Compact Band Notched UWB Filter Based on Open-load Stub

Xuemei Zheng[1, 2], **Yanyan Wang**[1], **and Tao Jiang**[1]

[1]College of Information and Communications Engineering
Harbin Engineering University, Harbin, China
[2]College of Information Engineering, Northeast Dianli University, Jilin, China

Abstract— In recent years, the UWB filters and UWB antennas have attracted much research interest and many design methods have been presented. At present, the research of typical band notched filter for suppressing narrow-band interference signal, by adjusting the number and width of notched stop-band, which is not systematic and deep enough. This paper proposed two compact UWB band pass filters based on open-loaded stub structure. The main advantages of two proposed filters are that the frequency of the notched band can be easily tuned in a wide UWB frequency band. The notch frequency of two filters can be changed by adjusting the size of rectangular resonator and the length of the open-load stub. The simulation results indicated that the filter with one open-load stub can cover the UWB frequency range and enhance the interference immunity from 4.7 GHz to 5.3 GHz in low frequency and from 8.8 GHz to 9.8 GHz in high frequency. The filter with two open-load stubs can generate two notch bands from 5.4 GHz to 5.6 GHz in low frequency and 9.3 GHz to 9.6 GHz in high frequency. The proposed two compact UWB band pass filters can efficiently reduce the interference from undesired signals in WLAN band and in X-band with certain application prospects.

1. INTRODUCTION

Since the FCC announced the unlicensed UWB (ultra-wide band) band from 3.1 GHz to 10.6 GHz for short-range communication in 2002, UWB technology has become an important research area [1]. Many scholars have studied the UWB filter and the UWB antenna, according to the UWB filter design requirements such as compact structure, small size, good group delay, wide bandwidth and so on. In the UWB frequency range, there are some narrow-band wireless communication systems, such as the WiMAX from 3.3 GHz to 3.6 GHz, WLAN from 5.15 GHz to 5.825 GHz, RFID signals at 6.1 GHz, the C-band from 4 GHz to 8 GHz and X-band from 8 GHz to 12 GHz in satellite communication system. In order to avoid the signal interference for UWB communication systems, more and more the UWB filters and UWB antennas with notch characteristics were designed to suppress interference performance. Different methods and structures have been proposed to implement UWB filter, such as asymmetric structure [2], DGS structure [3], loaded open stubs structure [4] and an etching slot structure [5]. At UWB antenna design, Yingsong Li used a comb structure to design UWB antenna [6], the slotted structure in [7], the L-type grooved structure in [8], the U-type grooved structure in [9], the H-type structure in [10] to design the notch antenna. Although most of these ultra-wide band BPF segments are suitable for certain frequencies [11, 12], they have some defects, such as poor group delay performance and complex filter structure.

In this paper, two novel compact band notched UWB filters based on open-load stub structure are presented. The main advantage of the proposed filters is that the frequency of the notched band can be adjusted within the UWB frequency range, so that the filters can efficiently reduce the interference in WLAN band and in X-band.

2. FILTER DESIGN

The proposed filter with one open-load stub has designed on the basis of [13] and formed the resonator to achieve the low frequency notch band, which has used the open-load stub to achieve the high frequency notch band. The basic filter has four short-circuited stubs with length of $\lambda/4$, where λ is the guide wavelength of the central frequency. To reduce the size of the filter, the proposed BPF has been designed with fold branch to instead of the general branch. It can be seen that the performance of basic UWB filter is shown in Fig. 1. It can obtain good passband property with the UWB band range from 3.3 GHz to 10.9 GHz is shown in Fig. 2. The filter with one open-load stub is shown in Fig. 3. It consists of cavity and open-load stub at the central section. Based on the surface current analysis of the filter with one open-load stub, the paper further propose filter with two open-load stubs, which is shown in Fig. 4.

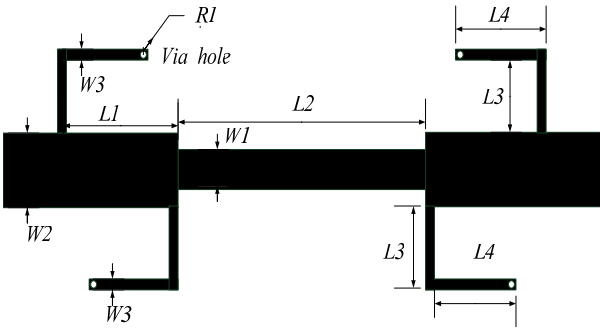

Figure 1: UWB BPF without notch structure.

