Novel W-slot DGS for Band-stop Filter

Lin Chen, MinquanLi, Wei Wang, Jiaquan He, Wei Huang

***Abstract*-A novel W defected ground structure (WDGS) was presented. The structure of WDGS was simple, processing easy and performance excellent. After this unit structure was applied to the design of the band-stop filter, its band-stop characteristic was enhanced efficiently and the dimension was reduced. The effects of the WDGS geometric parameters on frequency and width were analyzed in detail. A band-stop filter was built by three cascaded WDGS. The bandwidth of the filter was increased effectively and the attenuation to signals was improved. The results show that the filter rejects signals from -25dB to -37dB in 2.6GHz-3.4GHz.**

Index Terms—W-slot DGS, band-stop filter, microstrip line

I. INTRODUCTION

In microwave and millimeter-wave band, the defected ground structure (DGS) opens up a new path for the design of microwave device [1],[2]. The DGS is to sculpture missing patterns to change the distributed capacitance and inductance of microstrip line to realize band-stop characteristic. Its structure is simple, the performance excellent, and it is easy to create the modeling of equivalent circuit and the analysis of electromagnetic theory. However, the conventional DGS band-stop filter does not apply to the circuit design of lower frequency and smaller size [3],[4].

The size of the WDGS microstrip band-stop filter proposed in this paper is small and it is more effective in rejecting signal. It can be better integrated in microwave communication system to reject signal in 2GHz-5GHz [5],[6]. The filter has such advantages as small size which is occupied by the circuit prone to the integration of circuits, high performance, low power dissipation and simple craftsmanship, thus it is of great value to be researched and applied.

II. W-SLOT DGS AND CHARACTERISTIC ANALYSIS

Fig.1 shows the sketch of W-slot defected ground structure. For the dimensions l=7mm, g=0.2mm, and w=1.33mm, the transfer characteristics of the W-slot DGS are calculated. The characteristic impedance of the microstrip line is assumed to be 50 Ω and the simulation is performed by using HFSS12.

Manuscript received June 6, 2013. This work was supported in part by the NSF of Anhui Province of China under Grant KJ2011A007 and 1208085MF104, in part by the Key Program of NSFC under Grant 60931002.

Lin Chen, Minquan Li, and Wei Wang are with the Key Laboratory of Intelligent Computing & Signal Processing, Ministry of Education, Anhui University, Hefei 230039, China. (Corresponding author’s mobile phone number:13865913448; e-mail:450084812@qq.com).

MinquanLin is a professor with the Department of Electronics from Anhui University(e-mail: "li_mq68"<li_mq68@yahoo.com.cn>;)

The substrate with the thickness of 1.2 mm and a dielectric constant of 10.2 was used for all simulation.

The single DGS unit has its attenuated nadir point and cut-off frequency. The frequency features resemble Butterworth low-pass filter frequency response. Besides LC parallel circuit possesses band rejection characteristic. They can be determined by resonant frequency and cut-off frequency.

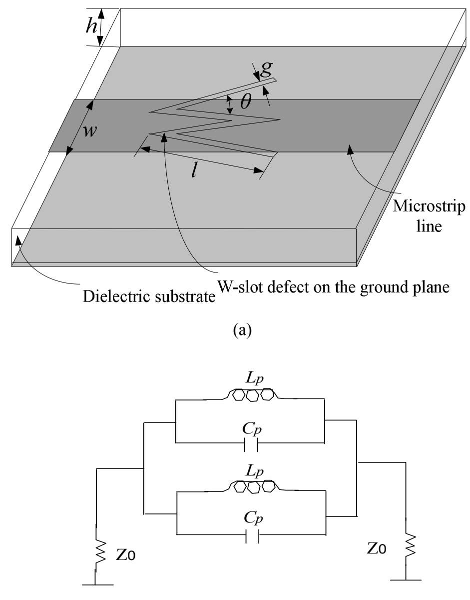


Fig.1 Sketch of WDGS (a) and equivalent circuit (b)

The impedance of LC equivalent circuit equals to the impedance of Butterworth low-pass filter, so equivalent capacitance and equivalent inductance can be attained. The circuit parameters of the equivalent circuit are extracted from the simulated scattering parameters as :

$$C = \frac{f_c}{2\pi Z_0 g_1 (f_0^2 - f_c^2)} \quad (1)$$

$$L = \frac{1}{4\pi^2 f_0^2 C} \quad (2)$$

Here, f_0 is the resonance frequency, f_c is the 3-dB cutoff frequency, and Z_0 is the characteristic impedance of the microstrip line.

