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# Novel Band-Notched UWB Bandpass Filter Using Microstrip/Slotline Ring Resonators

**Can Cui*, Zhi Hou, Hui Wang, and Wen Wu**

**Abstract**—A novel ultra-wideband (UWB) bandpass filter (BPF) with notched band based on microstrip/slotline ring resonators is presented in this paper. The UWB BPF is fabricated with two microstrip ring resonators on the top copper layer and a slotline ring resonator on the bottom ground layer. Thus, an ultra-wide passband can be achieved owing to the coupling effects and microstrip/slotline transitions of these three ring resonators. Then, a notched band which is created at 8.0 GHz for satellite communication system is designed based on loaded short-circuited stubs. Both the simulated and measured results show that this compact UWB BPF has good performances of wide passband and notched band.

## 1. INTRODUCTION

Recently, a lot of researches focusing on ultra-wideband (UWB) bandpass filters (BPFs) have been reported with increasing demands for broad bandwidth in wideband wireless communication systems. The frequency spectrum adopted for UWB communication system in this letter, i.e., 3.1–10.6 GHz, follows the one authorized by the Federal Communications Commission (FCC) for short range and high speed wireless communications [1–15]. In [1], a compact UWB BPF was presented based on shorted stubs and defected ground structure (DGS) with dual notched bands while a multimode resonator (MMR) was used for UWB BPF as shown in [2]. In [3, 4], UWB BPFs based on stub-loaded resonators were presented and implemented. This kind of UWB BPFs had very sharp skirt characteristics with two or more transmission zeros set at the lower and upper stopbands. In [5], cross-shaped resonators were used to fabricate UWB BPFs with wide passband and tunable transmission poles. Super compact UWB BPF was fabricated in [6] with a three line coupled resonator and loaded stubs. In [7], planar coupled resonators were used to design UWB BPFs. A novel type of MMR, which was constructed by cascading interdigital coupled microstrip line sections with loaded short-ended stepped impedances stubs, was implemented in [8]. Asymmetric feed structures were introduced in [9, 10] for notched-bands applications. In [11–13], short line, radial stub, and embedded stepped impedance resonator (SIR) were used to create a notched band for avoiding signal interference. Compact UWB BPFs with dual-, triple-, and quad-notched bands were presented in [14, 15].

In this paper, a compact band-notched UWB BPF with microstrip/slotline [16] ring resonators and loaded stubs is presented. The ultra-wide passband is achieved by the coupling effects and microstrip/slotline transitions of the ring resonators. Then, a notched band set at 8.0 GHz is fabricated using microstrip shorted circuited stubs, and the performance of upper stopband is improved by loaded open-ended slotlines on the bottom ground layer. The simulated and experimental results are given and discussed, which show good agreement with each other.

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* Corresponding author: Can Cui (cuican100@163.com).
The authors are with the Ministerial Key Laboratory of JGMT, Nanjing University of Science and Technology, Nanjing 210094, China.

## 2. NOVEL BAND-NOTCHED UWB BPF DESIGN

Demand for UWB BPFs is increasing nowadays with the development of wideband communication systems. A novel compact band-notched UWB BPF is designed and fabricated based on microstrip/slotline transitions, as depicted in Fig. 1. The basic resonator of this UWB BPF is the microstrip/slotline transition, which can be perceived as the coupling structures to provide strong enough couplings so as to drive the ring resonators for enhancement wide passband.