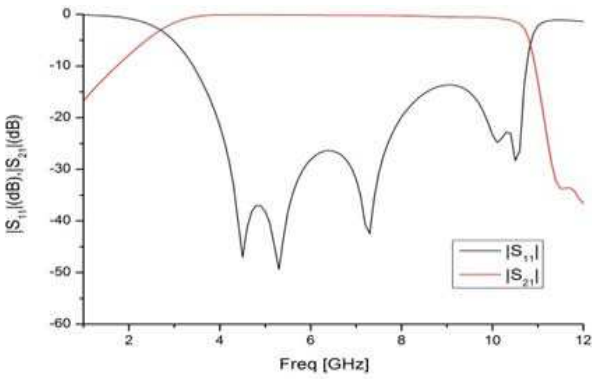

Figure 2: S-parameters of UWB BPF without notch structure.

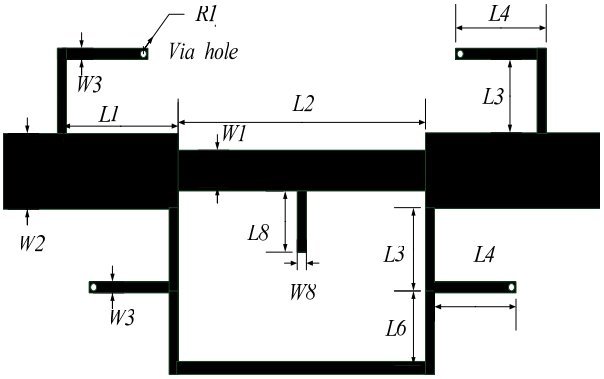

Figure 3: Configuration of the proposed UWB filter with one open-load stub.

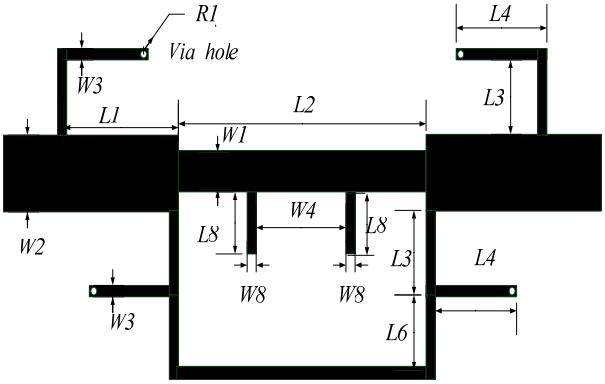

Figure 4: Configuration of the proposed UWB filter with two open-load stubs.

3. SIMULATION RESULTS AND DISCUSSION

The design S parameters is optimized by 3D EM commercial software HFSS 13.0. To verify the effectiveness of two proposed filters, the structure of two proposed band notched UWB filter are selected as follows: $L1 = 5\,\text{mm}$, $L2 = 14\,\text{mm}$, $L3 = 4\,\text{mm}$, $L4 = 5.3\,\text{mm}$, $L6 = 2\,\text{mm}$, $L8 = 2\,\text{mm}$, $R1 = 0.1\,\text{mm}$, $W1 = 1.7\,\text{mm}$, $W2 = 3\,\text{mm}$, $W3 = 0.3\,\text{mm}$, $W4 = 1.4\,\text{mm}$, $W8 = 0.3\,\text{mm}$. The substrate is RT/Duorid5880 with the thickness of 1.0 mm and the dielectric constant of 2.2. The UWB filter with one open-load stub has two notch frequency bands at 5.1 GHz and 9.3 GHz while retaining an UWB band from 3.1 GHz to 10.7 GHz. The low notch central frequency of the filter with two open-load stubs is at 5.3 GHz and the high notch central frequency is at 9.4 GHz.

