Band-notched UWB Printed Log-Periodic Dipole Antenna Fed by Half Mode Substrate Integrated Waveguide

Chao Yu[1], #Wei Hong[2], Chen Yu, Zhen Qi Kuai, Wei Qin
State Key Laboratory of Millimeter Waves,
School of Information Science and Engineering,
Southeast University, Nanjing, China
[1] chaoyu@emfield.org
[2] weihong@seu.edu.cn

1. Introduction

Ultra-wideband (UWB) systems approved by U.S. Federal Communications Commission (FCC) [1] utilize spectrum resource ranging from 3.1 to 10.6 GHz, a valuable bandwidth for high-speed indoor data-communication application. As a key component of UWB systems, UWB antenna has drawn more and more attention worldwide to be designed for the purpose of transmitting very short and low power pulses. However, interferences from other narrowband communication systems will be inevitably introduced into UWB systems. For instance, Wireless Local Area Network (WLAN), operated at the bands of 2400-2484MHz, 5150-5350MHz, 5725-5825MHz, will cause interferences in UWB frequency band. Therefore, it is necessary to design antennas with band notched function in specified frequency bands. Recently, various band-notched antennas have been proposed for UWB communication systems [2]-[4].

Directional antenna can gain a great concentration of radiated power in a specified direction and is necessary for UWB application, but only a few researches have focused on such category of antennas. Printed log-periodic dipole antenna (PLPDA) [5][6] has sparked a great deal of research interest and is becoming an attractive candidate in this area, due to its elegant merits, such as low profile, light weight, low cost, and easy integration. However, the feeding system of PLPDA needs to be further developed. It is too complex and costly to use stripline as feeding system on the grounds that stripline is of a two layer structure [7], while using coaxial cable will result in strict requirements on structure in high frequency band [6].

In present study, a band-notched UWB printed log-periodic dipole antenna fed by half mode substrate integrated waveguide (HMSIW) is proposed. The natural balance structure of HMSIW [8]-[10] makes it suitable for the feeding system of PLPDA. Moreover, this property is independent of frequency in a wide bandwidth. HMSIW inherently cannot support the $TE_{(2m)n}$ modes and TM modes, and it will gain a broad dominant mode bandwidth. This antenna was fabricated with a standard printed circuit board (PCB) process. The measured results of the proposed antenna are consistent with simulated results, obtained by using Ansoft High Frequency Structure Simulator (HFSS) 11.0.

2. Antenna Configuration

The geometry of the proposed antenna is depicted in Fig. 1. The proposed antenna is fabricated on Rogers RT/Duroid 5880 substrate with dielectric constant ε_r=2.2, loss tangent tan δ=0.0009, and thickness h=1.5748mm. Log-periodic dipole antenna design can be found in [11] and it will not be discussed in detail here. The scale factor τ=0.61 and spacing factor σ=0.155 are chosen, which indicates that the number of dipole elements should be 10. Left rectangle metal sheet and HMSIW in Fig. 1 are designed as the reflector of log-periodic dipole antenna to enhance the directivity. The width of HMSIW Wsiw is determined by (1), if TE_{10} mode is considered.

Table 1: Optimal parameters of the proposed antenna

Parameter	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	Wce	Lsiw	Wsiw	Lt1	Wt1	Lt2	Wt2
Value(mm)	16	9.6	5.9	3.6	2.2	1.3	0.8	0.5	0.3	0.2	5.6	13.4	16.7	17	8.9	6	8.7
Parameter	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	Wn1	Ln1	Wn2	Ln2	Ws	D1	D2
Value(mm)	2.7	2.1	1.3	0.8	0.5	0.3	0.2	0.2	0.2	0.2	0.2	10.6	0.5	0.3	0.5	0.5	0.5
Parameter	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	W	L	W50	L50	Dv	D	D3
Value(mm)	5.35	9.7	6.3	3.85	2.35	1.5	0.85	0.6	0.4	0.3	57	88.7	4.4	7	1	0.5	8

