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DESIGN OF A COMPACT DUAL BAND ANTENNA FOR WIRELESS COMMUNICATIONS

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Abstract—A compact and planar dual band antenna for wireless communication is presented. The impedance bandwidth of the proposed antenna can cover Bluetooth (2.4–2.484 GHz) and ultrawideband (UWB: 3.1–10.6 GHz) bands. It is composed of a semi-bevelled-rectangle patch and a bended L-shaped strip and fed by a microstrip line. The antenna is built on a FR4 substrate with only 21 mm × 35 mm surface area included the ground plane. Details of the antenna design and the measured results included voltage standing wave ratio, radiation patters, peak gain, etc., are presented and discussed.

1. INTRODUCTION

Since the approval of ultra-wideband (UWB) by the Federal Communications Commission (FCC) in 2002 [1], ultra-wideband (UWB: 3.1–10.6 GHz) antenna design and application have become the focus of wireless communications [2–7]. Due to the current trend for the next-generation wireless communication systems, the combination of UWB signals with a second service, such as Bluetooth (2.4–2.484 GHz), operating at a different frequency band is desirable. However, the antenna in [2–7] can only cover the UWB band and not be suitable for some UWB and Bluetooth application. There have been relatively few reports in the literature of UWB and Bluetooth antennas [8–12]. In [8], a Bluetooth antenna with UWB functionality and a compact size of 16 mm × 26 mm is reported. However, the operating frequency at high band of the antenna is only from 4.5 to 11 GHz and cannot cover the

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whole band of UWB. In [9], an integrated Bluetooth and UWB antenna with a size of $42\,\text{mm} \times 46\,\text{mm}$ is reported, the operating frequency at high band of the antenna can cover the whole UWB band but the overall size of the antenna is somewhat large. Recently, some internal Bluetooth/UWB antennas have been reported in [10] and [11], these antennas have very compact sizes and can cover the whole UWB band, however, they can only be used for some special application owing to their non-planar configuration. A planar Bluetooth/UWB slot antenna with dual notched bands and a compact size of $23\,\text{mm} \times 28\,\text{mm}$ has been reported in [12], however, the configuration of the antenna complicates the design of such antennas.

In this letter, we propose a simple planar Bluetooth/UWB antenna with a compact size of $21\,\text{mm} \times 35\,\text{mm}$. The original antenna is an UWB antenna that composed of a semi-bevelled-rectangle patch and fed by a microstrip line. By adding a bended L-shaped strip to the semi-bevelled-rectangle patch, an extra Bluetooth band can be achieved. The design procedure of the antenna and parameters of the L-shaped strip are analysed in detail and the experimental results of the proposed antenna are presented and discussed.

2. ANTENNA CONFIGURATION

The specific geometry with detailed dimensions of the proposed antenna is illustrated in Fig. 1. The antenna is printed on a FR4 substrate with thickness of 1.6 mm and relative permittivity ε_r of 4.6, and has compact dimensions of 21 mm by 35 mm included the ground plane. It is composed of a semi-bevelled-rectangle patch and a bended T-shaped strip of width 1 mm, and fed by a $50\,\Omega$ microstrip line of width 1.5 mm. A trapezia notch in the ground plane is used to adjust the gap between the radiating element and ground plane in order to obtain a wide bandwidth of the UWB band.

3. ANTENNA DESIGN

The design procedure of the proposed antenna is shown in Fig. 2. First, design an UWB antenna by using semi-bevelled-rectangle patch as shown in Fig. 2(a). Second, introduce an L-shaped strip to the patch and optimize the dimensions of the L-shaped strip as shown in Fig. 2(b). Finally, bend the L-shaped strip to the patch to miniaturize the antenna furthermore as shown in Fig. 2(c). Note that the antennas in the design procedure are denoted as antenna 1, antenna 2, and proposed antenna. Fig. 3 shows the simulation results of the antennas in the design procedure. It can be observed that the impedance