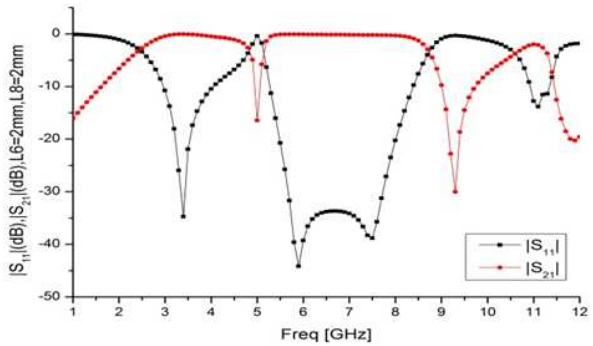

Figure 5: The simulated $|S_{11}|$ and $|S_{21}|$ of the BPF filter with one open-load stub.

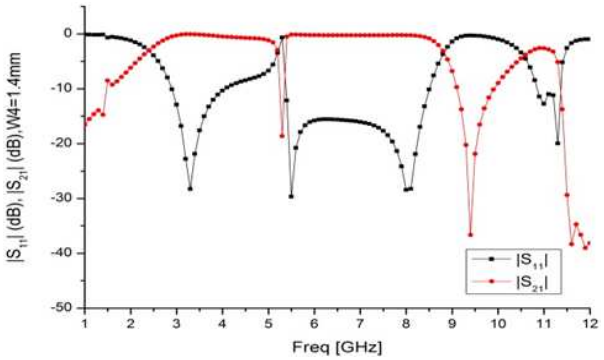

Figure 6: The simulated $|S_{11}|$ and $|S_{21}|$ of the BPF filter with two open-load stubs.

The Fig. 5 shows the simulated $|S_{11}|$ and $|S_{21}|$ of the filter with one open-load stub when $L8 = 2\,\text{mm}$, $L6 = 2\,\text{mm}$, which can generate two narrow notched bands inside the wide-band passband. Its low notch frequency is 5.1 GHz and its high notch frequency is 9.3 GHz. The Fig. 6 shows the simulated $|S_{11}|$ and $|S_{21}|$ of the filter with two open-load stubs when $L8 = 2\,\text{mm}$, $L6 = 2\,\text{mm}$, $W4 = 1.4\,\text{mm}$, which can generate two narrow notched bands at 5.3 GHz in low frequency and at 9.4 GHz in high frequency. By comparing Fig. 5 and Fig. 6, the performance of the filter with two open-load stubs is better than the filter with one open-load stub. The lowest notch point of $|S_{21}|$ changes from $-30\,\text{dB}$ to $-37\,\text{dB}$, notch bandwidth of $-20\,\text{dB}$ is near 240 MHz and the in-band ripple is small.

The Fig. 7 shows that $L8 = 2\,\text{mm}$, $L6 = 1.6\,\text{mm}$, $L6 = 1.8\,\text{mm}$, $L6 = 2.0\,\text{mm}$, with the increase of the length of $L6$, the notch frequency of the BPF filter with one open-load stub is reduced. As shown in Fig. 8, when $L6$ of the BPF filter with two open-load stubs increased from 1.6 mm to 2 mm, the notch central frequency of $|S_{21}|$ in high frequency decreased from 9.6 GHz to 9.3 GHz. The notch central frequency of $|S_{21}|$ in high frequency decreased with the increasing of $L6$. The lowest notch point of $|S_{21}|$ changes from $-30\,\text{dB}$ to $-37\,\text{dB}$. The filter with two open-load stubs can generate two notch bands from 5.4 GHz to 5.6 GHz in low frequency and 9.3 GHz to 9.6 GHz in high frequency.

