# Integrated Bluetooth and UWB Antenna with Single Band-Notched

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***Abstract*** — A novel integrated Bluetooth and ultra-wideband (UWB) antenna with single band-notched is proposed in this paper. The operating frequency ranges of the proposed antenna is 2.3 GHz - 2.56 GHz, 2.96 GHz - 5.11 GHz and 5.95 GHz - 11.44 GHz, which covers Bluetooth (2.4 GHz - 2.484 GHz) and UWB (3.1 GHz - 10.6 GHz) band, besides the range of IEEE 802.11a WLAN (5.15 GHz - 5.825 GHz) with VSWR less than 2. Its main part consists of a hexagonal geometry, an L-shaped strip and two mushroom-like electromagnetic band gap (EBG) cells. The performance of the antenna is simulated and optimized by CST Microwave Studio and the simulated results meet the design requirements well.

***Index Terms*** — Antenna, band-notched antenna, Bluetooth, electromagnetic band gap (EBG), ultra-wideband (UWB).

## I. INTRODUCTION

In recent years, UWB systems have attracted a lot of attentions since the Federal Communications Commission (FCC) released the frequency band from 3.1 GHz to 10.6 GHz for communication applications [1]. Meanwhile, Bluetooth is a short-range wireless technology that has been widely used in wireless portable devices, cell phones, and other mobile devices. Many papers focusing on ultra-wideband and Bluetooth integrated antenna have been reported [2-6]. However, over the frequency range of UWB, there are other narrowband wireless communication systems, such as IEEE 802.11a wireless local area network (WLAN), operating in the range 5.15 GHz - 5.825 GHz. Therefore, in order to avoid mutual interference, a stop band should be designed to reject such used band. To solve the problems, people have made lots of attempts. One method is etching slots in the patch of the antenna or ground [7-12]. The other method is adding parasitic structures in antenna [13-15]. In recent years, the EBG structure is another choice to serve in the band-notched antennas, which has the advantage of compact size and good band-notched property [16-19].

Based on aforesaid studies, a novel integrated Bluetooth and UWB antenna with single band-notched is presented. It can cover the frequency bands of Bluetooth and UWB antenna. In order to avoid interference from IEEE 802.11a WLAN systems, two mushroom-like EBG cells are loaded on both sides of the feeding line to generate notch band. The notch band can be tuned by changing the size of EBG cell. All the simulations are carried out by CST Microwave Studio. The simulation results reveal that the Bluetooth function can be easily realized by adding an additional L-shaped strip and the band-notched function can be realized by adding a pair of EBG cells. At last, voltage standing wave ratio (VSWR), radiation pattern characteristics, gain, efficiency, and group delay of the proposed antenna are presented and discussed.

## II. ANTENNA DESIGN

The details of the proposed monopole antenna are illustrated in Fig. 1. A patch is etched on an FR-4 substrate with a relative dielectric constant of $\varepsilon_r = 4.4$. The dimension of the substrate is $36 \times 42 \times 1$ mm$^3$. The antenna constants a hexagonal pattern, an L-shaped strip, two mushroom-like EBG cells, a rectangular ground plane on the back side of the substrate and a 50 Ω microstrip line as feeding structure. The hexagonal structure serves as an UWB antenna. The L-shaped strip serves as Bluetooth antenna, which is integrated with the UWB antenna. The two mushroom-like EBG cells are used to achieve single band-notched characteristic, loaded on the both sides of transmission line. *L* is the length of EBG cell, and *D* is the distance from EBG cell to transmission line.

The mushroom-like EBG cell we adopted has the advantages in terms of simple structure and easy to fabricate. In order to study the impact of the EBG cells

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on the UWB element, we analyze the performance of them by tuning the parameters $L$ and $D$ using CST Microwave Studio. Figure 2 shows the simulation results of VSWR with different values of $L$ and $D$. Figure 2 (a) indicates that center frequency becomes smaller with the increasing of $L$ when the value of $D$ remains (0.3 mm). And Fig. 2 (b) shows that the decreasing of $D$ will lead to wide and sharp band-notch when the value of $D$ remains (6.2 mm). In summary, band-notched characteristic mainly depends on the size of the metal patch and the distance between the metal patch and the microstrip. The frequency center can be adjusted by changing the length of patch, while the bandwidth can be adjusted by changing distance from metal patch to microstrip. Finally, the optimal parameters of $L$ and $D$ are chosen to be 6.2 mm and 0.3 mm, respectively.

