Compact Ultra-Wideband (UWB) Bandpass Filter with Dual Notched Bands

Shanshan Gao, Shaoqiu Xiao, and Jia-Lin Li

School of Physical Electronics,
University of Electronic Science and Technology of China, Chengdu, 610054, China
issgao@hotmail.com, xiaoshaoqiu@uestc.edu.cn, jialinuestc@yahoo.com.cn

Abstract ─ A compact ultra-wideband (UWB) bandpass filter with two controllable highly selective notched bands is presented. The modified stepped impedance resonator (SIR) and two interdigital feed-lines realize the UWB passband. The loaded stubs at each side of the modified SIR and the U-shaped slot on the ground plane produce two notched bands at desired frequencies without increasing the total size of the filter. High performance achieved by the proposed UWB filter is validated by both simulations and measurements.

Index Terms - Ultra-wideband (UWB), bandpass filter (BPF), stepped-impedance resonator (SIR), defected ground structure.

I. INTRODUCTION

In recent years, due to the attractive merits such as high speed date transmission rate, low power operation, and large data capacity, ultra-wideband (UWB) technology has attracted much attention since the Federal Communication Commission (FCC) released the frequency spectrum from 3.1 to 10.6 GHz for commercial applications in 2002 [1]. Filters [2-5] are the key components in UWB systems. Many researchers have explored various UWB bandpass filters via different methods: a ring resonator connected by a stub [6]; multiple-mode resonator [7]; short-circuited coplanar waveguide (CPW) multiple-mode resonator [8]. It is well known that there are some undesired narrow band RF signals such as wireless local-area network (WLAN) radio signals within the UWB frequency range. Thus, there is an increasing requirement in UWB bandpass filters and antennas with one or multiple notched bands within the allocated UWB spectrum [9-14].

This paper presents a UWB filter using the modified stepped impedance resonator (SIR) and two interdigital feed-lines. Two controllable highly selective notched bands within the UWB passband are generated by respectively using loaded stubs at each side of the modified SIR and etching a U-shaped slot on the ground plane. Characteristics of such a filter are studied and a demonstrator is validated by simulations and measurements.

II. NOTCHED BANDS DESIGN

In our initial works [15], a UWB bandpass filter with one controllable notched band within the UWB passband is realized by using a stub-loaded modified SIR and two identical interdigital feed-lines, as shown in Fig. 1(a) except the U-shaped slot. The UWB passband bandwidth is achieved by the modified SIR and two identical interdigital feed-lines. A controllable notched band within the UWB passband is generated by loading identical stub between the high impedance double-lines at each side of the modified SIR. By properly adjusting the length of the loaded stub i.e., L4, the lower notched band at desired frequency can be achieved, as shown in Fig. 1(b). The bandwidth of the notched band can be controlled by tuning the width of the loaded stub, i.e., W4. Figure 1(c) shows the simulated frequency responses with varying W4. It can be seen that the bandwidth decreases when increasing W4. According to above analysis, the loaded stubs can generate a notched band at desired frequency without significant influence on the passband performance.

