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An Ultra-wideband Circular Microstrip Antenna with Tuning Stub Fed by Microstrip Line above Wide-Slot Ground Plane

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1. Introduction

The antenna design in ultra-wideband (UWB) radio system requires the minimum distortion of impulse signal because it transmits very short pulses on the order of a nanosecond in duration without any carrier and occupies very large bandwidth of 7.5 GHz [1]. Therefore, the antenna for impulse UWB communications is necessary to possess a clean impulse response (constant magnitude and phase linearity). The antenna that meets these requirements will radiate a signal which is only a time derivative of the input signal [2]. As a result, antenna plays an important role in the UWB system. Currently, most of works about UWB system concentrate on the impulse communication after FCC report and order for part 15 was issued. The primary application of UWB is Wireless Personal Area Network (WPAN) with a small coverage area of less than 10 m in radius. These coverage areas depend on the operational mode such as high data rate (HDR) and low data rate/location tracking (LDR/LT) [3]. The development of UWB technology has greatly accelerated. Most of researches about UWB antennas obtained omnidirectional pattern due to their applications in mobile device. There are many types of these antennas in literature such as various planar monopoles protruded from perpendicular ground plane [4]-[6]. These antennas are ease fabrication but their structures are not low profile. To obtain low-profile structure, the planar monopole fed by coplanar waveguide [7]-[9], microstrip line [10], and microstrip line feed [11] are extensively conducted. The advantage of these antennas is that they are flat and convenient to integrate with electronic circuits. For some specific applications with long path area, such as on corridors, railways and streets, a bidirectional antenna is preferable to employ than an omnidirectional one due to their capability of expanding the coverage area in azimuth direction. This paper proposes an ultra-wideband antenna using circular microstrip with tuning stub fed by microstrip line above wide-slot ground plane. The antenna structure is flat, and its design is simple and straightforward. The simulation is carried out by CST program. The antenna measurements were set up to measure the return loss, radiation pattern and gain along the bandwidth.

2. Antenna Description

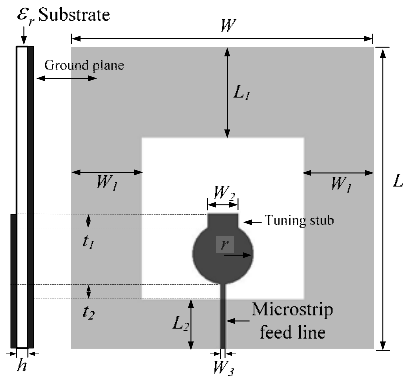

Figure 1: Geometry of the proposed antenna

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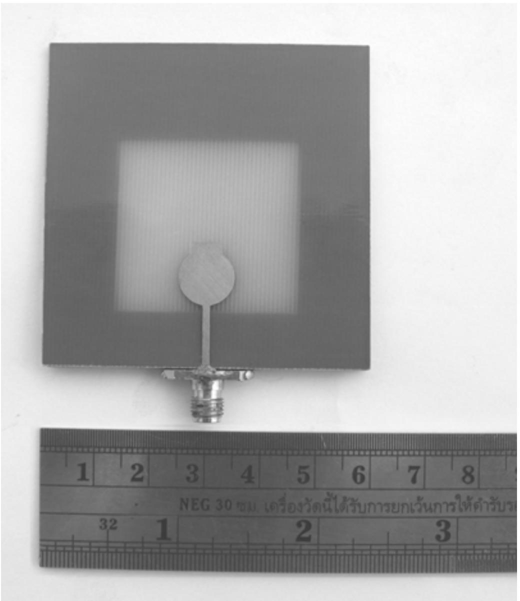
Let us consider Fig.1, the antenna structure consists of the circular patch of the radius a with the tuning stub of the width t_1 and the length W_2. This stub is used for adjusting the impedance matching. This patch is fed by the microstrip line of the width W_3 and length L_2+t_2.These structures mounted on the dielectric substrate with the dielectric constant of ε_r and the height h. The substrate is located on the ground plane of the width W and the length L. This ground plane is cut to form the wide-slot ground plane. The distances between the top and bottom sides of the ground to the slot are L_1 and L_2, respectively. The distance between the left and right sides of the ground to the slot is W_1.

