DESIGN AND OPTIMIZATION OF INTEGRATED BLUETOOTH AND UWB ANTENNA WITH DUAL BAND-NOTCHED FUNCTIONS

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ABSTRACT

A compact microstrip-fed printed planar integrated Bluetooth and ultra wideband (UWB) monopole antenna with dual band-notched characteristics in the 3.5 GHz WiMAX and 5.2/5.8GHz WLAN band is presented. The proposed antenna design consists of the semicircular ring patch and partial ground plane. The extra band (2.33-2.5GHz)for Bluetooth is obtained by adding the T-shaped strip at the top of the patch. Additionally, two L-shaped arc slots in patch and two U-shaped circular slots in partial ground plane are etched to reject the WiMAX and WLAN bands. The numerical and experimental results show that the proposed antenna has an impedance bandwidth of VSWR ≤ 2 from 2.33 GHz to 2.5 GHz for Bluetooth band and 3.04 GHz to 10.8 GHz for UWB band except the notch band frequencies 3.3- 4.1 GHz for WiMAX and 5 – 5.9 GHz for WLAN band.

KEYWORDS

Bluetooth antenna, Dual band-notched characteristics, UWB antenna

1. INTRODUCTION

UWB communication systems have attracted great attention in the wireless world because of their advantages, including high speed data rate, extremely low spectral power density, high precision, low cost and low complexity. The Federal Communication Commission (FCC) allowed the 3.1-10.6 GHz unlicensed band for UWB communication in February 2002[1]. Since then, many researchers have focused on the UWB technology and UWB antenna designs. However, this frequency band will cause interference with IEEE 802.16 (3.3-3.8GHz) Worldwide Interoperability for Microwave access (WiMAX) and IEEE 802.11a(5.15-5.85GHz) Wireless Local Area Network(WLAN). Therefore, the UWB antenna with band rejection characteristics is required to avoid possible interference between UWB and narrow bands like WiMAX and WLAN. Several types of monopole antennas have been proposed for UWB and band-notched applications [2-8]. A recently reported antenna has been designed by etching a rectangle slot in the CPW ground [2], by embedding a parasitic strip inside the polygon slot and an isolated slit employed in the bevelled T-stub [3], and use the two L-shaped quarter-waveguide resonators coupled to the ground plane with two shorting tracks at the sides of the antenna [8] to get the single band-notched characteristic. In [4], the dual notched bands were formed by embedding a pair of r-shaped stubs in the radiation patch and a modified G-slot defected ground structure in the feeding line. Nowadays, the Bluetooth covering the 2.4-2.484 GHz band is widely used in portable devices and essential to integrate multiple bands for use in one device. The integrated Bluetooth and UWB antenna with band-notched characteristics are

DOI : 10.5121/ijcnc.2012.4416

proposed in [9-12]. In [9], the antenna structure consists of a microstrip-fed main patch and electromagnetically couple parasitic patch with arc-shaped strips for achieving Bluetooth and UWB performance and the split ring resonator (SRR) slot etched on the main patch and the square patch close to microstrip feed line are aimed to obtain dual notched bands.

This paper proposes a compact microstrip-fed printed planar monopole antenna that covers both the Bluetooth and UWB band with WiMAX and WLAB band-notched. T-shaped strip is added at the top of the semicircular ring patch for Bluetooth and UWB performances. The two L-shaped arc slots in main patch and two U-shaped circular slots in partial ground plane are etched to reject the WiMAX and WLAN bands. Details of the proposed antenna design, simulated and measured results are discussed below.

2. ANTENNA DESIGN

2.1 Geometry of the Antenna

The geometry of the proposed Bluetooth and UWB antenna with dual notched bands is illustrated in Figure 1, with its geometry parameters. The proposed antenna is fabricated on a FR4 substrate with relative permittivity of 4.4, thickness of 1.6mm and a loss tangent of 0.02. The dimension of this antenna is 30×41 mm^2. The antenna provides the extra Bluetooth band operation due to the T-shaped strip added on the radiation patch. The T-shaped strip creates a notched band to prevent interference between the Bluetooth and UWB band. Two symmetrical L-shaped slot is etched in the radiation patch and two symmetrical U-shaped circular slot is etched in the ground plane to prevent the interference of WiMAX and WLAN band.