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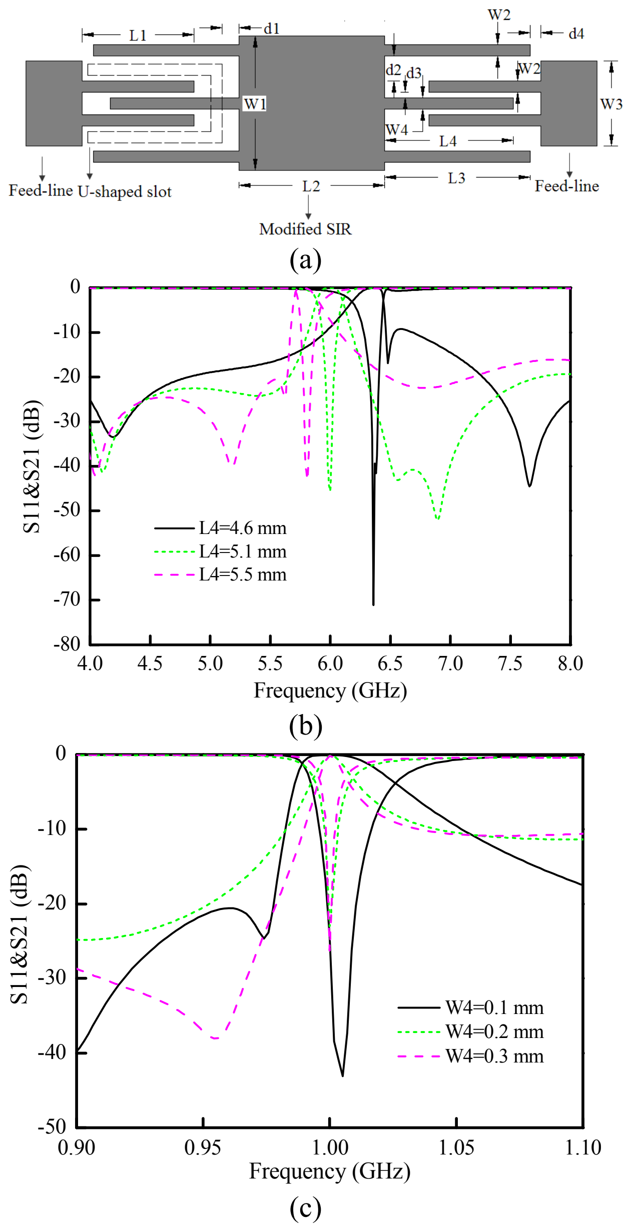


Fig. 1. (a) Structure of the UWB bandpass filter, (b) Simulated frequency responses of the loaded stubs for varying L4 (W4=0.1 mm), (c) Simulated frequency responses for varying W4 (L4=5.5 mm, d2=0.1 mm, and d3=0.1mm).

The concept of the defected ground structure (DGS) has been used extensively in the field of microwave devices design. Here a U-shaped DGS is proposed to generate the upper notched band. Figure 2 shows the configuration and equivalent circuit of the proposed DGS resonator. The U-shaped slot in the ground plane disturbs the shield

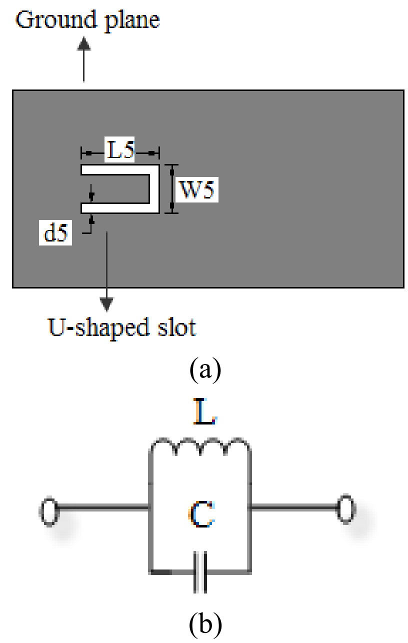


Fig. 2. (a) Configuration of the U-shaped slot, (b) Its equivalent circuit.

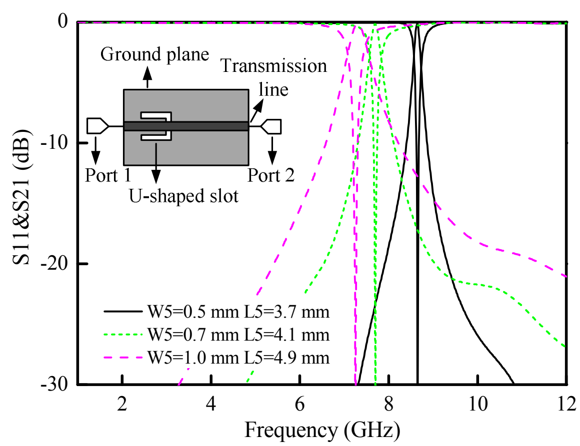


Fig. 3. Frequency responses of the proposed DGS for varying W5 and L5 (d5=0.1 mm).