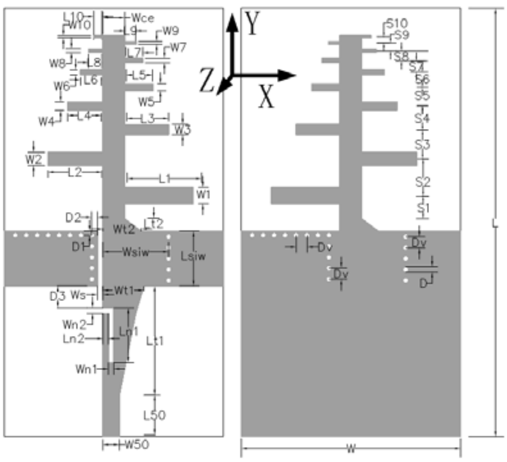

Fig.1 The configuration of the proposed antenna

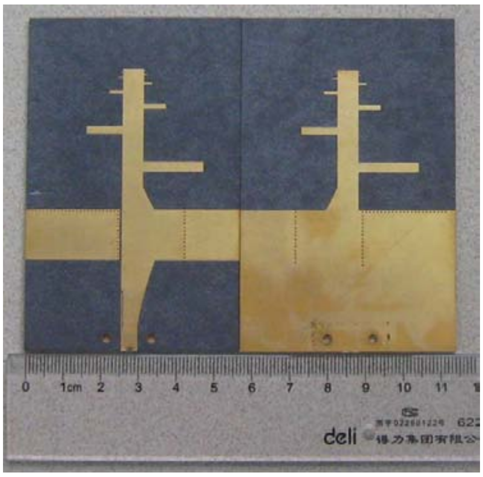

Fig.2 Photograph of fabricated antenna

$$Wsiw = \frac{1}{2}\frac{1}{2f_{min}\sqrt{\mu\varepsilon}} = \frac{c}{4f_{min}\sqrt{\varepsilon_r}} \quad (1)$$

where f_{min} is defined as the lowest operating frequency, c is defined as the velocity of light, ε_r is defined as the relative dielectric constant.

Concerning the L-shape slot in the band-notched design [3], [12], [13], the length calculated by (2) equals 10.8mm, which is about quarter wavelength of the center resonant frequency 5.5GHz.

$$L_{slot} = Ln_1 + Ln_2 = \frac{c}{4f_{notch}\sqrt{\varepsilon_{eff}}} \quad (2)$$

where f_{notch} is defined as the center frequency for the required notch band, ε_{eff} is defined as the effective dielectric constant of the narrow slot structure.

Two exponential tapered microsrip transitions are used to match the impedance. All optimal parameters of the proposed antenna are listed in Table 1. The photograph of fabricated antenna is shown in Fig. 2. The whole size of the proposed antenna is 57mm by 88.7mm.

3. Simulation and Experimental Result

In this section, experiments are carried out to verify the performance of the proposed antenna. Fig. 3 shows both simulated and measured results of VSWR. This antenna realizes the UWB band of 3.1~10.6 GHz (defined by VSWR< 2) with one narrow notched band of 5.25~ 6.2 GHz. Because of the fluctuation of the fabrication process, the slight shift of the center frequency for narrow notched band happens. Due to the influence of testing environment, the discrepancy between measured and simulated results is acceptable.

Fig. 4 shows the measured and simulated gain of the proposed antenna. Measured results correspond to simulated results except a minor shift of center frequency for notched band. The average measured gain of this antenna is about 7 dBi and drops sharply to about -4dBi at 5.55GHz, corresponding to the notch frequency. Fig 4 also gives an illustration on the band notched function of the proposed antenna.

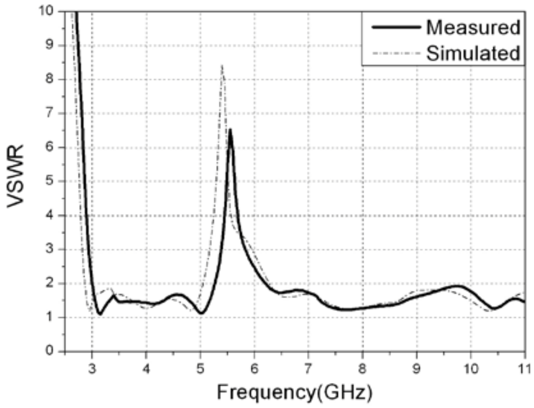

Fig.3 Measured (solid line) and simulated (dashed line) VSWR of the proposed antenna