The Fig. 9 shows the $|S_{21}|$ of the filter for different $L6$ with $L8 = 2\,\text{mm}$, $L8$ is the length of the open-load stub. By increasing the length of $L6$ from 1.4 mm to 2.6 mm, which can continue to lower the central frequencies of two notch bands, the filter can achieve low frequency notch band between 4.7 GHz to 5.3 GHz and high frequency notch band between 8.8 GHz to 9.8 GHz. The Fig. 10 shows that $L6 = 2\,\text{mm}$, $L8 = 1\,\text{mm}$, $L8 = 2\,\text{mm}$, $L8 = 3\,\text{mm}$, when the length of $L8$ is increased, the two notch frequencies are reduced. The low notch frequency and the high notch frequency both can be dominated by adjusting the length of $L6$ and $L8$. By adjusting the length of $L6$, the filter with one open-load stub can change the resonant frequency of resonator. By changing the open stubs length

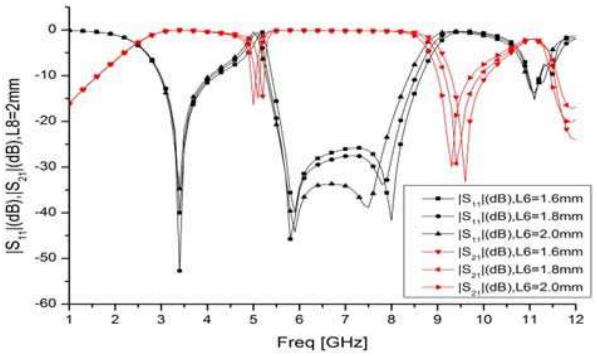

Figure 7: Simulated $|S_{11}|$ and $|S_{21}|$ of the BPF filter with one open-load stub for different $L6$ with $L8 = 2\,\text{mm}$.

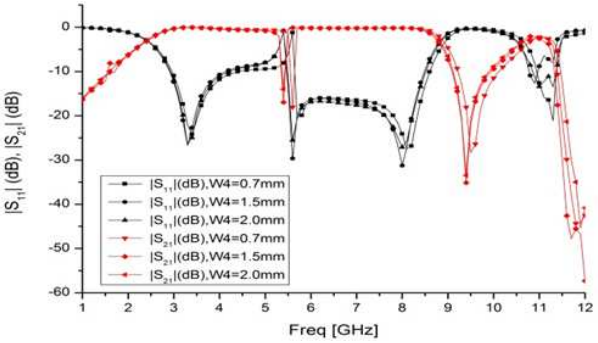

Figure 8: Simulated $|S_{11}|$ and $|S_{21}|$ of the BPF filter with two open-load stubs for different $W4$ with $L6 = 2\,\text{mm}$.

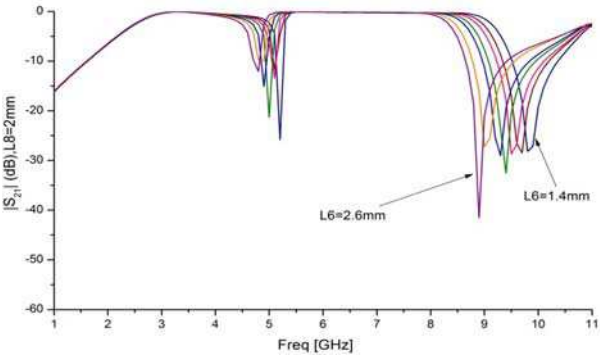

Figure 9: Simulated $|S_{21}|$ of the BPF filter with one open-load stub for different $L6$ with $L8 = 2\,\text{mm}$.

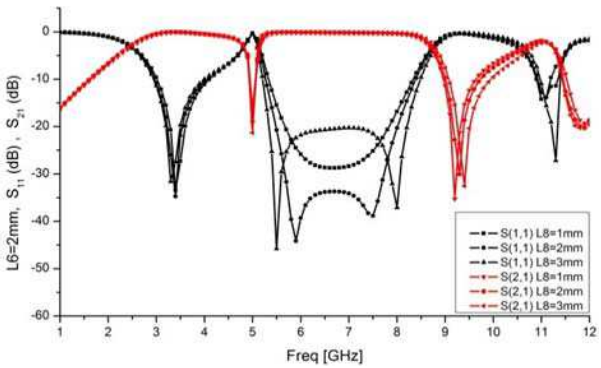

Figure 10: Simulated $|S_{11}|$ and $|S_{21}|$ of the BPF filter with one open-load stub for different $L8$ with $L6 = 2\,\text{mm}$.

of $L8$, the filter with one open-load stub can change the resonance characteristics and the coupling between the open stub and the resonator.