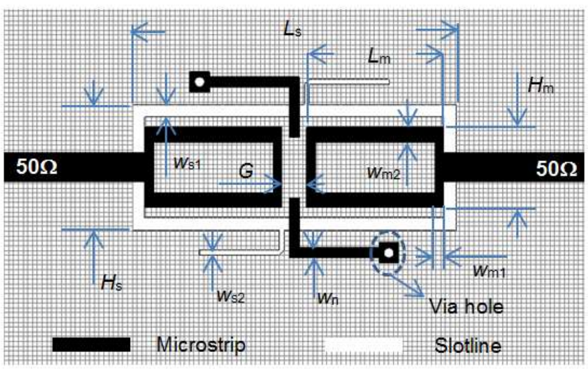



**Figure 1.** Configuration of the proposed wideband differential BPF.

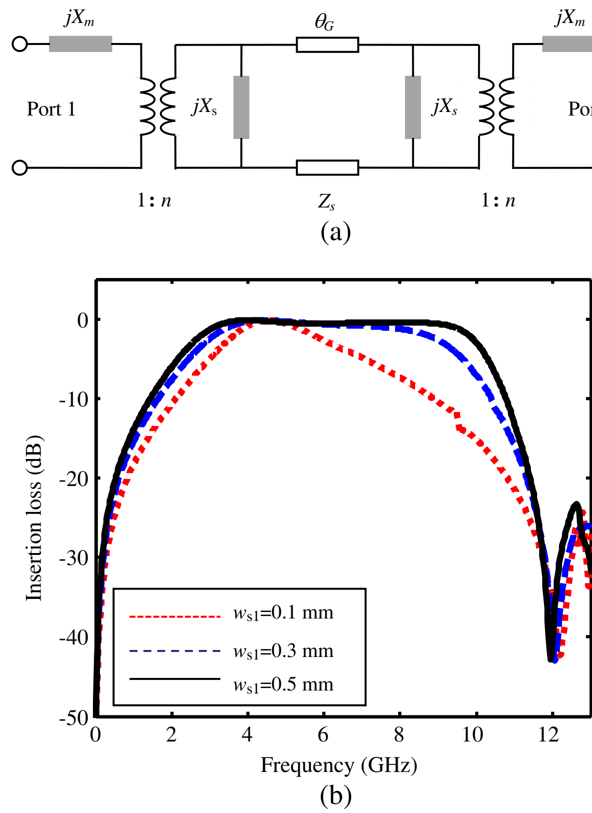



**Figure 2.** (a) Equivalent circuit of the basic UWB BPF and (b) simulated responses of $|S_{21}|$ under different $w_{s1}$.

Figure 2(a) presents an equivalent circuit of the basic bandpass filter. $Z_m$ and $Z_s$ are the microstrip and slotline characteristic impedances. $\theta_m$, $\theta_s$ and $\theta_G$ denote the electrical lengths of microstrip, slotline and the gap between two microstrip rings while $\lambda_s$ is the guided wavelength of slotline. The transformer turn ratio $n$ describes the coupling magnitude between the microstrip and slotline. In Fig. 2(a), the parameters can be obtained as [16]

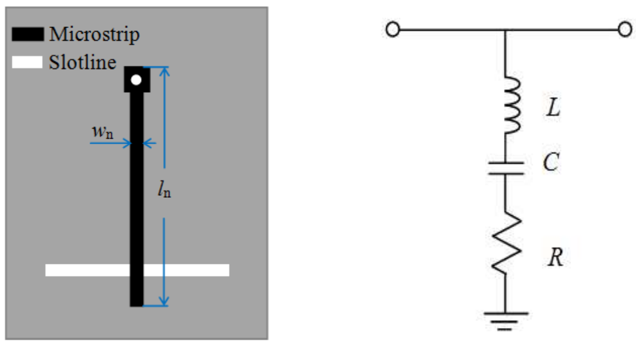
$$jX_m = -jZ_m \cot\theta_m \tag{1}$$
$$jX_s = jZ_s \tan\theta_s \tag{2}$$
$$\theta_G = 2\pi G/\lambda_s \tag{3}$$

where

$$\theta_m = 2\pi(l_m + 0.5H_m)/\lambda_m \tag{4}$$
$$\theta_s = \pi(l_s + H_s)/\lambda_s \tag{5}$$

Figure 2(b) shows the simulated $S$-parameters of the basic UWB BPF with different strengths of coupling. It is seen clearly that the passband gets wider with wider slotline width $w_{s1}$, i.e., the passband is wider while the coupling is stronger.