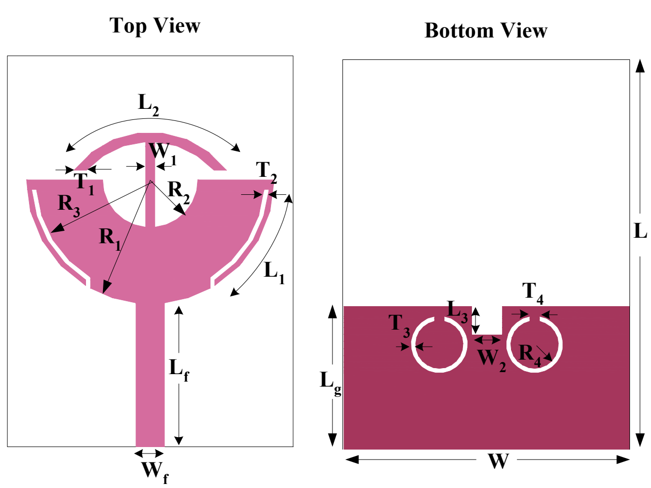


Figure 1: The geometry and parameters of proposed antenna

2.2 Parametric Study

The simulation tool Ansoft High Frequency Structure Simulator (HFSS) is used for performing the design and optimization process. In the optimization process, some parameters like T-strip, L-slot and U-slot are the main factors for extra resonant mode and notch bands. The lengths of T-strip (L_2), L-slot (L_1), the width of L-slot (T_2) and the gap of U-slot (T_4) are selected in the parametric study and study one parameter at a time and others are fixed to get better understanding for these parameters.

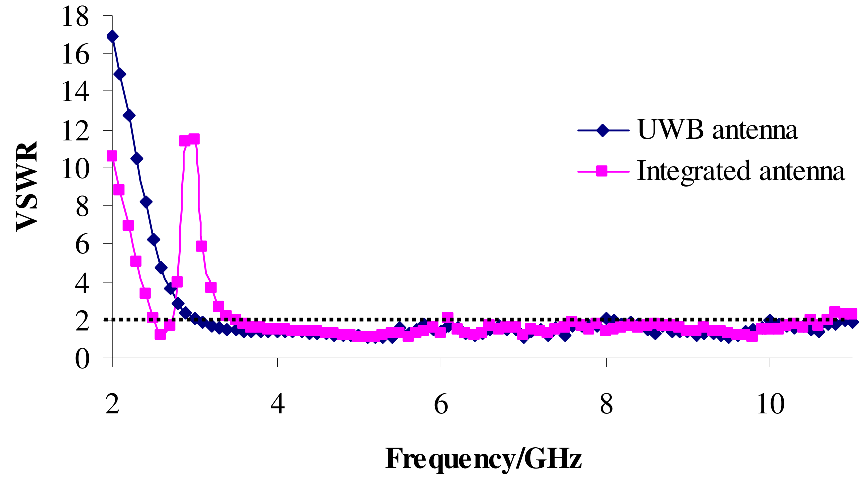


Figure 2: Simulated VSWR characteristics of the UWB antenna and Integrated Bluetooth/UWB antenna

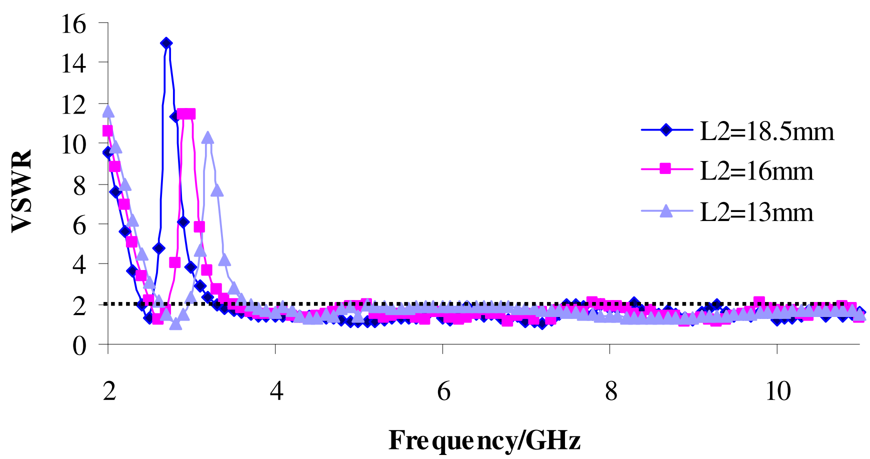


Figure 3: Simulated VSWR characteristics of the antenna with different value of L_2

