UWB Printed Slot Antenna With Bluetooth and Dual Notch Bands

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***Abstract*—A novel technique to add an extra Bluetooth band and dual notch bands simultaneously to a compact ultrawideband (UWB) printed slot antenna is proposed. The UWB slot antenna, covering 3.1–11 GHz, is in the shape of an octagon and is fed by a rectangular patch with a beveled bottom edge. To create an extra band outside the UWB frequency range, centered at the 2.4-GHz Bluetooth band, a quarter-wavelength stub is attached to the high concentrated current area in the ground plane. Two notch bands, centered at 3.5-GHz WiMAX and 5.8-GHz WLAN, are also created by placing two stubs similar to that of the extra band. The proposed antenna has a compact size (23×28 mm^2), almost stable radiation pattern, and reflection coefficient of lower than -10 dB across the entire passband. A prototype of the proposed antenna is fabricated, and the measured results are shown to be in good agreement with the simulated results.**

***Index Terms*—Multiband, notch bands, printed slot antenna, ultrawideband (UWB).**

I. Introduction

IN RECENT years, ultrawideband (UWB) systems, over the 3.1–10.6-GHz band, have attracted a lot of attention for the commercial applications. An important part of the UWB system is the antenna. For most of the applications, the antenna is required to have an omnidirectional and stable radiation pattern, high radiation efficiency, low group delay, and low profile [1].

Because of the existence of other wireless frequency bands, such as the wireless local area network (WLAN) operating at 5.15–5.35 and 5.725–5.825 GHz and worldwide interoperability for microwave access (WiMAX) operating at 3.5 and 5.8 GHz, it is desirable to design a UWB antenna to avoid interference by rejecting these frequency bands.

The printed planar monopole antenna is a good candidate for the UWB system because of its low cost, ease of fabrication, and compactness. Among them, printed slot antennas are desirable owing to their wide impedance bandwidth and higher gain. A few UWB printed slot antenna configurations have been reported in the literature, which includes the printed slot planar inverted-cone antenna [2] and an experimental study of a printed wide-slot antenna for wideband applications [3]. The overall size of these antennas is somewhat large, and they do not have a good radiation pattern, especially at the end of the frequency band.

Adding an extra band to the wideband antenna is also desirable. In [4], by adding a narrow L-shaped strip to the middle part of a UWB printed monopole antenna, an extra Bluetooth band is created. In [5], an L-shaped slot was etched out of the ground plane of the circular monopole antenna to create an extra band.

In the literature, few techniques have been reported to design printed slot antennas with band-notch behavior. This includes a C-shaped parasitic strip combined with a circular slot antenna [6], parasitic strip and slit in the slot antenna [7], use of variable length on-ground slits in the open slot antenna [8], and use of a square-ring resonator to improve the frequency notch behavior of the UWB slot antenna [9]. However, all these antennas have a single-notch frequency band. In [10], a dual-notched-band UWB slot antenna is obtained by cutting rectangular and L-shaped slits in the ground plane.

In this letter, a novel technique for simultaneously adding an extra frequency band at 2.4 GHz (Bluetooth band) without increasing the size of the antenna and two frequency notched bands centered at 3.5 GHz (WiMAX band) and 5.8 GHz (WLAN band) to a UWB printed slot antenna are proposed. The extra band and dual band notches, which are independent of each other, are created by attaching the stubs of a quarter-wavelength to the ground plane near the feed line. The center frequency of the notched bands can be finely tuned by changing the length of the stubs. The simulation results are carried out using a commercially available software package HFSS, and the measured results are presented and discussed.

II. Antenna Design

The geometry of the proposed UWB printed slot antenna with the capability of adding and rejecting bands is shown in Fig. 1. The antenna is printed on Rogers 4003 substrate with a size of 23×28 mm^2, thickness of 0.8 mm, relative permittivity of 3.38, and loss tangent of 0.0027.

The slot antenna of the proposed structure has an octagonal shape and a rectangular feeding patch with beveled bottom edges. The beveling of the patch results in a better impedance matching. As shown in Fig. 1, to increase the impedance bandwidth of the slot antenna, the lower edge of the slot near the feed line is also beveled by an angle of α.