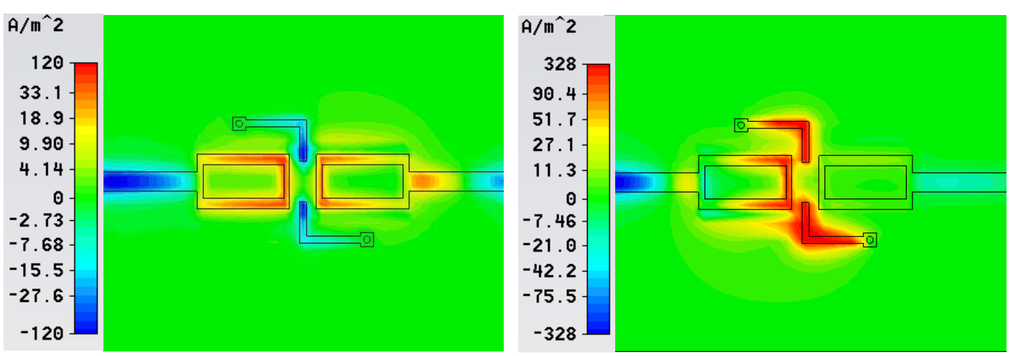
To avoid signal interference, coupled shorted stubs are loaded to generate a notched band at 8.0 GHz for satellite communication systems. This shorted stub is placed on the top layer using microstrip lines and is set orthogonality with the slotline on the bottom layer, as show in Fig. 3(a). The loaded stubs are connected at each end to the bottom layer using via holes which is placed at the center of square pads. The equivalent circuit model is shown in Fig. 3(b), where $L$ represents the stub and via-hole inductance, $C$ the capacitance of the stub over the slotline, and $R$ the resistive loss associated with the stub and via-hole. For a fixed value of $w_n$, the area of the short-ended microstrip above the slotline is unchanged, hence the capacitance $C$ remains constant, but $L$ increases for longer microstrip lengths $l_n$.




(a) (b)

**Figure 3.** (a) Proposed shorted stub over the slotline for notch band generation and (b) equivalent circuit model of the loaded shotred stub.

Thus, the shorted stub is designed by appropriately choosing $l_n$ and $w_n$ so that the resonance frequency $\omega_n = (LC)^{-1/2}$ occurs at the required notch frequency. The resistive losses in the stub ($R$) determine the depth of the notch frequency. To observe this more clearly, Figs. 4(a) and (b) show the current density of the proposed UWB BPF at the central frequency and notched-band frequency of the filter, respectively. The current density at the passband of the structure shows that the coupled shorted stubs does not resonate and has no effect on the overall performance of the filter at the central frequency and these can be obtained from Fig. 3(a), whereas Fig. 3(b) shows the shorted stubs at the notched frequency is acting, and no coupling exists between two microstrip ring resonators on top layer, which means no signal at notched frequency passes through to the output port.




(a) (b)

**Figure 4.** Current density of the proposed UWB BPF with notched band (a) at the central frequency ($f_0 = 6.7$ GHz), (b) at the notched-band frequency ($f_n = 8.0$ GHz).

The frequency responses of the notched band can be controlled easily by adjusting the structural parameters of the coupled shorted stubs. Fig. 5 shows the simulated return losses of the mentioned filter by varying $l_n$ (total length of the bended coupled shorted stub).

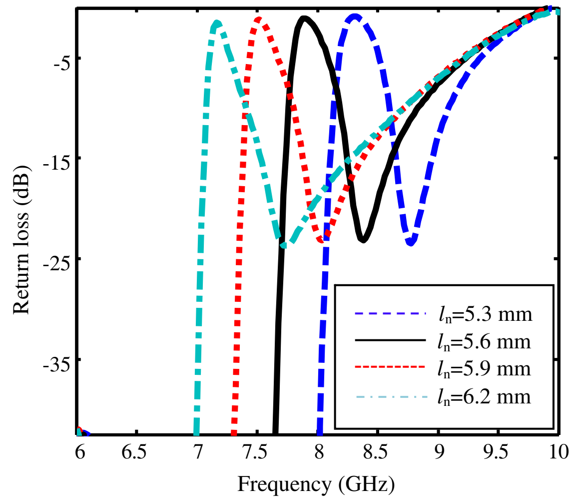



**Figure 5.** Simulated responses of $|S_{11}|$ under different ln.

Based on the approach above, a novel compact band-notched UWB BPF can be designed with another two bended open-ended slotline stubs, and the total length of which is represented as $l_o$, loaded on the bottom ground layer to improve the out-of-band performance.