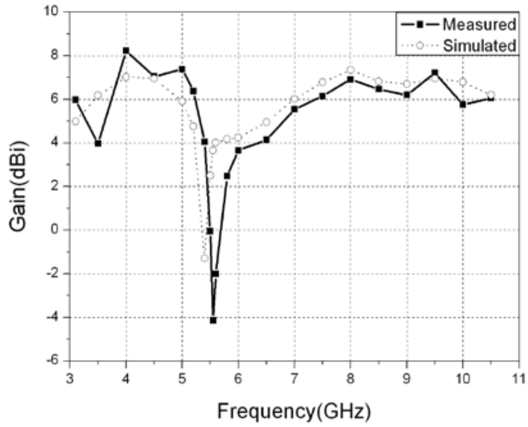

Fig.4 Measured(solid line)and simulated (dashed line) antenna gain

Fig. 5 shows the measured and simulated radiation patterns at xoy-plane (E-plane) and yoz-plane (H-plane) at different frequencies. These frequencies chosen are located at 3.5GHz, 4.5GHz, 6.5GHz, 7.5 GHz, 8.5GHz, 9.5 GHz, in the passband of this antenna. It can be seen that both in E-plane and H-plane, the radiation patterns keep good directivity with slightly changing through the whole frequency band and all the back lobes are suppressed below -15dB. However, the side lobes in yoz-plane (H plane) will deteriorate with the increase of the frequency, especially in the high frequency bands, such as 9.5 GHz. Overall, good agreements between measured and simulated radiation patterns are achieved.

4. Conclusion

In this paper, a new band-notched UWB antenna in the category of directional antenna has been successfully developed by introducing the HMSIW as the feeding system. With the advantages of HMSIW and PLPDA, the antenna can easily earn mass production with a low cost. By combining the L-shape slot with the proposed UWB antenna, the narrow notch band near 5.5GHz can be created to avoid interferences from other narrowband communication systems in this frequency band. The good performances presented in this paper indicate that antenna of this kind will be a promising candidate for UWB applications.

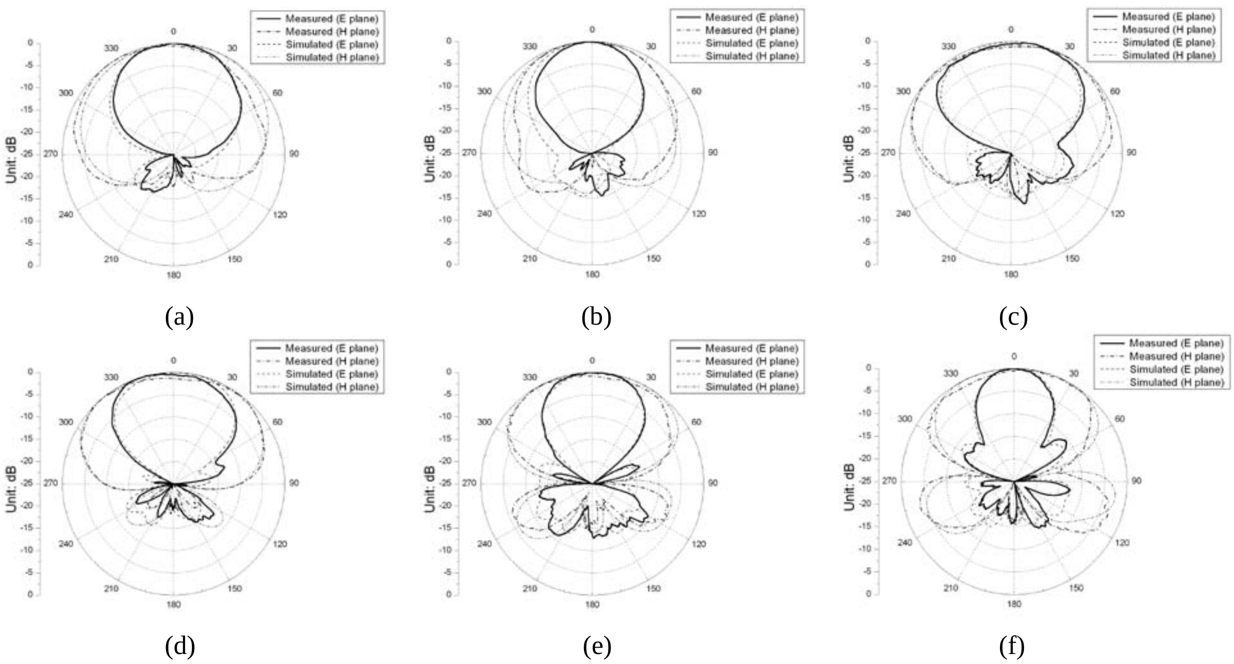

Fig.5 Measured and simulated radiation patterns at different passband frequencies
(a) 3.5GHz (b) 4.5GHz (c) 6.5GHz (d) 7.5GHz (e) 8.5GHz (f) 9.5GHz

