responses are shown in Fig. 4, and a good agreement between the measurement and simulation is obtained. The dual center frequencies of the filter are located at 3.825 GHz and 5.325 GHz with 3 dB fractional bandwidth of 14.6% and 16.3% respectively. And the rejection level at both center frequencies is more than 25 dB.

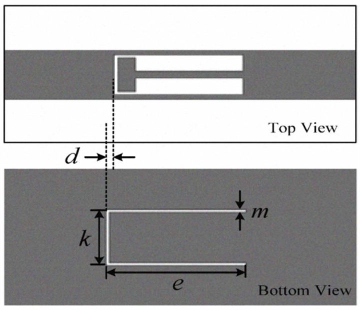

Fig. 3. Geometry of the proposed DBBSF.

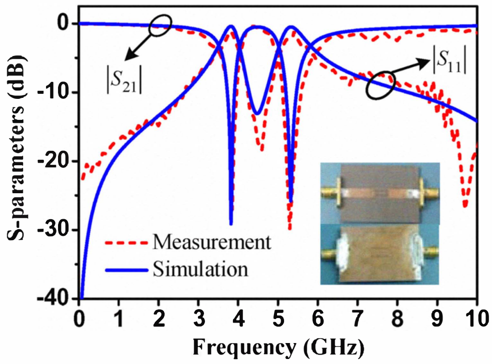

Fig. 4. Simulated and measured S-parameters of the fabricated DBBSF.

It is worth noting that for the realization of aforementioned DBBSF, the first stopband and the second stopband are mainly determined by the T-shaped DMS and the U-shaped DGS respectively. To demonstrate that, the single T-shaped DMS and the single U- shaped DGS are simulated by HFSS with the same dimensions of the fabricated DBBSF. The simulated results show that the single T-shaped DMS has a resonance frequency at 3.71 GHz and the single U-shaped DGS resonates at 5.27 GHz, which are very close to the two resonant frequencies of the fabricated DBBSF located at 3.825 GHz and 5.325 GHz. Little frequency shift means that the mutual coupling between the T-shaped DMS and U-shaped DGS would be negligible.

To further investigate the mutual coupling, the DBBSF with different relative longitudinal positions *d* is simulated. The lower and higher center frequencies of the stopband keep almost the same when *d* changes, which can be clearly seen in Fig. 5. The maximum change between two resonant frequencies of the DBBSF and that of single T-shaped DMS and single U-shaped DGS is 0.135 GHz and 0.125 GHz correspondingly. Namely, the mutual coupling between the T-shaped DMS and U-shaped DGS may be neglected. Henceforth, the lower resonant frequency can be freely changed by adjusting the dimensions of T-shaped DMS while the higher resonance remains invariant; and the higher resonant frequency may be freely varied by tuning the dimensions of U-shaped DGS while the lower resonance remains unchanged. The characteristic of the independence of one band from the other for this miniaturized DBBSF, which is one of the most important parameters in the implementation of dual-band structure, will bring flexibility and convenience to the practical applications.

This compact DBBSF occupies a rectangular area of 9.0 mm * 4.5 mm. For comparison, the occupied rectangular area of the proposed and published filters is normalized as (length/ λg) * (width/ λg) and listed in Table I, where f_L and f_H is the lower and higher center frequency respectively, $f_C = (f_L + f_H)/2$ and λg is the guided wavelength at f_C . The proposed DBBSF has the minimal normalized size. Furthermore, it is implemented in the signal strip and ground

TABLE I
SIZE COMPARISON FOR DIFFERENT REPORTED DBBSFS

DBBSF	Frequency (GHz)		Rectangular Area (mm*mm)	Normalized Size ($\lambda_g \times \lambda_g$)
	f_L	f_H		
Ref. [4]	1.7	2.3	34.0*29.4	0.566*0.490
Ref. [5]	1.5	3.15	28.0*23.8	0.368*0.313
Ref. [6]	2.55	5.05	14.0*20.0	0.468*0.668
Ref. [7]	0.9	2.1	28.9*29.3	0.247*0.250
This work	3.825	5.325	9.0*4.5	0.201*0.101

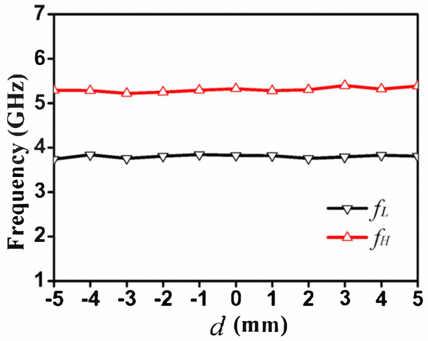

Fig. 5. Variation of the lower and higher center frequency as a function of the relative longitudinal position d .

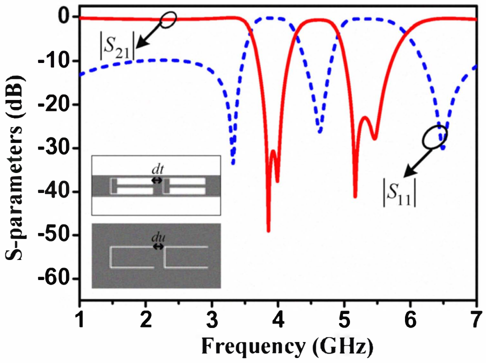

Fig. 6. Simulated S-parameters of the two-stage DBBSF ($dt = du = 0.9$ mm , other parameters are the same with fabricated DBBSF).

plane, without needing extra space like other published filters. Henceforth, the compactness is further demonstrated.

To obtain an improved stopband rejection, a two-stage DBBSF is constructed using the T-shaped DMS unit cell and U-shaped DGS unit cell. Fig. 6 shows the simulated results of this DBBSF, where the maximum stopband rejection is more than 49 dB. Two split resonance frequencies in both stopbands are due to the electromagnetic coupling between the same unit cells. By increasing the distance dt and du, the coupling coefficients will be reduced and two split resonances will get close. The normalized size of this two-stage DBBSF is 0.434 λg * 0.103 λg , which is still smaller than the occupied area of other published DBBSFs.

IV. CONCLUSION

A compact DBBSF is proposed by using the T-shaped DMS and U-shaped DGS in this paper. Taking full advantage of the space of signal strip and ground plane, a miniaturized DBBSF is designed and implemented. The measurement agrees well with the simulation for the fabricated DBBSF. The negligible mutual coupling in the DBBSF indicates that the lower and higher resonance can be controlled independently by adjusting the dimensions of T-shaped DMS and U-shaped DGS respectively. A two-stage DBBSF is also presented and simulated, which has maximum stopband rejection up to 49 dB. The proposed DBBSFs with compact size and high performance will be attractive for the practical applications in multiband wireless communication systems.

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