## 3. RESULTS AND DISCUSSION

For validation, the UWB BPF is fabricated on the substrate RO4003 with dielectric parameter of 3.55 and the thickness of 0.508 mm. The dimensions optimized by ADS are $L_s = 13.0$, $L_m = 5.5$, $H_s = 5.0$, $H_m = 3.2$, $w_{s1} = 0.5$, $w_{s2} = 0.2$, $w_{m1} = 0.35$, $w_{m2} = 0.6$, $w_n = 0.4$, $l_n = 5.6$, $l_o = 4.2$ and $G = 1.0$ (all in millimeters), respectively.

Figure 6(a) shows the simulated and measured results, which are in good agreement with each other. The insertion loss, return loss and group delay variation are, respectively, below 1.2 dB, above 12 dB and 0.45 ns in most of the passband. The 10 dB fractional bandwidth (FBW) of the notched band is 6.7%, and the attenuation is more than 30 dB at the central frequency of 7.9 GHz. Thus,

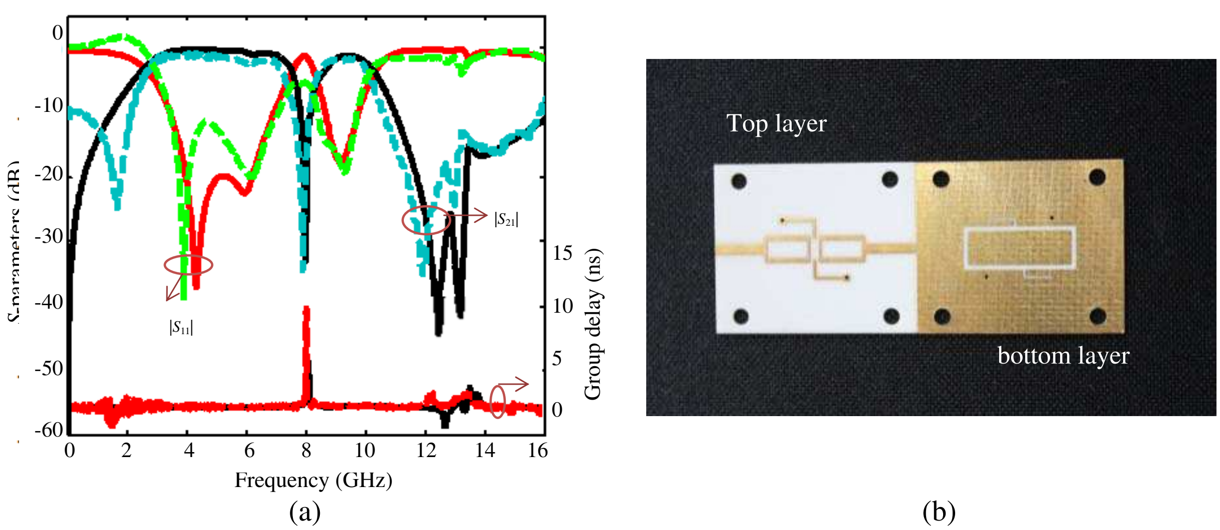



**Figure 6.** (a) Simulated (solid lines) and measured (dashed lines) results and (b) photograph of the proposed UWB BPF.

the introduced technique for compact UWB and narrow notched-band implementation is applicable in wideband communication systems.

## 4. CONCLUSION

A novel UWB BPF witha notched band based on microstrip/slotline ring resonators is designed, fabricated, measured, and discussed in this letter. This filter has a novel structure, compact size, and perfect attenuate performances. Thus, it will be a good candidate for wideband communication systems.

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