First of all, the primitive antenna and 50Ω microstrip feed line are calculated according to the substrate's relative permittivity and thickness. The T-shaped strip is added on the radiation patch to get extra resonant frequency of 2.4 GHz Bluetooth. The length of the strip and slot can be approximated by

$$L_{notch} = \frac{c}{4f_{notch}\sqrt{\varepsilon_{eff}}} \tag{1}$$

$$\varepsilon_{eff} \approx \frac{(\varepsilon_r+1)}{2} \tag{2}$$

where ε_{eff} is the approximate effective dielectric constant and f_{notch} is the center frequency of notch band, c is the speed of light. The simulated VSWR characteristics of the primitive UWB antenna and integrated Bluetooth and UWB antenna are illustrated in Figure 2.

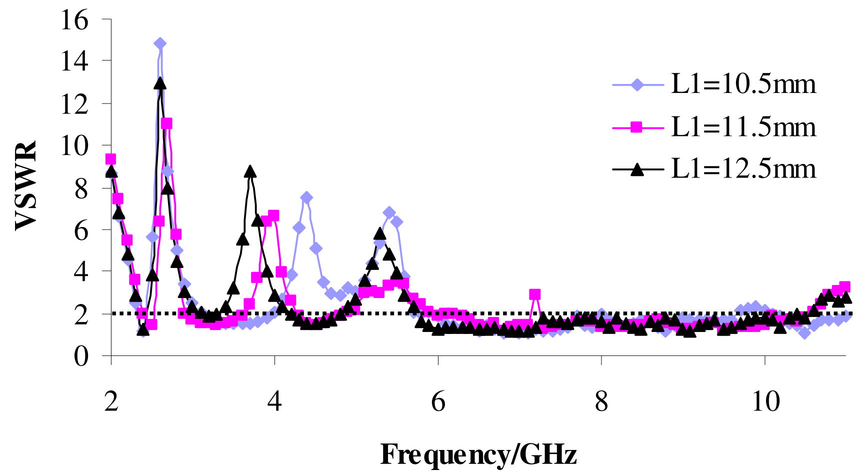


Figure 4: Simulated VSWR characteristics of the proposed antenna with different value of L_1

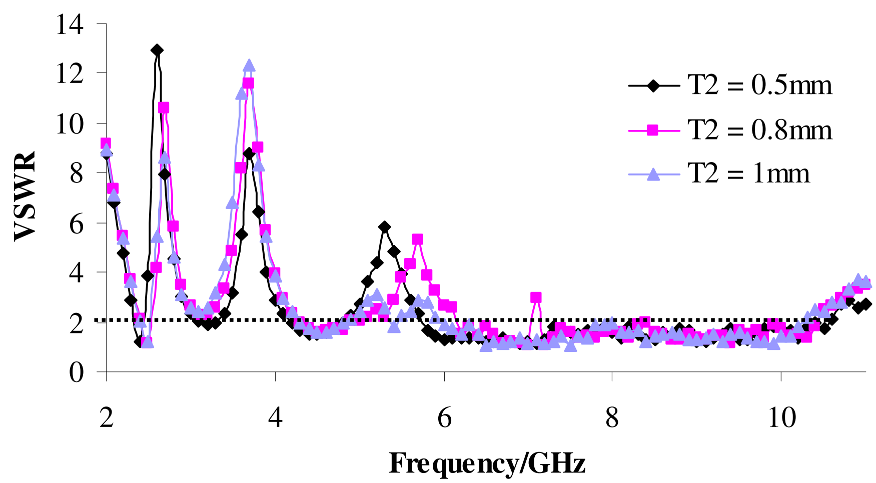


Figure 5: Simulated VSWR characteristics of the proposed antenna with different value of T_2

Figure 3 shows the simulated VSWR characteristics of the integrated Bluetooth and UWB antenna without band notches for the different values of L_2. The T-shaped strip creates a notched band and an extra Bluetooth pass band simultaneously. It can be seen that the value of L_2 effect obviously to the frequency of notch band and extra Bluetooth pass band. With the increasing of the L_2, the notch frequency is decreasing and the VSWR of the notch band increasing. At the same time, additional Bluetooth frequency is appeared.