It needs to be mentioned that once the extra stubs are added to the structure, the cuts created at the two top corners of the slot will result in a better impedance matching as will be explained.

To design a suitable UWB antenna, the parameters are obtained as follows: $W_{\mathrm{P}} = 10$ mm, $W_{\mathrm{S}} = 28$ mm, $W_{\mathrm{F}} = 1.5$ mm, $W_1 = 1$ mm, $W_2 = 2$ mm, $W_3 = 7$ mm, $L_{\mathrm{F}} = 7.5$ mm,

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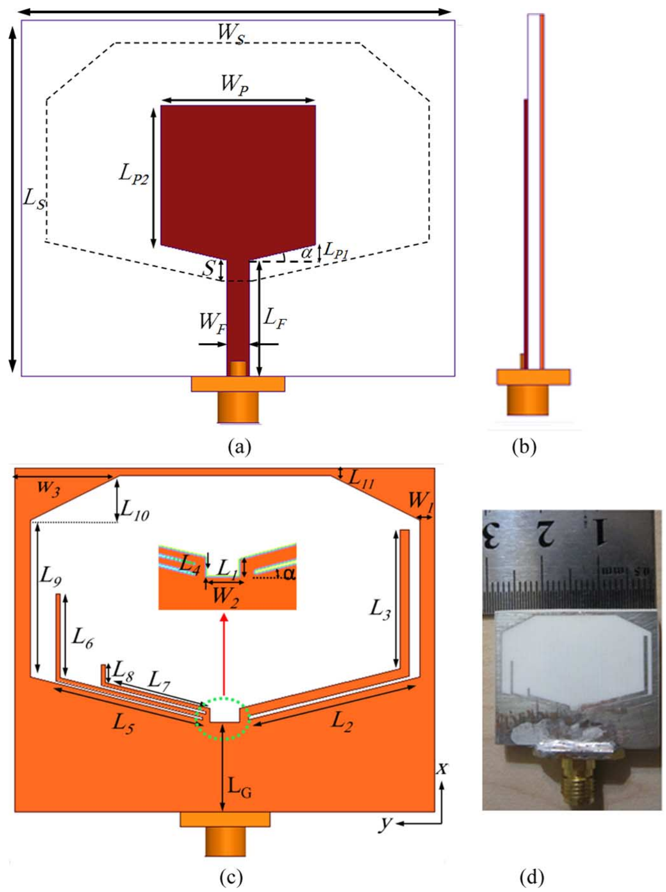


Fig. 1. Configuration of the proposed printed UWB slot antenna with extra band and dual notched bands. (a) Top view. (b) Side view. (c) Bottom view. (d) Fabricated antenna. The bottom view shows the enlarged feed area.

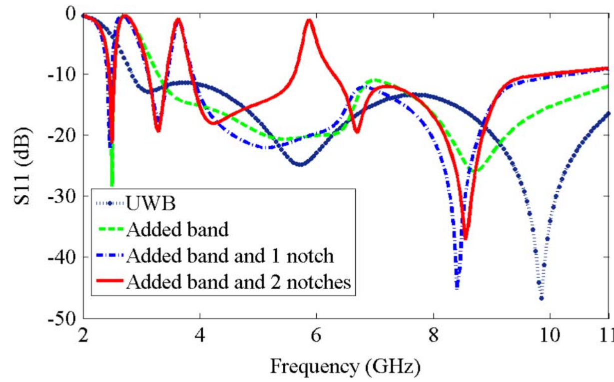


Fig. 2. Simulated reflection coefficient of the printed UWB slot antenna with added extra band and two notch bands.

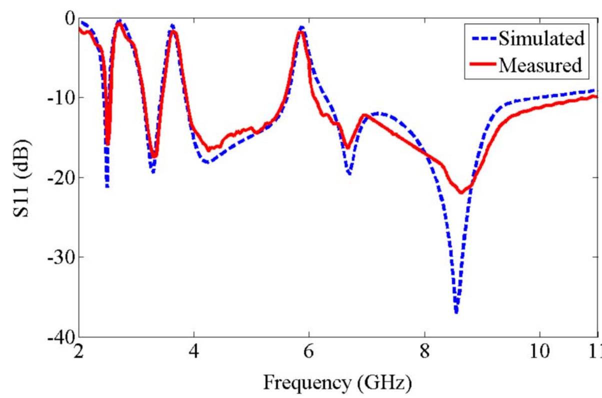


Fig. 3. Simulated and measured reflection coefficient of the printed UWB slot antenna with added extra band and two notch bands.