current distribution in the ground plane, which changes the capacitance and inductance of the transmission line. Thus, the resonance frequency of the proposed DGS depends on the physical dimensions of the U-shaped slot. In order to investigate the influence of the proposed DGS dimensions on the frequency characteristics, three cases are simulated. The value of d5 is fixed to 0.1 mm for all cases when the values of W5 and L5 are varied. The linewidth of the transmission line for the proposed DGS section is chosen as 50 Ω

Table 1: Extracted equivalent circuit parameters for varying W5 and L5

W5 (mm)	L5 (mm)	Resonance Frequency (GHz)	Cutoff Frequency (GHz)
0.5	3.7	8.65	8.57
0.7	4.1	7.70	7.58
1.0	4.9	7.25	7.09
W5 (mm)	**L5 (mm)**	**Capacitance (pF)**	**Inductance (nH)**
0.5	3.7	9.901	0.034
0.7	4.1	6.579	0.065
1.0	4.9	4.918	0.098

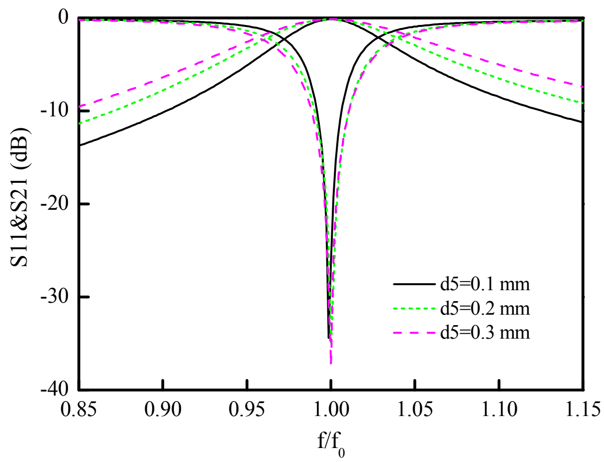


Fig. 4. Simulated frequency responses for varying d5 (W5=1.0 mm, L5=4.9 mm).

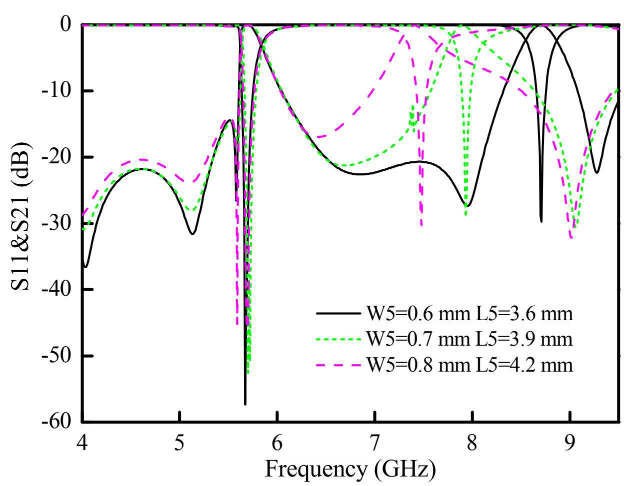


Fig. 5. Simulated frequency responses for varying W5 and L5 (L4=5.6 mm, W4=0.1 mm, d5=0.1 mm).