4. CONCLUSION

In this paper, two compact UWB filters have been proposed. The performance of the filter with two open-load stubs is better than the filter with one open-load stub. Both two compact UWB filters achieved wide passband with dual notched bands by changing the length of the open-load stub structure. The predicted results were confirmed by the simulation experiment, where the low notch frequency and the high notch frequency can be changed respectively. The filter with one open-load stub can enhance the interference immunity from 5.15 GHz to 5.3 GHz in WLAN and 8.8 GHz to 9.8 GHz in X-band with certain application prospects. The filter with two open-load stubs can generate two notch bands from 5.4 GHz to 5.6 GHz in WLAN and 9.3 GHz to 9.6 GHz in X-band with certain application prospects.

ACKNOWLEDGMENT

This paper is funded by the International Exchange Program of Harbin Engineering University for Innovation-oriented Talents Cultivation. This work was also partially supported by the Navy Defense Foundation of China (4010403020102), the Science and Technology innovative Talents Foundation of Harbin (2013RFXXJ083), the Foundational Research Funds for the Central Universities (HEUCF 131602, HEUCFD1433).

REFERENCES

1. FCC, "Revision of Part 15, the Commission's rules regarding to ultra-wide-band transmission system," First Note and Order Federal Communication Commission, ET-Docket 98-153, 2002.
2. Wong, S. W. and L. Zhu, "Implementation of compact UWB band pass filter with a notch-band," *IEEE Microwave Wireless Compon. Lett.*, Vol. 18, No. 1, 10–12, 2008.
3. Thai, H. D., J. Y. Lee, and I. S. Kim, "New bandstop filter based on capacitively coupled $\lambda/4$ short-circuited lines embedded into U.S. UWB BPF," *IEEE MTT-S International Microwave Symposium Digest*, 225–228, 2010.
4. Wei, F., C. J. Gao, and B. Liu, "UWB bandpass filter with two notch-bands based on SCRLH resonator," *IET Electronics Letters*, Vol. 46, No. 16, 1134–1135, 2010.
5. Ghatak, R., P. Sarkar, and R. K. Mishra, "A compact UWB bandpass filter with embedded SIR as band notch structure," *IEEE Microwave Wireless Compon. Lett.*, Vol. 21, No. 5, 261–263, 2011.
6. Yang, X. D., Y. S. Li, and C. Y. Liu, "A toothbrush-shaped patch antenna for millimeter wave communication," *Journal of Electromagnetic Waves and Applications*, Vol. 23, No. 1, 31–37, 2009.
7. Li, Y. S., X. D. Yang, C. Y. Liu, and T. Jiang, "Compact CPW-fed ultra-wideband antenna with dual band-notched characteristics," *IET Electronics Letters*, Vol. 46, No. 14, 967–968, 2010.
8. Yang, X.-D., Y.-S. Li, Q.-T. Li, and C. Liu, "Analysis and experimental investigation on a novel wideband sleeve dipole array antenna," *AEUE — International Journal of Electronics and Communications*, Vol. 65, No. 4, 373–376, 2011.
9. Li, Y. S., X. D. Yang, C. Y. Liu, and T. Jiang, "Compact CPW-fed ultra-wide band antenna with dual band notched characteristics," *IEICE Electronics Express*, Vol. 20, No. 7, 1597–1601, 2010.
10. Li, Y. S., X. D. Yang, C. Y. Liu, and T. Jiang, "A sleeve monopole antenna with wide impedance bandwidth for indoor base station applications," *Progress In Electromagnetics Research C*, Vol. 16, 223–232, 2010.
11. Sahay, J., D. Goutham, and S. Kumar, "A novel compact ultrawide band filter for reconfigurable notches," *Microwave and Optical Technology Letters*, Vol. 57, No. 1, 88–91, 2015.
12. Mirzaee, M., S. Noghanian, and B S. Virdee, "High selectivity UWB bandpass filter with controllable bandwidth of dual notch bands," *Electronics Letters*, Vol. 50, No. 19, 1358–1359, 2014.
13. Wei, F., Q. Y. Wu, X. W. Shi, et al., "Compact UWB bandpass filter with dual notched bands based on SCRLH resonator," *IEEE Microwave Wireless Compon. Lett.*, Vol. 21, No. 1, 28–30, 2011.