The design of the proposed antenna includes three steps. First, a UWB antenna (without added L-shaped and EBG cells) is designed, which operates from 3.3 GHz to 12 GHz (VSWR≤2) in Fig. 3. Second, an L-shaped strip is attached to one side of the UWB antenna which serves as a resonance occurred at 2.4 GHz. At last, the proposed single band-notched integrated antenna (with added L-shaped strip and EBG cells) is achieved by adding two EBG cells. It has a usable Bluetooth passband about 260 MHz (2.3 GHz - 2.56 GHz) and a notch band about 840 MHz (5.11 GHz - 5.95 GHz) with the center frequency of 5.6 GHz. It is clearly observed that the proposed antenna with added L-shaped strip and EBG cells cannot change the property of ultra-wideband, and we can add notch band by this approach easily.

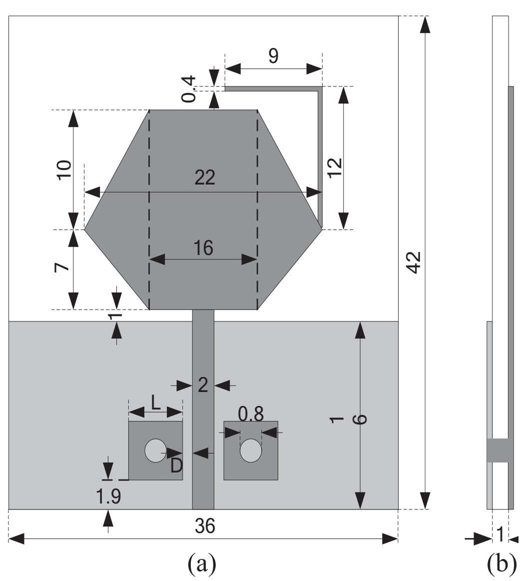


Fig. 1. Structure of the proposed antenna: (a) top view, and (b) side view (Units in mm).

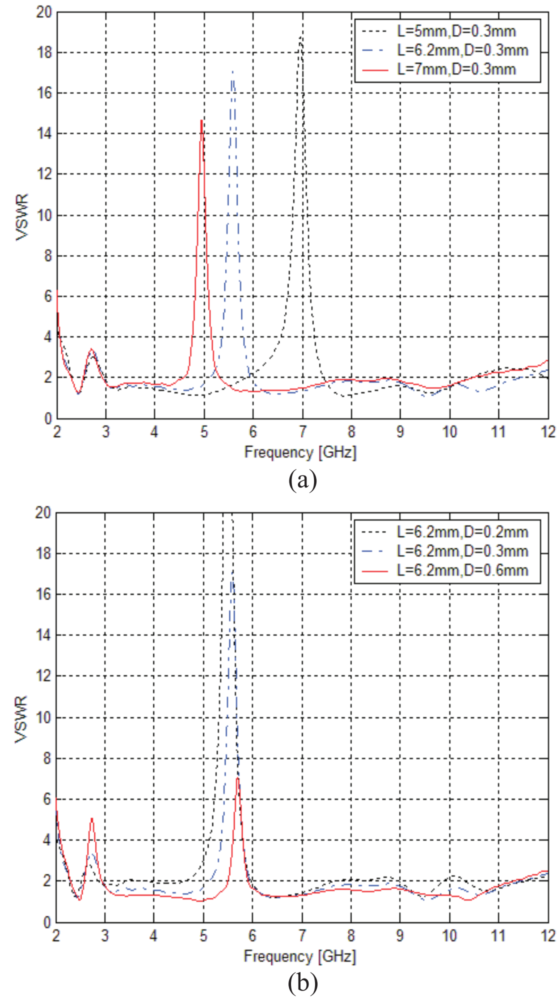


Fig. 2. Simulated VSWR with different: (a) $L$, and (b) $D$.