Figure 4 shows the simulated VSWR characteristics of the antenna as the function of frequency for the different values of L_1 with other parameters are fixed. It can be seen that the value of L_1 is not affected to the first and third band notch frequencies. To get the desired 3.5GHz WiMAX notch band, the length of L-shaped slot is adjusted. The notch frequency is decreasing when the increasing of L_1. Similar for the 5.2/5.8GHz WLAN notch band, the length of the circular U-shaped slot (varying the values of T_4 with fixed R_4) is adjusted. The 5.2/5.8GHz WLAN notch band is decreasing when the increasing of circular slot length.

The width of L- shaped slot is also affected to the bandwidth of the second notch band. The simulated VSWR characteristics curves with various values of T_2 are illustrated in Figure 5. With the increasing of the width of the L-shaped slots, the bandwidth of the second notch band is getting wide and move to lower frequency edge.

3. Results And Discussions

After the parametric study of several adjustments on parameters, the final proposed antenna is achieved. The design parameters of the proposed antenna are given in Table 1.

Table 1: Parameters of the proposed antenna

Parameter	L	W	R_1	R_2	R_3	R_4	W_f	W_1	W_2
Value(mm)	41	30	13	5	12	2.5	3	1	3.2
Parameter	L_f	L_g	L_1	L_2	T_1	T_2	T_3	T_4	
Value(mm)	15.5	15	12.5	18.5	1	0.5	0.5	1	

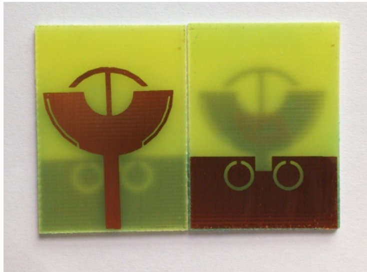


Figure 6: Photograph of the proposed antenna

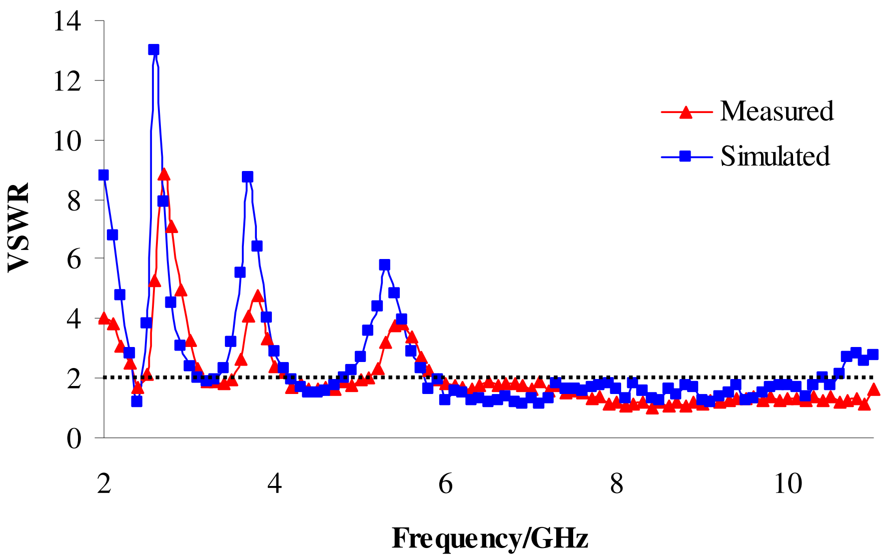
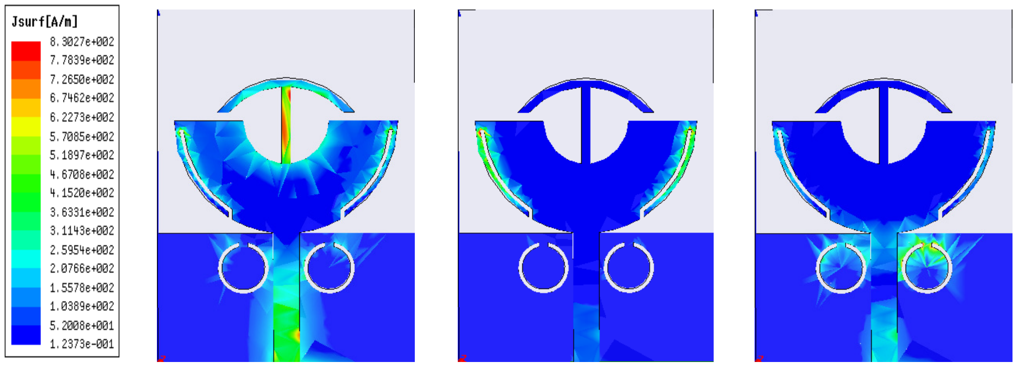