The simulated transfer characteristics for various angle (θ) are shown in Fig.2.The dimensions of the W-slot DGS are w=1.33mm, h=1.2mm, l=7mm and g=0.2mm. As θ increases, the equivalent parallel capacitor increases. When the angle equals to $\pi/2$, $\pi/3$, $\pi/6$ and $\pi/8$, the resonant frequency changes over. In TABLE I, it is confirmed that the resonant frequency increases as the angle decreases.

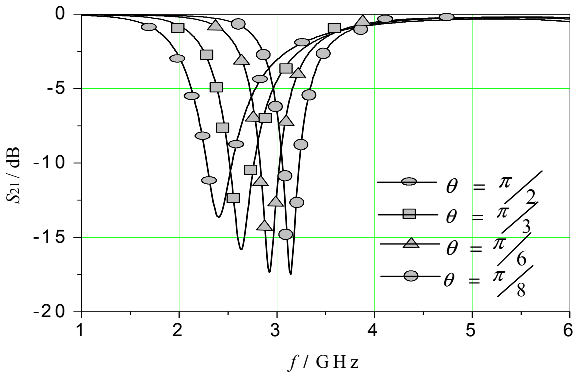


Fig.2 Simulated S21-parameters of the WDGS with different θ values (l=7mm, g=0.2mm, w=1.33mm, ε_r of substrate = 10.2, h=1.2mm)

TABLE I Absolute attenuation with different θ values

θ	Resonant Frequency (GHz)	Cutoff Frequency (GHz)	Absolute Attenuation (dB)
$\pi/2$	2.4	2	-13.7
$\pi/3$	2.63	2.28	-16
$\pi/6$	2.92	2.62	-17.4
$\pi/8$	3.15	2.85	-17.5

In Fig.3, the simulated transfer characteristics for the W-slot DGS are plotted as functions of length (l).The dimensions of the W-slot DGS are $\theta=\pi/8$ and g=0.2mm. As the length increases, the resonant frequency decreases.

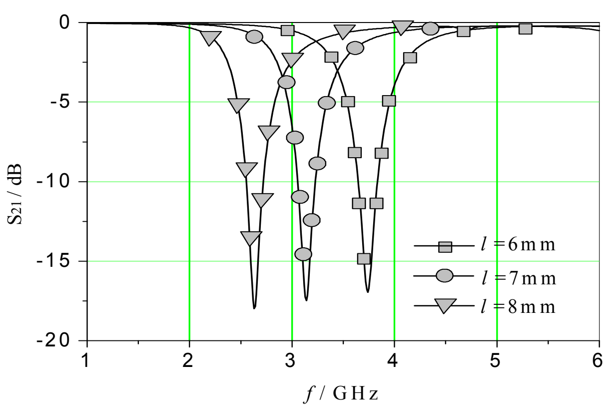


Fig.3 Simulated S21-parameters of the WDGS with different l values (g=0.2mm, $\theta=\pi/8$, w=1.33mm, ε_r of substrate = 10.2, h=1.2mm)

TABLE II Absolute attenuation with different l values

l/mm	Resonant Frequency (GHz)	Cutoff Frequency(GHz)	Absolute Attenuation (dB)
6	3.78	3.42	-17
7	3.15	2.82	-17.5
8	2.62	2.4	-18

Fig.4 shows the simulated transfer characteristic as functions of various widths (g). This parameter does not affect attenuation much, but it exerts pronounced effect on absolute bandwidth. The dimensions of the W-slot DGS are l=7mm and $\theta=\pi/6$. From TABLE III, one may clearly observe that the increased width causes rapid increase in absolute bandwidth.