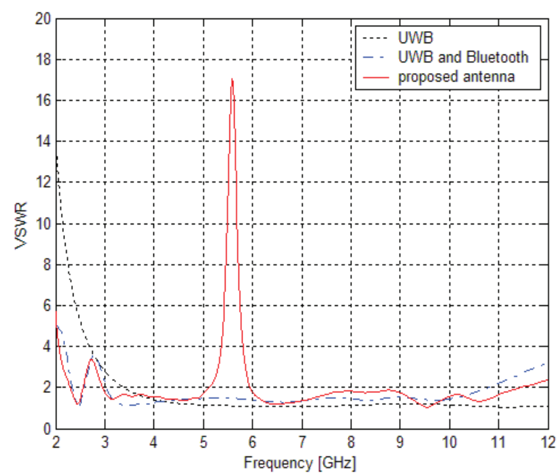


Fig. 3. Simulated VSWR of UWB, UWB and Bluetooth, and proposed single band-notched integrated antenna.

## III. RESULTS AND ANALYSIS

For better understanding of the proposed antenna behavior, the current distributions on the integrated antenna at 2.4 GHz, 5.6 GHz, and 8.5 GHz are presented in Fig. 4. The current density is significantly high in L-shaped strip as shown in Fig. 4 (a), which denotes that the L-shaped strip resonates at 2.4 GHz. As shown in Fig. 4 (a) and (c), the current density is very low in EBG cells at 2.4 GHz and 8.5GHz, while relatively high at resonant frequency 5.6 GHz in Fig. 4 (b). At 5.6 GHz, the currents mainly distribute in metal patches and few are coupled to radiation patch. Therefore, the input power will be prevented within the notch band. The current distribution results confirm that the L-shaped and EBG cells are relatively independent, and they have significant effect on Bluetooth and band-notch performance separately.

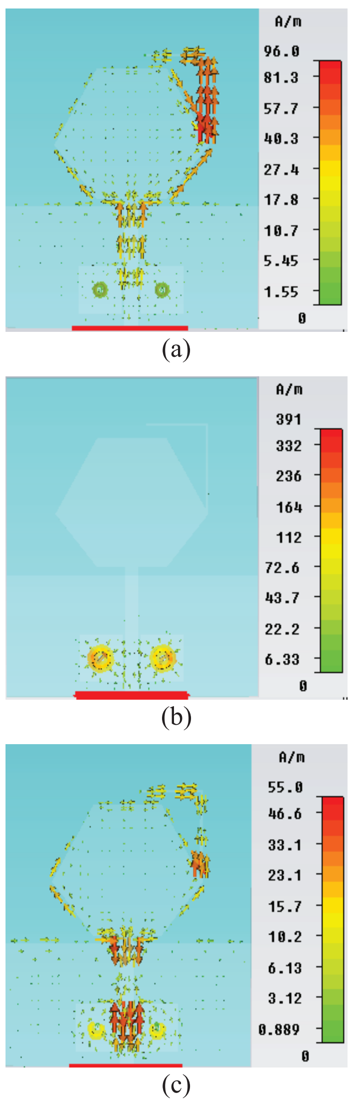


Fig. 4. Simulated current distribution at frequencies of: (a) 2.4 GHz, (b) 5.6 GHz, and (c) 8.5 GHz.

The co-polarization and cross-polarization radiation patterns of the proposed antenna in both E- and H-planes at three frequency points of 2.4 GHz, 6 GHz, and 10 GHz are shown in Fig. 5. The antenna is design in *x*-*y* plane, and the maximum radiation direction is along the *y*-axis. As shown in Fig. 5, the values of co-polarization is bigger than the values of cross-polarization in E-plane, and the values of cross-polarization are all less than -10 dB. In H-plane, the values of co-polarization are also bigger than the values of cross-polarization except the point of 10 GHz. The radiation patterns of E-plane are nearly figure-eight and H-plane are stable omni-directional.