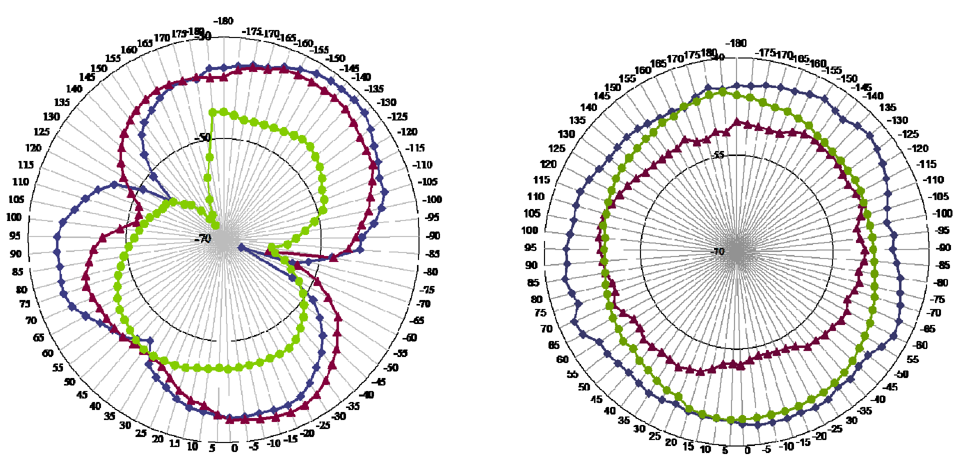
Figure 7: Measured and simulated VSWR characteristics of the proposed antenna



(a) (b) (c)

Figure 8: Surface current distributions of the proposed antenna at different frequencies.
(a) 2.8 GHz; (b) 3.5 GHz; (c) 5.5 GHz

In order to evaluate the performance of the optimized proposed antenna, a prototype of the proposed antenna was implemented and fabricated. The photograph of the fabricated antenna is shown in Figure 6. The VSWR was measured by Agilent 8722ES Vector Network Analyzer. Figure 7 shows the measured and simulated VSWR characteristics of the proposed antenna. The simulated bandwidth is 2.33-2.48GHz and 3.04-10.8 GHz except 3.3-4.1GHz and 5-5.8GHz notched bands and the measured bandwidth is 2.33-2.5 GHz and 3.15-11GHz except for 3.5-4.1GHz and 5.1-5.9GHz notched bands. The simulated notched band's centre frequency between the Bluetooth and UWB is 2.6 GHz and maximum VSWR value is 12.96. The measured notched band's centre frequency between the Bluetooth and UWB is 2.7 GHz and maximum VSWR value is 7.93. The simulated VSWR values of WiMAX and WLAN bands are 8.75 at 3.7 GHz and 5.79 at 5.3GHz and the measured VSWR values are 4.79 at 3.8GHz and 3.96 at 5.5GHz. The WLAN band notch is shifted a little due to the fabrication accuracy and SMA connector to transmission line, which is not taken into account in the simulation results.



(a)E-plane (b) H-plane

[2.4 GHz ; 3.3GHz ; 6.5 GHz]

Figure 9: Measured radiation patterns of the proposed antenna

Surface current distributions of the proposed antenna at 2.8, 3.5 and 5.5GHz are studied for better understanding of the proposed antenna and are illustrated in Figure 8. The current distribution is highest along the T-shaped strip at 2.8GHz. Similarly, the drastically increased current distributions around L-shaped slot and U-shaped slot at 3.5 GHz and 5.5GHz which indicate that the slots and slits introduce the band notched functions at the respective frequencies.