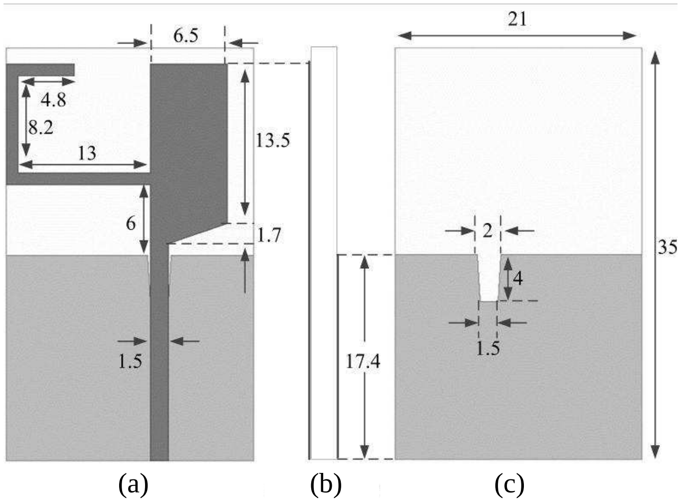

Figure 1. Geometry of the proposed antenna. (a) Top view. (b) Side view. (c) Bottom view.

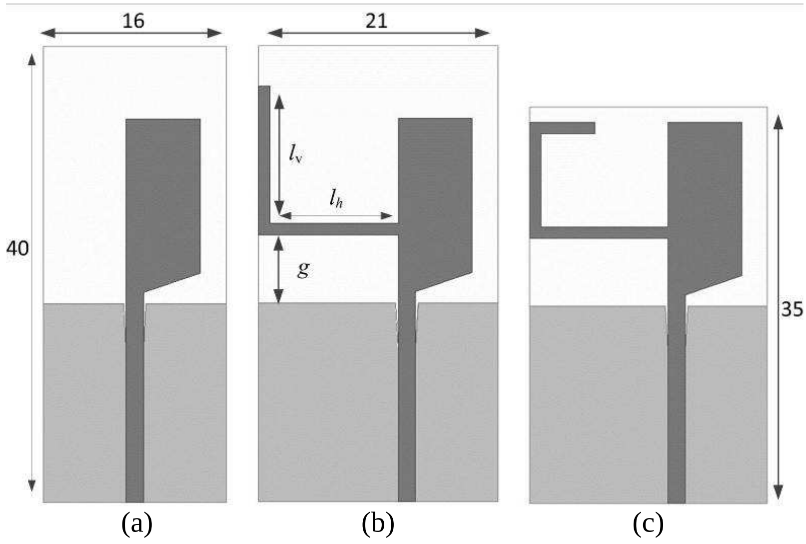

Figure 2. Design procedure of the proposed antenna. (a) Antenna 1. (b) Antenna 2. (c) Proposed antenna.

bandwidth of antenna 1 can cover the UWB band, the impedance bandwidth of antenna 2 and the proposed antenna can both cover the Bluetooth and UWB band.

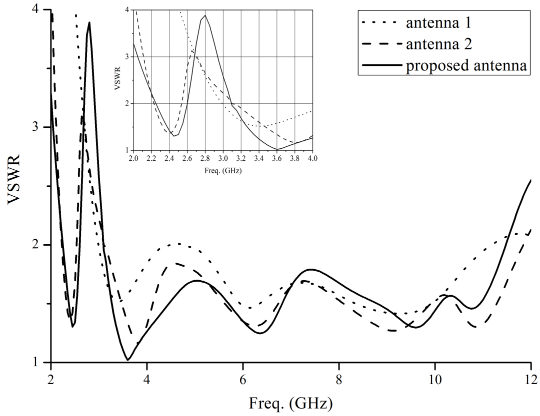

Figure 3. Simulated VSWR against frequency of the antenna in the design procedure.

4. PARAMETER STUDY

In order to get the influence of the L-shaped strip or the bended L-shaped strip to the UWB antenna, the parameters of the strip should be analysed. Due to the simple structure and for a better understanding the influence of the strip on the antenna performance, the parameters of the L-shaped strip, i.e., g, l_h and l_v as shown in Fig. 2(b), are simulated by using High-Frequency Structure Simulation (HFSS), Version-12, software. The simulated results are shown in Fig. 4–Fig. 6. As shown in Fig. 4, by increasing the length of g, the resonant frequency of UWB band in the low band will be increased also, and thus the low band of UWB will not be covered, while by decreasing the length of g the resonant frequency of Bluetooth band will be increased and the Bluetooth band will not be covered. By increasing the length of l_h, the resonant frequency of UWB band and Bluetooth band will be influenced, too, as shown in Fig. 5. Note that there is a significant difference on the VSWR level of the antenna between l_h of 10 mm and other values of l_h. The reason for this phenomenon is that the close distance between the vertical arm (along z-axis) of the L-shaped strip and the UWB antenna will lead large mutual interaction between the two elements. It can be seen from Fig. 6 that the resonant frequency of the Bluetooth band is mainly determined by the length of l_v. In other words, by increasing or decreasing the length of l_v, the resonant frequency of the Bluetooth will be decreased or increased with inconspicuous influence on the UWB band. From the simulated results