$L_S = 23$ mm, $L_G = 6$ mm, $L_9 = 10.5$ mm, $L_{10} = 3$ mm, $L_{11} = 0.5$ mm, and $\alpha = 14°$.

The patch antenna described operates over the UWB frequency. To provide an extra independent band below the UWB range, one should create an extra resonance. An open-circuit stub of a quarter-wavelength can provide this resonance. At this lower frequency band, the UWB antenna is inactive, and hence it can be used as the ground plane for the stub to provide the required resonance. To have an efficient resonant band, this stub should be fed from the high concentrated current area of the structure. The current distribution is strong in the ground plane near the main feed line. Therefore, to create an extra band centered at 2.4 GHz without increasing the overall size of the antenna, one can attach a beveled L-shaped stub of a quarter-wavelength and appropriate width to the ground plane near the feed line.

To create a band-notch behavior within the UWB over which the patch antenna is active, one needs to short out the radiation of the patch at the required notch center frequency. A stub of a quarter-wavelength can provide this behavior. Thus, to create a notch band within the UWB frequency, a beveled L-shaped stub of a quarter-wavelength placed beside the patch and fed from the high concentrated current area in the ground plane can be used. It will be shown in Section III that the length of such stubs can be optimized to allow a good tuning of the notch center frequency.

To have good impedance matching in UWB, these beveled L-shaped stubs should be placed near the ground and beveled by an angle α. It needs to be mentioned that attaching any of such stubs to the antenna structure has little effect on the impedance matching of the original UWB antenna, which means that the initial parameters of the UWB antenna remain fixed.

Fig. 1 shows the complete structure of the proposed antenna with the geometry of the beveled stubs. The total length of any of the beveled L-shaped stubs (e.g., $L = L_1 + L_2 + L_3$ for the extra band stub) can be obtained approximately from the following formula:

$$L = \frac{c}{4f\sqrt{\frac{\varepsilon_r+1}{2}}} \tag{1}$$

where ε_r, c, and f are dielectric constant, the velocity of light in free space, and the center frequency of the desired bands, respectively.

To reject the frequencies of 3.5 GHz (WiMAX) and 5.8 GHz (WLAN), the stubs with lengths $L_{S1} = L_4 + L_5 + L_6 = 15.8$ mm and $L_{S2} = L_1 + L_7 + L_8 = 9.3$ mm and with a width of 0.25 mm are used. To add the extra Bluetooth band, the stub with a length of $L_{S3} = L_1 + L_2 + L_3 = 21$ mm and width of 0.6 mm is used. Through optimization, the dimensions of the stubs are as follows: $L1 = 0.9$ mm, $L2 = 11$ mm,

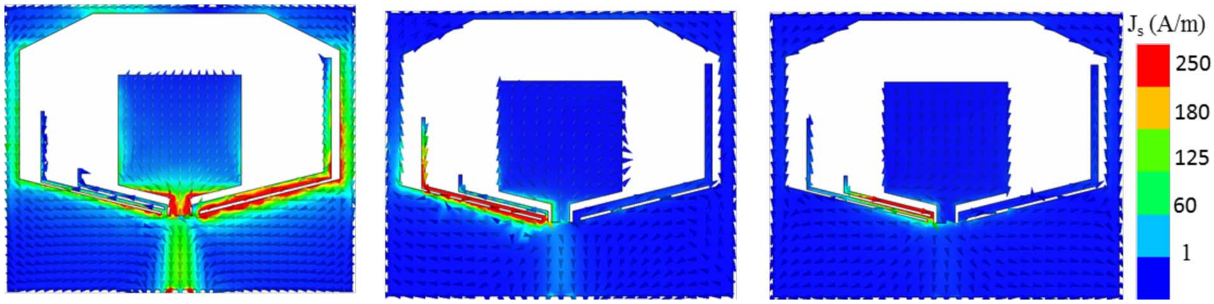


Fig. 4. Simulated current distribution on the printed UWB slot antenna with stubs at frequencies of (a) 2.4, (b) 3.5, and (c) 5.8 GHz.