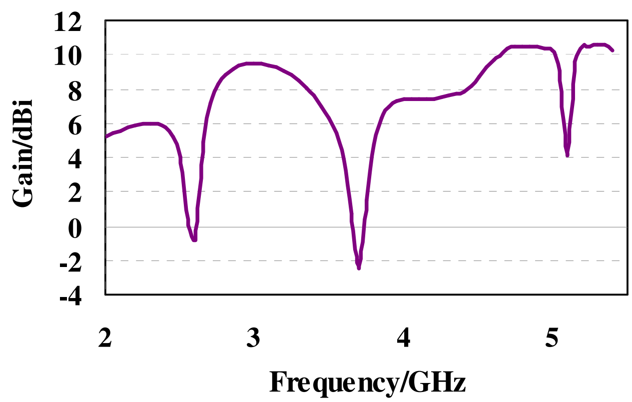


Figure 10: The peak gain of the proposed antenna

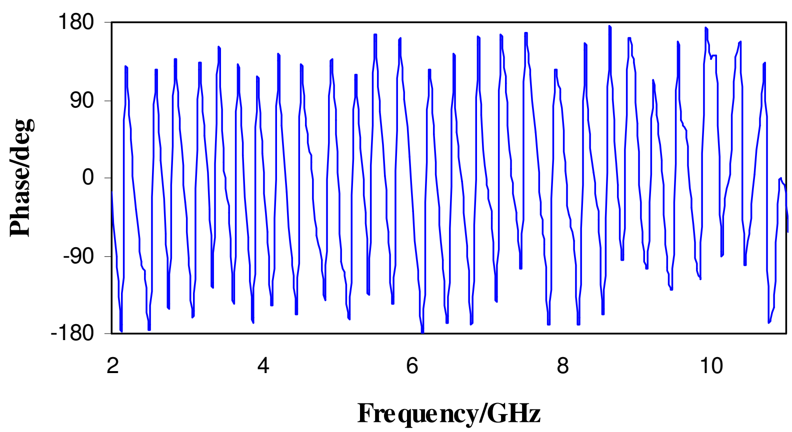


Figure 11: Phase response of the proposed antenna

The measured radiation patterns at 2.4GHz, 3.3GHz and 6.5GHz are shown in Figure 9. It can be seen that measured E-plane radiation pattern is a bidirectional as a traditional monopole antenna and H-plane radiation pattern is nearly omnidirectional. The peak gain of the antenna from 2- 5.5GHz is shown in Figure 10. The gain of the proposed antenna decrease sharply at the notched bands of 2.6, 3.7 and 5.1GHz. The phase of the radiated field is illustrated in Figure 11, measured by an Agilent 8722ES vector network analyzer. The group delay is measured by placing the two identical antennas in face to face with a distance of 30cm to evaluate the dispersion performance of the proposed antenna. The measured group delay is illustrated in Figure 12. The variation of group delay is within 2ns apart from the notched bands.

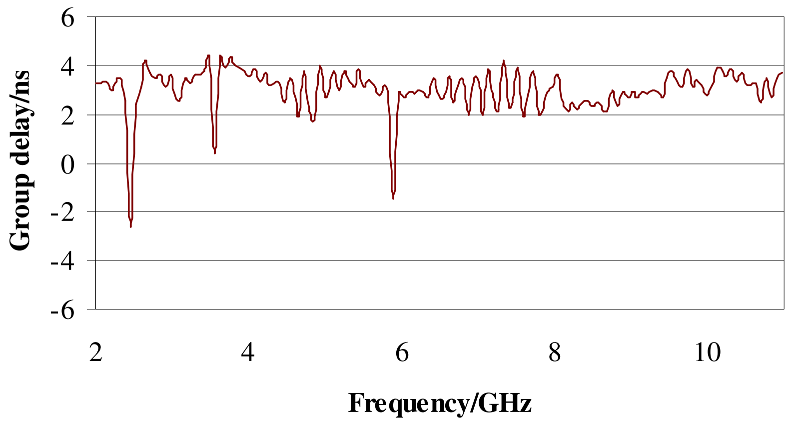


Figure 12: Group delay of the proposed antenna

4. CONCLUSIONS

A compact printed planar integrated Bluetooth and ultra-wideband antenna with dual band notched characteristics is presented. The proposed antenna has been simulated, fabricated and tested. To mitigate the potential interference between UWB system and narrowband systems such as WiMAX and WLAN, the L-shaped arc slot and U-shaped circular slot are etched on the current routes of patch and ground plane. The T-shaped slit not only produces the Bluetooth band but also notches the unnecessary band between the Bluetooth and UWB bands. It is observed that the radiation patterns are nearly omni-directional across the Bluetooth and UWB band. The group delay is within 2ns in the working band, which shows that the proposed antenna is suitable for Bluetooth and UWB applications.

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