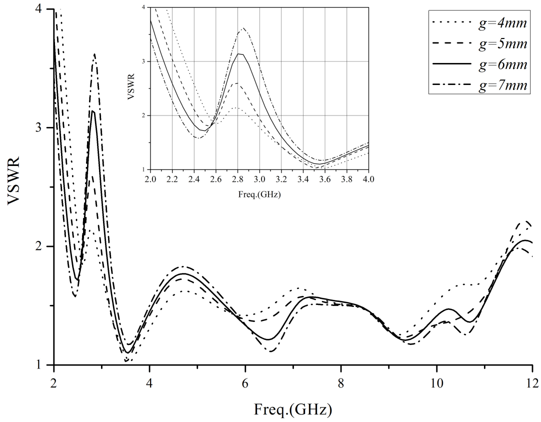

Figure 4. Simulated VSWR against frequency with different g ($l_v = 13\,\text{mm}$, $l_h = 13\,\text{mm}$).

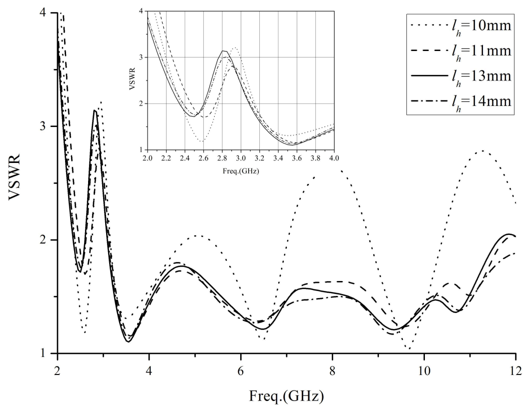

Figure 5. Simulated VSWR against frequency with different l_h ($g = 6\,\text{mm}$, $l_v = 13\,\text{mm}$).

of the parameters, it can be concluded that the mutual interaction intensity between the two elements is mainly determined by the length of g and l_h while the resonant frequency of the Bluetooth band is mainly determined by the length of l_v. By properly adjusting the length of g, l_h and l_v, the dual band operation can be achieved. The optimized parameters are as follows: $g = 6\,\text{mm}$, $l_h = 13\,\text{mm}$, and $l_v = 13\,\text{mm}$. Note that the total length of the L-shaped strip is same with the bended L-shaped strip.

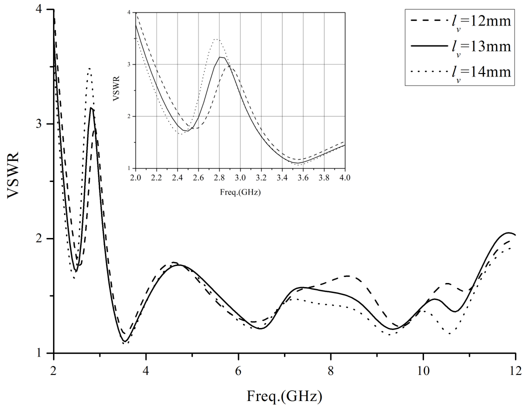

Figure 6. Simulated VSWR against frequency with different l_v ($g = 6\,\text{mm}$, $l_h = 13\,\text{mm}$).

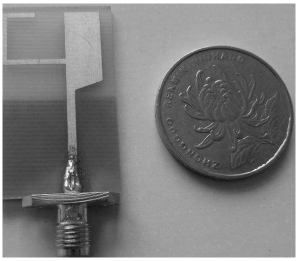

Figure 7. Photograph of the proposed antenna.