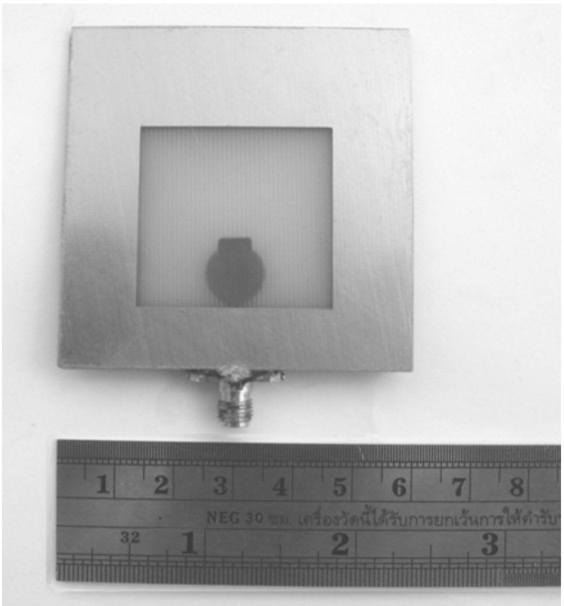
The antenna design is based on the conventional transmission line model. The desired bandwidth is 3.1-10.6 GHz. Therefore the radius of circular patch is designed to resonate at the middle band of 6.8 GHz. The tuning stub is used to improve the level of return loss. The microstrip line is designed to provide 50 Ohm at the operating frequency of 6.8 GHz. The dimension of the wide-slot ground plane is varied to enhance the bandwidth. The parametric study of the antenna is omitted for brevity the resultant of design parameters are tabulated in table1.

3. Results

The prototype antenna that the parameters are tabulated in Table 1 was fabricated as shown in Fig.2.



(a) Front view



(b) Rear view

Figure 2: Prototype antenna

The antenna measurement was set up to measure the return loss, radiation pattern and gain. Fig.3 shows the measured return loss compared with the simulation. It is found that the results are reasonable agreement. The discrepancy is expected from the fabrication error. The bandwidth of return loss better than 10 dB covers 2.8-15.3 GHz from the simulation and 2.8-14.1 GHz from the measurement. This frequency range is efficiently wide for FCC Report and Order for Part 15. The radiation patterns along the frequency range were measured. Fig.4(a)-(c) show the radiation pattern in E-plane of this antenna at 3.1, 6.8 and 10.6 GHz, respectively, whereas Fig.5(a)-(c) show the H-plane counterpart. The bidirectional patterns along these frequencies are obtained. The simulated and experimental results are in good agreements.