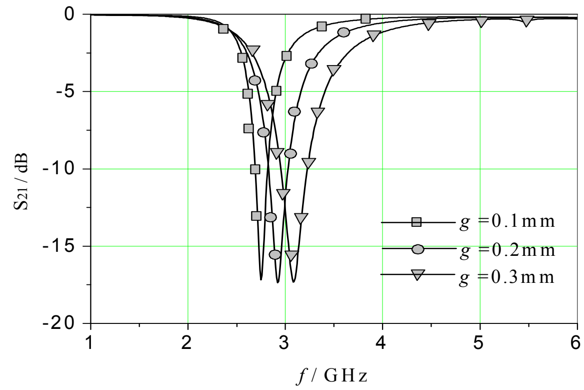


Fig.4 Simulated S21-parameters of the WDGS with different g values (l=7mm, $\theta=\pi/6$, w=1.33mm, ε_r of substrate = 10.2, h=1.2mm)

TABLE III Absolute bandwidth with different g values

g/mm	Resonant Frequency (GHz)	Cutoff Frequency(GHz)	Absolute bandwidth (GHz)
0.1	2.75	2.55	0.45
0.2	2.91	2.62	0.67
0.3	3.08	2.65	0.95

III. BAND-STOP FILTER DESIGN

For a design of a filter satisfying the required rejection bandwidth and attenuation, multiple DGS are cascaded along with the transmission line. Fig.5 illustrates the configuration of the band-stop filter with there cascaded W-slot DGSs. The dimensions for the W-slot are l=7mm, g=0.2mm, $\theta=\pi/8$ for each DGS and the characteristic impedance of the line is 50 Ω . The distance between the W slots are fixed as s=7mm.

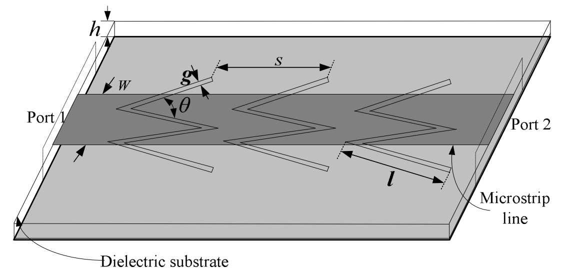
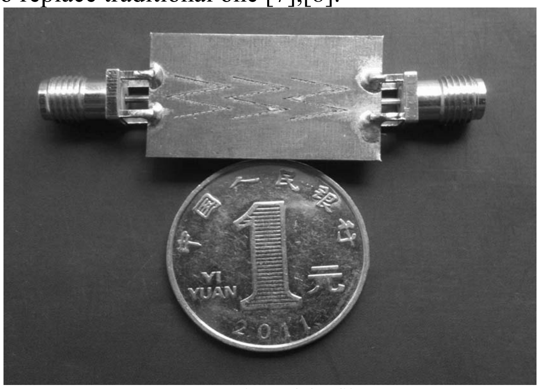
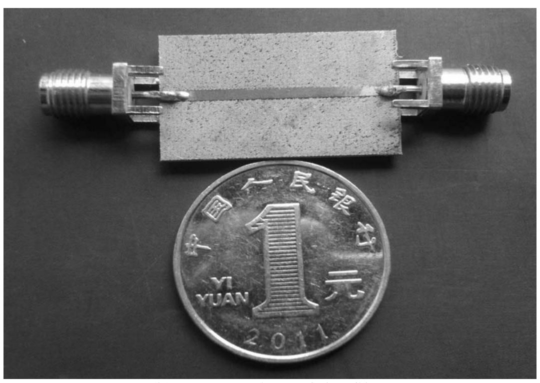


Fig.5 sketch of a filter consisted of three WDGS (l=7mm, g=0.2mm, w=1.33mm, s=7mm, $\theta=\pi/8$, ε_r of substrate = 10.2, h=1.2mm)

The simulation results show that this band-stop filter has quite wide stop-band , its suppression over the signal within the range from 2.6GHz to 3.4GHz being less than -25dB. The transferring characteristics of W-slot DGS band-stop filter in pass-band are comparatively smooth and the attenuation being quite low. Thus this novel band-stop filter has such desirable advantages as excellent performance, small size, low price and easy to manufacture. So the filter can be independently used to replace traditional one [7],[8].