5. EXPERIMENTAL RESULTS AND DISCUSSION

With the optimized parameters in Fig. 1, an example dual band antenna was fabricated as shown in Fig. 7. The impedance bandwidth has been measured using an Agilent 8722ES vector network analyser. Fig. 8 shows the simulated and measured VSWR against frequency for the proposed UWB antenna. It is observed from the measured results that the designed antenna operates over 2.36 GHz–2.6 GHz and 3.1 GHz–11.5 GHz for VSWR ≤ 2 and can cover the Bluetooth and the whole UWB band. The discrepancy in VSWR between the simulated and measured results at higher frequency range can be mostly attributed to the effects of the SMA-connector in the measurement. The radiation patterns at 2.4 GHz, 4 GHz, and 8 GHz are measured and shown in Fig. 9. It can be seen that the antenna has a quasi-Omni-directional radiation pattern in the H-plane which indicates that the proposed antenna can be a good candidate for some wireless communication application at Bluetooth and UWB band. The simulated and measured peak antenna gain with good agreement is shown in Fig. 10. The measured result shows a gain level of about 9 dBi, with gain variations 6 dBi across the operating band. The relative large gain level at low frequency and high frequency of the proposed antenna is due to the semi-bevelled-rectangle patch and the bended L-shaped strip all acting as the radiators at these frequencies which lead to a slightly directivity of the proposed antenna.

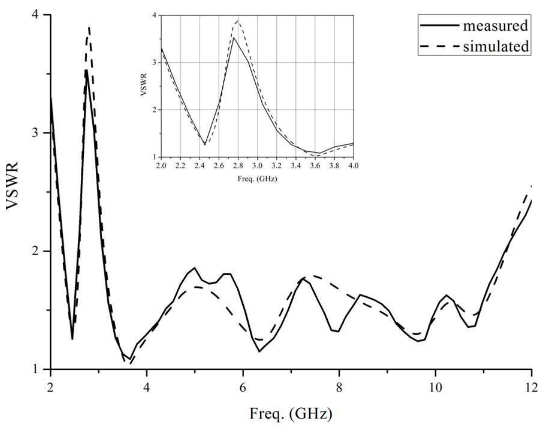

Figure 8. Simulated and measured VSWR against frequency.

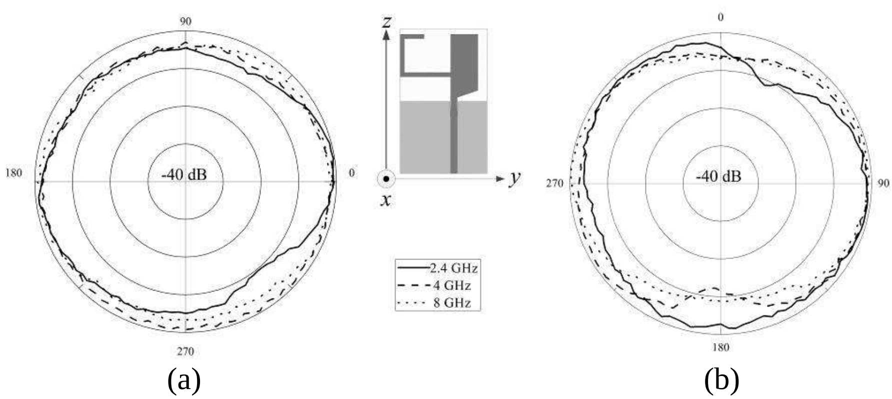

Figure 9. Measured radiation pattern of the proposed antenna. (a) H-plane (x-y plane). (b) E-plane (x-z plane).

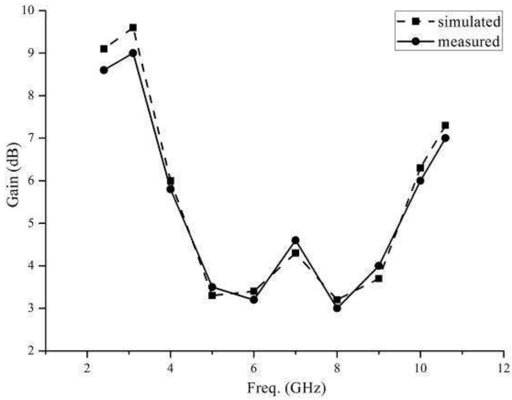

Figure 10. Simulated and measure peak gain against frequency of the proposed antenna.

6. CONCLUSIONS

A compact and planar dual band antenna for wireless communications is presented. The antenna exhibits a dual band operation covering Bluetooth (2.4–2.484 GHz) and UWB (3.1–10.6 GHz) frequency bands with voltage standing wave ratio (VSWR) less than 2. Good radiation patterns and the compact size indicate that the proposed antenna can be a good candidate for some portable wireless communication application at Bluetooth and UWB band.

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