Table 1: Design parameters

Parameters	Size(mm)
L	60
W	60
t_1	2
t_2	1
r	5
W_2	6
L_1	18
L_2	10
ε_r	4.4
h	1

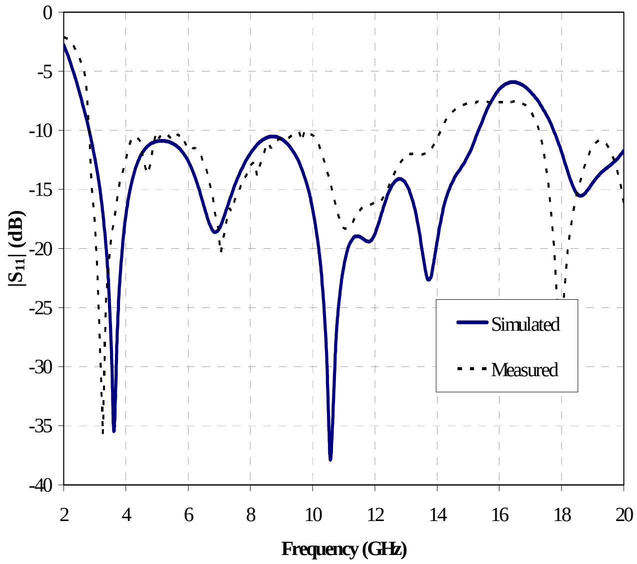
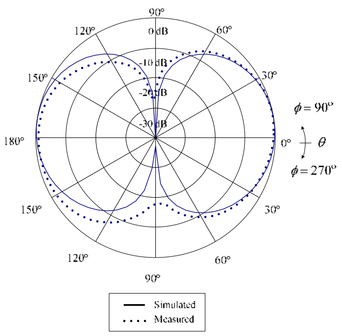
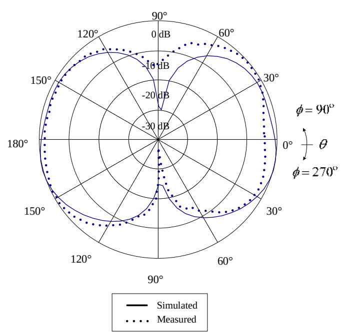


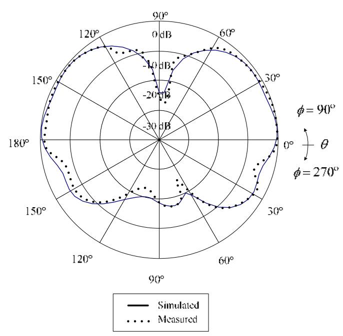
Figure 3: Simulated and Measured $|S_{11}|$



(a) 3.1 GHz

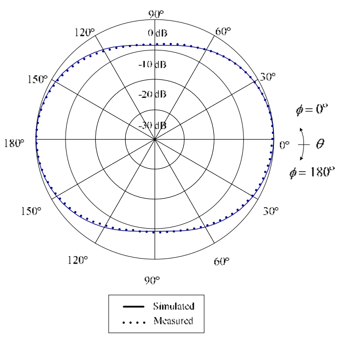


(b) 6.8 GHz

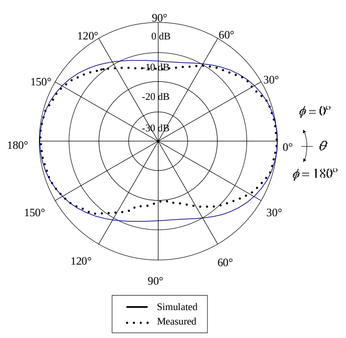


(c) 10.6 GHz

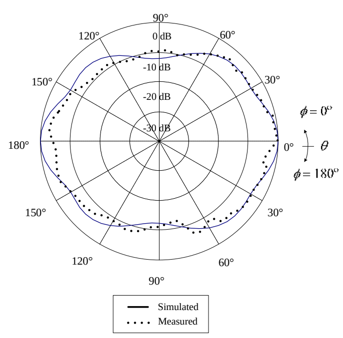
Figure 4: Simulated and Measured E-plane patterns



(a) 3.1 GHz



(b) 6.8 GHz



(c) 10.6 GHz

Figure 5: Simulated and Measured H-plane patterns

The antenna gain of boresight direction at the frequency of 3-11 GHz was measured as shown in Fig.6. It is found that the gain of 4.4 dBi is obtained at 3.1 GHz. The variation of gain along the frequency of 3-11 GHz is similar to minus sine curve. The minimum and maximum gains of 2.8 and 6.8 dBi at the frequency of 5.0 and 9.0 GHz are observed. The average gain is 5.0 dBi. It is found that the gain is lowest because the beam is shifted from boresight direction and the gain is highest due to the narrow beam at that frequency.