(a) Top view of the filter



(b) Bottom view of the filter

Fig.6 The photos of top and bottom views of the fabricated filter PCB

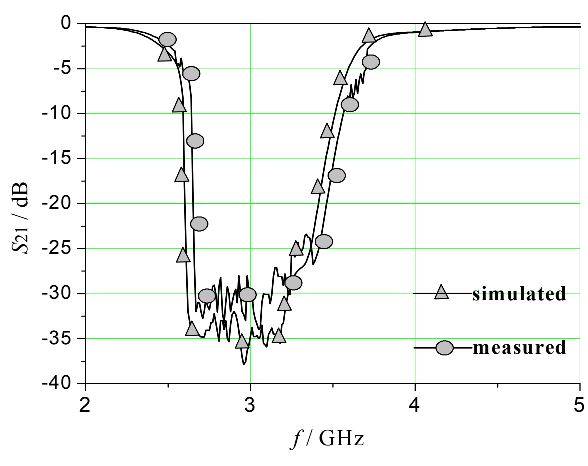


Fig.7 Simulated and measured S21-parameters of filter

Fig. 6 shows the top and bottom views of the fabricated band-stop filter with three cascaded W-slot DGSs units. The dimensions for WDGS are: l=7mm, g=0.2mm, $\theta=\pi/8$, s=7mm and w=1.33mm. The substrate is a R03210 circuit board with a thickness of 1.2mm and a dielectric constant of 10.2. Fig.7 shows the comparative results between simulation and measurement on the fabricated three cascaded W-slot DGSs. It can be seen that they quite correspond to each other. It is also proved that the performance of WDGS is superior and filters of cascade connection can be widely used in small type microwave and radio frequency components.

IV. CONCLUSION

A Novel W-slot DGS has been proposed in this paper and the influences that DGS parameters exert on transferring characteristics have been discussed. Three cascaded W-slot DGSs filter have been designed and fabricated, it rejects the signals at the frequencies from 2.6 GHz to 3.4GHz with less than -25dB suppression. The transfer characteristic in the pass-band shows low loss and flatness as a function of the frequency. The size of W-slot DGS filter is 0.16λg×0.24λg , which is even smaller than the Compact Band-stop Filter (0.16λg×0.35λg) [9],[10]. The proposed structure may have wide applications in the design of microwave components and antenna arrays.

REFERENCES

[1] R. Li, D. I. Kim, C. M. Choi, "Compact structure with three attenuation poles for improving stopband characteristics," IEEE Microwave Wireless Compon..,vol. 16, pp. 663-665, Dec. 2006.

[2] V. Radisic, Y. Qian, R. Coccioli, and T. Itoh, "Novel 2-D photonic bandgap structure for microstrip lines," IEEE Microw. Guided Wave Lett., vol. 8, pp. 69–71, Feb. 1998.

[3] D. J. Woo, T. K. Lee, C. S. Pyo, and W. K. Choi, "High-Q band rejection filter by using U-slot DGS," in Proc. 35th Eur. Microw. Conf., Paris, France, pp. 1279–1282, Oct. 2005.

[4] S. J. Wu, C. H, Tsai, T. L. Wu, T. Itoh. "A novel wideband common mode suppression filter for GHz differential signals using coupled patterned ground structure," IEEE Transactions on Microwave Theory and Techniques, Lett., vol. 57, pp. 848-855, Apr. 2009.

[5] Duk-Jae Woo,Taek-Kyung Lee, Jae-Wook Lee, "Novel U-Slot and V-Slot DGSs for Bandstop Filter With Improved Q Factor," IEEE Transactions onMicrowave Theory and Techniques, vol. 54, pp. 2840-2847, Jun. 2006.

[6] C. S. Kim, J. S. Park, D. Ahn, and J. B. Lim, "A novel 1-D periodic defected ground structure for planar circuits," IEEE Microw. Guide Wave Lett., vol.10, pp. 131–133, Apr. 2000.

[7] S. Y. Huang, and Y. H. Lee, "A compact E-shaped patterned ground structure and its applications to tunable bandstop resonator," IEEE Trans. Microw. Theory Tech., vol. 57, pp. 657-666, Mar. 2009.

[8] C.S.Kim, J.S.Lim, S.Nam, K.Y.Kang, D.Ahn, "Equivalent circuit modelling of spiral defected ground structure for microstrip line," Electron. Lett., vol.38, pp. 1109-1110, Sep.2002.

[9] Maohui Yang, Jun Xu, Yuliang Dong, "A Novel Open-loop DGS for Compact Bandstop Filter With Improved Q Factor," IEEE Trans.on antennas propagation and EM theory, pp. 649-652, Nov. 2008.

[10] N.C.Kamakar, S.M.Roy, "Quasi-static modeling of defected ground structure," IEEE Trans. Microw. Theory Tech.,vol.54, pp. 2160-2168, May 2006.