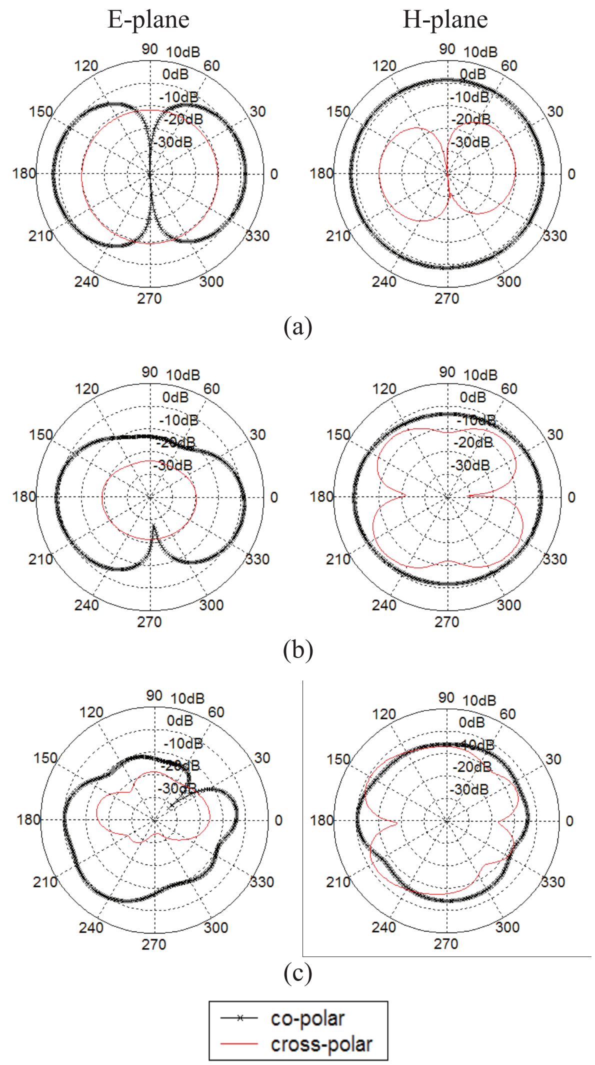


Fig. 5. Simulated radiation patterns of the proposed antenna at: (a) 2.4 GHz, (b) 6 GHz, and (c) 10 GHz.

The simulated antenna gain is shown in Fig. 6. It varies approximately from 2.1 dB to 5.5 dB over the operating frequency range, and decreases to -0.18 dB at

5.6 GHz. It also can be seen from the figure, the gain below 7 GHz is less than the value of above, which is because the wavelength gets longer below 7 GHz. By comparison, the size of the UWB element is small relative to the wavelength. The simulated radiation efficiency varies from 55% to 97% over the operating frequency range of the proposed antenna, and drops to 11% at center frequency of WLAN band, as shown in Fig. 7. The trend is consistent with the gain. The value of the group delay simulated by CST is mainly between 0 ns and 1 ns, which is nearly constant besides 2.4 GHz and 9.5 GHz in Fig. 8.

At last, the proposed antenna and the other antennas cited in this paper are compared in Table 1. From the table, the antenna proposed in this paper not only can work in the UWB and Bluetooth bands, but also has the advantages of good WLAN band ranges and gain.

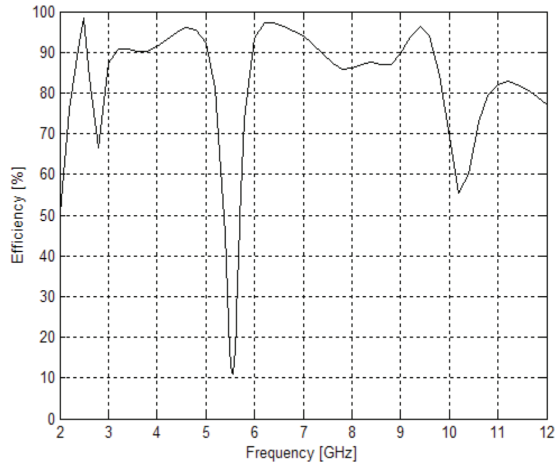


Fig. 7. Simulated efficiency of the proposed antenna.