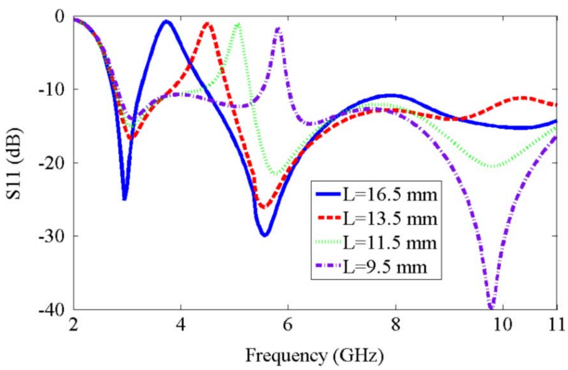


Fig. 5. Simulated reflection coefficient of the printed UWB slot antenna with single notch band for various stub lengths.

$L3 = 9.1$ mm, $L4 = 0.45$ mm, $L5 = 10$ mm, $L6 = 5.35$ mm, $L7 = 7.2$ mm, and $L8 = 1.2$ mm.

III. RESULT

The simulated reflection coefficient of the printed UWB slot antenna with and without the presence of any of the stubs is shown in Fig. 2. It is seen that the patch-fed slot antenna without the stubs provides an impedance bandwidth covering 3.1–10.6 GHz. The addition of a stub with length L_{S3} to the antenna creates the extra band at 2.4 GHz to the initial UWB. Stubs with lengths of L_{S1} and L_{S2} can create two notched bands centered at 3.5 and 5.8 GHz. The simulated results confirm that the added stubs operate independently and have little effect on each other. Fig. 3 shows the measured and simulated reflection coefficient of the proposed UWB antenna with the extra band and dual notched bands. From this figure, it is seen that the notched bands have very high reflection coefficient values, about -2 dB, while that of the added band is well below the -10-dB level, which means a good impedance matching.

For better understanding of the proposed antenna behavior, the simulated current distribution on the antenna at frequencies of 2.4, 3.5, and 5.8 GHz is presented in Fig. 4. The current distribution results on each of the stubs show that while the current is maximum at one end, the minimum is located at the other end of the stubs, which is in agreement with the quarter-wavelength dimension of stubs. It can also be seen that, at the desired frequency, only the corresponding stub is active while the others are inactive, confirming the independence of the frequency bands. The direction of the current vectors in the extra band stub is the same as that in the radiating patch, while the directions of the current vectors in the stubs (related to the notched bands) are opposite to that in the radiating patch, resulting in shorting out the radiating patch at the relevant notch frequency.

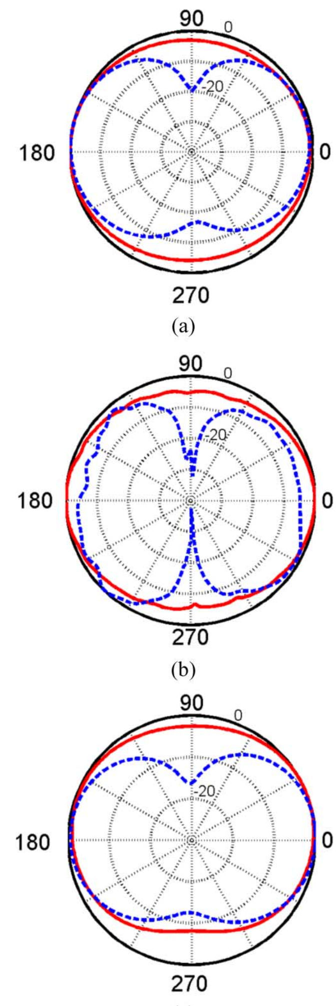


Fig. 6. Measured radiation pattern (dB) of the proposed antenna at frequencies of (a) 2.4, (b) 4.5, and (c) 7 GHz. Solid line represents H-plane (yz plane), and dashed line represents E-plane (xz plane).