for simulations. The simulated results are plotted in Fig. 3. As the physical dimensions of the U-shaped slot increases, the equivalent capacitance decreases and the equivalent inductance increases, thus the resonance frequency slowly shifts to lower position due to the increased inductance. The circuit parameters of the equivalent circuit can be extracted [16]

$$C = \frac{\omega_c}{2Z_0} \cdot \frac{1}{\omega_0^2 - \omega_c^2} \tag{1}$$

$$L = \frac{1}{4\pi^2 f_0^2 C} \tag{2}$$

where ω_c is the 3-dB cutoff angular frequency, ω_0 is the resonance angular frequency, Z_0 is the characteristic impedance of the transmission line, and f_0 is the frequency of the attenuation pole location. Table 1 lists the circuit parameters of the equivalent circuit which are extracted from the simulated scattering parameters in Fig. 3. The bandwidth of the notched band can be controlled by the width of the gap, i.e., d5. Figure 4 shows the frequency responses with varying d5. It can be seen that the bandwidths are proportional to d5. Accordingly, the upper notched band can be achieved by properly tuning the dimensions of the proposed U-shaped slot, but the position of the lower notched band doesn't change as shown in Fig. 5.

III. SIMULATED AND MEASURED RESULTS

Based on the above study, a novel UWB bandpass filter with two controllable highly rejected notched bands is designed. One notched band is controlled by the loaded stub, and another one is determined by the U-shaped slot on the ground plane without increasing the total size of the filter. The dimensions for the UWB filter [referred to Figs. 1(a), 2(a)] are: W1=1.5 mm, W2=0.1 mm, W3=0.76 mm, W4=0.1 mm, W5=0.7 mm, L1=4.9 mm, L2=2.0 mm, L3=5.6 mm, L4=5.6 mm, L5=4.1 mm, d1=2.6 mm, d2= 0.1 mm, d3=0.1 mm, d4=0.1 mm, d5=0.1 mm. Simulation was accomplished using Ansoft HFSS, and measurement was carried out on an Agilent E8363B network analyzer. Figure 6 illustrates the simulated and measured frequency responses of the proposed filter. From this figure we can see

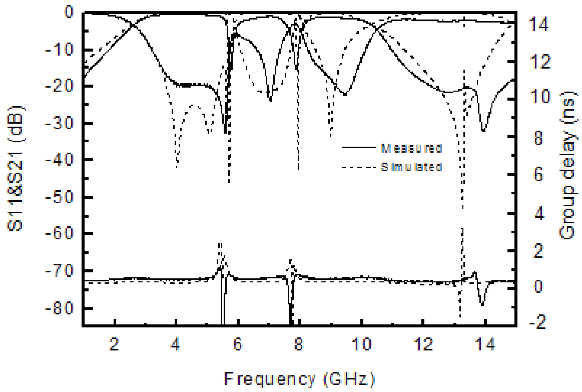
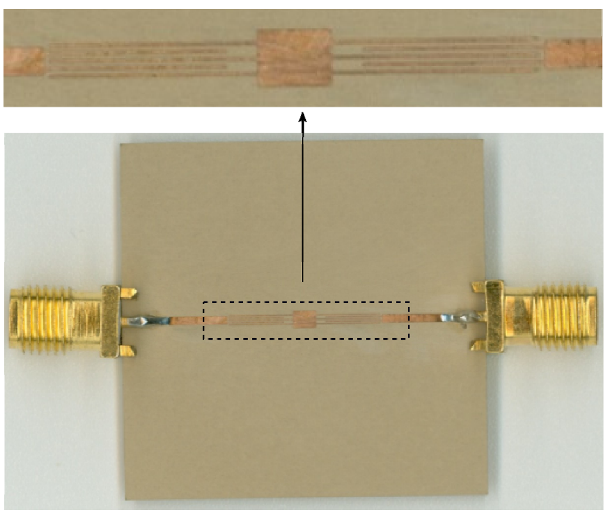
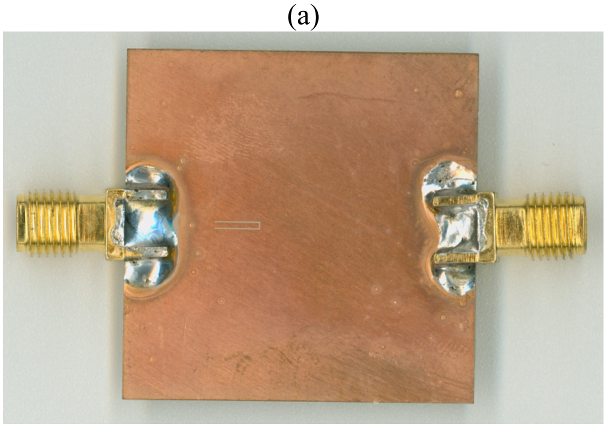


Fig. 6. Simulated and measured results.