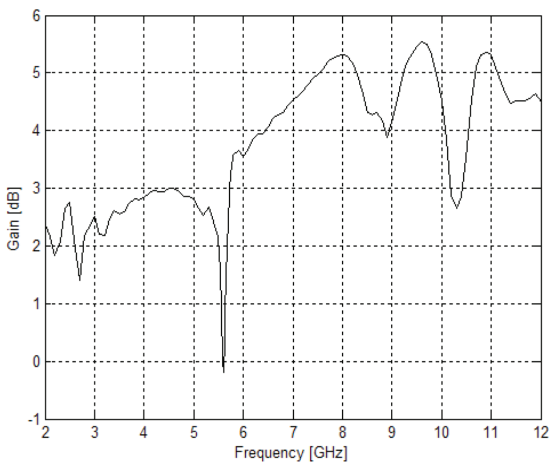


Fig. 6. Simulated gain of the proposed antenna.

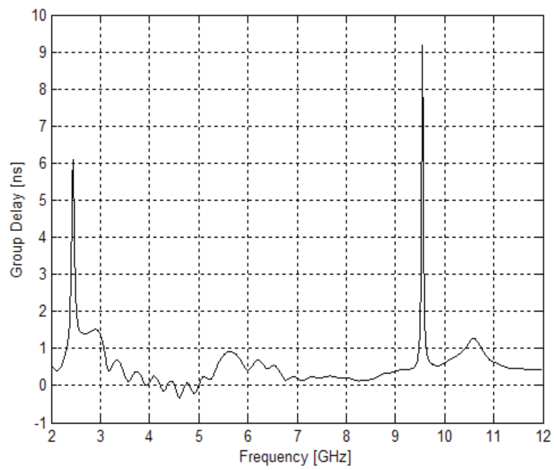


Fig. 8. Simulated group delay of the proposed antenna.

Table 1: Performance comparison

| Antennas | Dimensions ($mm^3$) | $\varepsilon_r$ of Substrate | Operating Bands | WLAN Band Ranges (GHz) | Gain Except WLAN Band (dB) |
|---|---|---|---|---|---|
| This paper | 36×42×1 | 4.4 | Bluetooth and UWB | 5.11-5.95 | 2.1-5.5 |
| A in Ref. [6] | 42×46×1 | 4.4 | Bluetooth and UWB | 5.2-5.8 | 2.8-7.2 |
| B in Ref. [6] | 42×46×1 | 4.4 | Bluetooth and UWB | 5.2-5.8 | 2.8-6.6 |
| Ref. [10] | 24×28×1 | 2.65 | UWB | 4.65-6.4 | 3-6 |
| Ref. [11] | 25×30×0.8 | 4.4 | UWB | 5.17-6.14 | 2.7-6 |
| Ref. [16] | 38×40×1 | 4.4 | UWB | 5.2-5.9 | 1.5-4.5 |
| Ref. [17] | 30×32×1.6 | 4.4 | UWB | 5-5.9 | 2-6.9 |

## IV. CONCLUSION

A compact and planar Bluetooth and UWB antenna with single band-notched is presented. On the basis of ultra-wideband, we add Bluetooth function by embedding an L-shaped parasitic strip. Hence, the antenna can operate on both Bluetooth and UWB frequency range for VSWR≤2. Through adding two simple mushroom-like EBG cells on both sides of the microstrip line, a notch band from 5.11 GHz to 5.95 GHz is generated to suppress the interference of IEEE 802.11a WLAN. The simulation results show that the proposed antenna with a compact size, simple structure, good WLAN band-notched characteristics, and wide bandwidth can be a good candidate for UWB application. Therefore, the results of the work are useful for short-range wireless communication systems.

## ACKNOWLEDGMENT

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