Fig. 5 shows the simulated reflection coefficient of the printed UWB slot antenna with single notched band for various stub

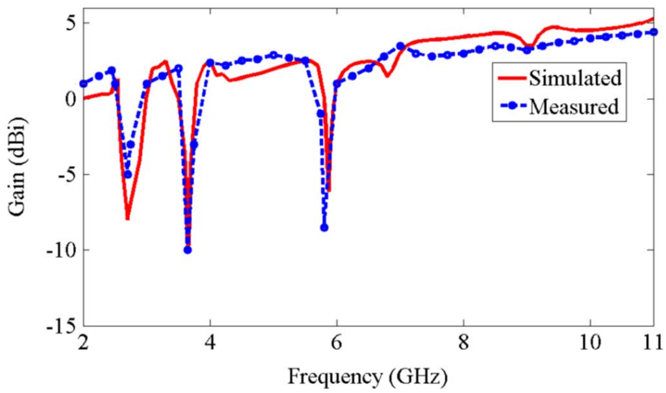
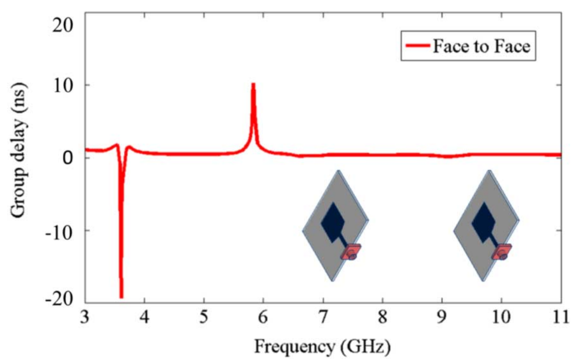
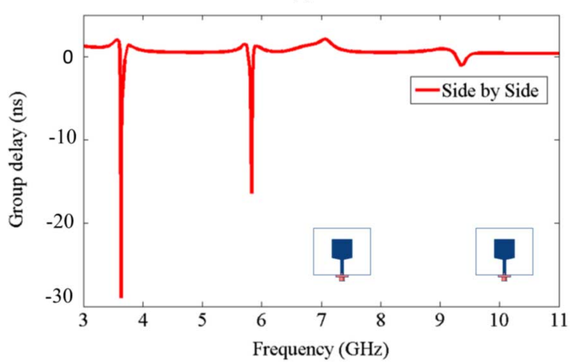


Fig. 7. Simulated and measured peak gain of the proposed antenna.



(a)



(b)

Fig. 8. Simulated group delay of the proposed antenna for both (a) face-to-face and (b) side-by-side configurations.

lengths. It is seen that an increase in stub length results in a decrease in the notch center frequency, and vice versa. This confirms the validity of (1) and shows that use of such stubs in the original UWB slot antenna can lead to tunable notched bands.

The measured E- and H-plane radiation patterns of the proposed antenna at three passband frequencies of 2.4, 4.5, and 7 GHz are shown in Fig. 6. The results show that the radiation patterns of the antenna are stable in both planes.

The simulated and measured peak gain of the proposed antenna across the Bluetooth and UWB are shown in Fig. 7. The reduction in the antenna gain in the notch bands is significant and confirms the band-rejection behavior of the proposed antenna.

Fig. 8 presents the simulated group delay of the proposed antenna for both side-by-side and face-to-face configurations. Apart from the notched bands, the group delay variation over 3.1–10.6 GHz is almost smooth, showing that the proposed antenna is suitable for operation over the UWB.

IV. Conclusion

The design of a UWB slot antenna with an extra band and dual notched bands has been presented. The UWB slot antenna has an octagonal shape. By attaching three beveled L-shaped stubs of a quarter-wavelength to the ground plane of the slot near the feed line, an extra band at 2.4 GHz (Bluetooth band) and two notched bands centered at 3.5 GHz (WiMAX) and 5.8 GHz (WLAN) are created. The stubs act independently, and their addition to the slot antenna does not change the behavior of the original UWB slot antenna. The quality of the added and rejected bands is quite good. The measured results agree with the simulated ones.

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