(a)



(b)

Fig. 7. Photograph of the fabricated UWB filter (a) top view, (b) bottom view.

that the measured passband is from 2.64 GHz to 10.27 GHz, and the two notched bands are centered at 5.74 GHz and 7.86 GHz, respectively. The attenuations at the center of the notched bands are about -15.551 dB and -15.432 dB, respectively. Within the passbands, the return losses are below -10 dB. Meanwhile, there is a transmission zero located at 13.9 GHz, which realizes a good out-of-band rejection. The simulated and measured group delays are also shown in Fig. 6. It is seen that the measured group delays within the passbands are all less than 0.2 ns. The deviation between the simulated and measured results is mainly caused by SMA connectors and fabrication. Figure 7 displays the photograph of the fabricated UWB filter.

IV. CONCLUSION

A compact UWB bandpass filter with two controllable sharply rejected notched bands has been proposed in this letter. The UWB passband was realized by using the modified SIR and two interdigital feed-lines. Two notched bands at the desired frequencies within the UWB passband have been achieved by adopting the loaded stubs and U-shaped DGS without increasing the total size of the UWB filter. The proposed new UWB bandpass filter features compact size, easy fabrication, and is suitable for UWB wireless systems.

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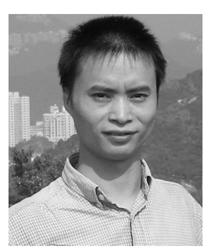
Shanshan Gao was born in Sichuan Province, China. She received the M.S. degrees in radio physics from the University of Electronic Science and Technology of China (UESTC), Chengdu, in 2008, and is currently working towards the Ph.D. degree in radio physics at UESTC. Her research interests include design and implementation of microwave passive devices for ultra-wideband wireless communication systems.

Shaoqiu Xiao received the Ph.D. degree in electromagnetic field and microwave engineering from the University of Electronic Science and Technology of China (UESTC), Chengdu, in 2003. From January 2004 to June 2004, he was with UESTC as an Assistant Professor. From July 2004 to March 2006, he was with the wireless Communications Laboratory, National Institute of Information and Communications Technology of Japan (NICT), Singapore, as a Researcher with a focus on the planar antenna and smart antenna design and optimization. From July 2006 to June 2010, he was with UESTC as an Associate Professor. He is now a Professor with UESTC. His current research interests include microwave passive circuits, planar antenna and arrays, and electromagnetics in ultra-wideband wireless communication. He has authored/coauthored more than 100 technical journals, conference papers, books, and book chapters.



Jia-Lin Li was born in Yibin, Sichuan Province, China. He received the M. S. degree from the University of Electronic Science and Technology of China (UESTC), Chengdu, China, in 2004, and the Ph. D. degree from the City University of Hong Kong, Hong Kong, in 2009, both in electronic engineering. From September 2005 to August 2006, he was a Research Associate with the Wireless Communication Research Center, City University of Hong Kong, Hong Kong. Since September 2009, he has been with the Computational Electromagntics Laboratory (CEMLab), Institute of Applied Physics, School of Physical Electronics, UESTC, where he is currently a Professor of Radio Physics. His research interests include the high performance active/passive microwave/millimeter-wave antennas, circuits and systems realized on PCB, multilayer PCB, LTCC, etc.

Dr. Li received the Outstanding Performance Award for Research Degree Students in the Academic Year 2007-2008 from the City University of Hong Kong, and the APMC Champion at the 2008 Asia-Pacific Microwave Conference.