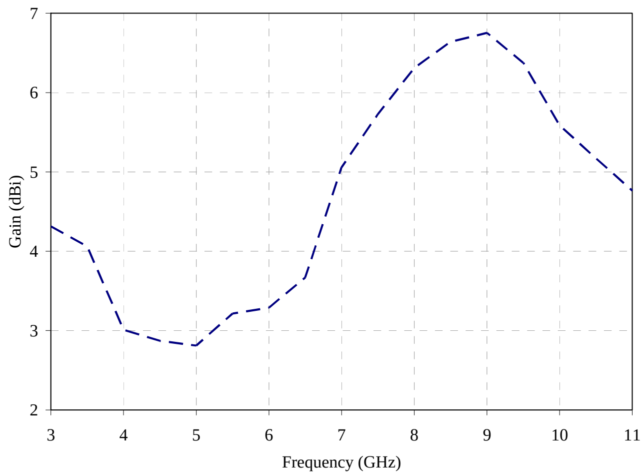


Figure 6: Measured antenna gain

4. Conclusions

This paper proposes an ultra-wideband antenna using circular microstrip with tuning stub fed by microstrip line above wide-slot ground plane. The antenna structure is flat, and its design is simple and straightforward. The simulation is carried out by CST program. The antenna measurements were set up to measure the return loss, radiation pattern and gain along the bandwidth. The bandwidth over 3.0-10.6 GHz is obtained. The bidirectional pattern without side lobe is achieved. The average gain is around 5 dBi.

References

[1] D. Porcino and W. Hirt, "Ultra-wideband radio technology: potential and challenges ahead," *IEEE Commun. Mag.*, vol. 4, pp. 66-74, July 2003.

[2] Federal Communications Commission, First order and report: revision of part 15 of the commission's rules regarding UWB transmission systems, Apr. 22, 2002.

[3] A. F. Molisch, J. R. Foerster, and M. Pendergrass, "The evolution of wireless LANs and PANs-channel models for ultrawideband personal area networks," *IEEE Trans. Wireless Commun*. vol. 10, no. 6, pp. 14-21, Dec. 2003.

[4] M. Hammoud, P. Poey, and F. Colombel, "Matching the input impedance of a broadband disc monopole," *Electron. Lett.,* vol. 29, pp. 406-407, Feb. 1993.

[5] N. P. Agrawall, G. Kumar, and K. P. Ray, "Wide-band planar monopole antennas," *IEEE Trans. Antennas Propagat.*, vol. 46, no. 2, pp. 294-295, Feb. 1998.

[6] S. Y. Suh, W. L. Stutzman, and W. A. Davis, "A new ultrawideband printed monopole antenna: the planar inverted cone antenna (PICA)," *IEEE Trans. Antennas Propagat*., vol. 52, no. 5, pp. 1361-1365, May 2004.

[7] Y. Kim and D. H. Kwon, "CPW-fed right-angled dual tapered notch antenna for ultra-wideband communication," *Electron. Lett.,* vol. 41, no. 12, pp. 674-675 , June 2005.

[8] J. Liang, L. Gua, C. C. Chiau, X. Chen, and C. G. Parini, "Study of CPW-fed circular disc monopole antenna for ultra wideband applications," *IEE Proc.-Microw. Antennas Propag.*, vol. 152, no. 6, pp. 520-526, Dec. 2005.

[9] T. G. Ma and C. H. Tseng, "An ultrawideband coplanar waveguide-fed tapered ring slot antenna," *IEEE Trans. Antennas Propagat*., vol. 54, no. 4, pp. 1105-1110, Apr. 2006.

[10] Y. J. Ren and K. Chang, "An annual ring antenna for UWB communications," *IEEE Antennas Wireless Propagat. Lett.*, vol. 5, pp. 274-276, 2006.

[11] C. C. Lin, Y. C. Kan, L. C. Kuo, and H. R. Chuang, "A planar triangular monopole antenna for UWB communication," *IEEE Microw. Wireless Components. Lett.*, vol. 15, no. 10. pp. 624-626, Oct. 2005.