Acknowledgments

This work is supported in part by the NSFC under grant 60621002, and in part by the National Hi-tech Research and Development Program of China (863 Program) (Grant No. 2007AA01Z2B4).

References

[1] First Report and Order, “Revision of Part 15 of the Commission’s Rule Regarding Ultra-Wideband Transmission System FCC 02–48,” Federal Communications Commission, 2002.
[2] C. Young Jun, K. Ki Hak, C. Dong Hyuk, L. Seung Sik, and P. Seong-Ook, "A miniature UWB planar monopole antenna with 5-GHz band-rejection filter and the time-domain characteristics," Antennas and Propagation, IEEE Transactions on, vol. 54, pp. 1453-1460, 2006.
[3] L. Wang-Sang, K. Dong-Zo, K. Ki-Jin, and Y. Jong-Won, "Wideband planar monopole antennas with dual band-notched characteristics," Microwave Theory and Techniques, IEEE Transactions on, vol. 54, pp. 2800-2806, 2006.
[4] N. H. M. Sobli and H. E. Abd-El-Raouf, "Design of a compact band-notched antenna for ultrawideband communication," in Antennas and Propagation Society International Symposium, San Diego, California, pp. 1-4, 2008.
[5] C. Shih-Yuan, W. Po-Hsiang, and P. Hsu, "Uniplanar Log-Periodic Slot Antenna Fed by a CPW for UWB Applications," Antennas and Wireless Propagation Letters, IEEE, vol. 5, pp. 256-259, 2006.
[6] M. M. Tajdini and M. Shahabadi, "Wideband planar log-periodic antenna," in Antenna Technology: Small and Smart Antennas Metamaterials and Applications, IWAT '07, Cambridge, UK, pp. 331-334, 2007.
[7] R. Pantoja, A. Sapienza, and F. M. Filho, "A microwave printed planar log-periodic dipole array antenna," Antennas and Propagation, IEEE Transactions on, vol. 35, pp. 1176-1178, 1987.
[8] H. Wei, L. Bing, W. Yuanqing, L. Qinghua, T. Hongjun, Y. Xiao Xin, D. Yuan Dan, Z. Yan, and W. Ke, "Half mode substrate integrated waveguide: a new guided wave structure for microwave and millimeter wave application," in Infrared Millimeter Waves and 14th International Conference on Teraherz Electronics, 2006. IRMMW-THz 2006. Joint 31st International Conference on, 2006, Shanghai, China, pp. 219-219, 2006.
[9] Z. Guohua, H. Wei, W. Ke, and K. Zhengqi, "Printed quasi-Yagi antenna fed by half mode substrate integrated waveguide," in Microwave Conference, 2008. APMC 2008. Hong Kong, China, pp. 1-4, 2008
[10] Z. Guo Hua, H. Wei, K. Zhen Qi, “Log-Periodic Dipole Antenna Fed by Half-Mode Substrate Integrated Waveguide,” Journal of Microwaves, vol. 25 no.1, pp. 1-4, 2009. (in Chinese)
[11] R. Carrel, "The design of log-periodic dipole antennas," in IRE International Convention Record, pp. 61-75, 1961.
[12] A. H. M. Zahirul Alam, M. R. Islam, and S. Khan, "Designing an UWB patch antenna with band notched by using L-shaped slot and unsymmetrical feedline," in Electrical and Computer Engineering, 2008. CCECE 2008. Canadian Conference on, 2008, Ontario, Canada, pp. 000101-000104, 2008.
[13] D. Yuan Dan, H. Wei, K. Zhen Qi, and Z. Jian Yi, "Band-notched ultra-wideband antenna designed and optimized by current distribution analysis," in Microwave and Millimeter Wave Technology, 2008. ICMMT 2008. International Conference on, 2008, Nanjing, P.R.China, pp. 1062-106, 2008.