A compact ultra wideband antenna with WiMax band rejection for energy scavenging

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Abstract. Radio Frequency (RF) energy harvesting has been rapidly advancing as a promising alternative to existing energy scavenging system. A well designed broadband antenna such as ultra-wideband (UWB) antenna can be used as one of the major components in an RF energy scavenging system. This paper presents a compact UWB antenna showing good impedance matching over a bandwidth of 2.8 to 11 GHz, suitable for broadband RF energy scavenging. Nevertheless, the antenna usage in wireless communication has a limitation due to the problem of interference between UWB system and other narrowband systems. Thus, the proposed antenna is successfully designed with a single band-notched at the targeted WiMAX operating band of 3.3 to 3.6 GHz.

1. Introduction
Radio Frequency (RF) energy harvesting aims at converting ambient RF energy extracted from propagating radio waves into storable electrical energy to power electronics [1]. A typical RF energy scavenging system consists of an antenna with impedance matching circuit, rectifier, voltage booster and a charging circuit. Therefore, broadband antennas such as UWB antennas play an important role in RF energy harvesting systems, since they are able to collect energy from various sources operating in their matching band. However, their usage in UWB wireless communication system has a limitation due to the consequences of having to share the spectrum with a number of other established narrowband applications such as WiMAX (3.3 – 3.6 GHz) and WLAN IEEE 802.11a (5.15 to 5.85 GHz). The interference from a strong narrowband signal, could affect the overall systems. To overcome this unwanted problem, it is desirable to design UWB antennas integrated with band rejection characteristics in the affected frequency bands. In recent times, numerous researchers have proposed diverse antenna geometries, design methods and structures in order to achieve band-notched features [2-4].

In this paper, an octagon-shaped microstrip antenna with ultra-wideband impedance matching from 2.8 to 11 GHz is proposed. A frequency band-notched from 3.3 to 3.6 GHz can be achieved by simply employing a slanted inverted U-shaped slot in the radiating patch. The outline of this paper is as follows. The geometry of the proposed UWB antenna is presented in section 2 while the characteristics of the antenna are presented in section 3. The conclusions are summarized in Section 4.
2. Antenna Geometry

The proposed UWB antenna configuration and its geometrical parameters are shown in Figure 1. This proposed antenna design consists of an octagon-shaped radiator fed by a microstrip line printed on a partial grounded substrate. The microstrip line feed is designed to match a 50 Ω characteristic impedance. With the aim to increase the impedance bandwidth, both the radiating plane and the ground plane have tapered shapes at both ends. Apart from that, a rectangular slit is added on top of the ground plane to further enhance the impedance bandwidth of the antenna. The proposed antenna is designed on a standard Taconic TLC-30 substrate with a dielectric substance of 3, a loss tangent of 0.003 and with thickness of 1.575 mm. The final optimized parameter values are tabulated in Table 1.

![Figure 1. Geometry of the proposed antenna (units in mm). (a) Front view (b) Rear View](image)

| Parameter | Value (mm) |
|-----------|------------|
| $a$       | 20.0       |
| $b$       | 18.0       |
| $c$       | 8.0        |
| $d$       | 12.0       |
| $e$       | 3.9        |
| $f$       | 12.0       |
| $g$       | 2.0        |
| $h$       | 3.65       |
| $i$       | 3.40       |

The geometry and dimensions of the UWB antenna with band-notched design (will be referred to as antenna 2) is illustrated in Figure 2. A slanted inverted-U shaped slot is etched onto the radiating patch in order to create a frequency band-notch at the targeted WiMAX band. The previously optimized design parameters of the UWB antenna need no additional retuning work when the band-notched design is applied. In general, the design concept of the notch function is to adjust the total length of the U-shaped slot to be approximately half-wavelength at the desired unwanted frequency [5]. The final design parameters of the slot are tabulated in Table 1 as well.
3. Results and Discussion

The simulations of the proposed antenna performance are performed using CST Microwave Studio. Figure 3(a) shows the calculated return loss curves of the proposed antenna with and without the notched band. It can be seen that the calculated return loss curve is less than -10 dB from 2.8 GHz to beyond 11 GHz for antenna 1, giving a clear indication that the impedance bandwidth is more than 8.2 GHz covering the entire UWB frequency range. Furthermore, the required frequency notch at WiMAX band from 3.3 to 3.6 GHz is successfully achieved as displayed in the return loss curve for antenna 2. A notch band with a peak of -3.3 dB is clearly demonstrated by the return loss curve for antenna 2.

![Figure 2](image.png)

**Figure 2.** Geometry of the proposed antenna with band notched design (antenna 2)

The comparison of simulated VSWR for the proposed antenna designs with and without slot is illustrated in Figure 3(b). From the Figure, it is evident that the addition of the slot onto the radiating patch is indeed initiates the desired filtering property. Compared to antenna 1 design, the targeted frequency band has been successfully blocks out by the antenna 2 with VSWR > 2 and still maintains good impedance matching at other frequencies in the UWB frequency band.

![Figure 3](image.png)

**Figure 3.** Simulated antennas performance (a) Return loss (b) VSWR
Figure 4 depicted the simulated far-field radiation pattern of antenna 2 in the E-plane and the H-plane at 3.4 GHz. It can be observed that, the patterns obtained are typical of those for monopole antennas. In the H-plane the pattern is quite omni-directional while the bidirectional pattern can be seen in the E-plane. It can be stated that the proposed band notched structure do not have any significant influence on the radiation patterns of the UWB antenna.

4. Conclusions
This paper proposed a compact UWB microstrip antenna design. The antenna has a total size equal to 26 x 32 mm$^2$ and has the capability of achieving an input impedance bandwidth from 2.8 to 11 GHz. With these features, the antenna is a promising candidate for compact and miniaturized RF energy scavenging system. Additionally, a slanted U-shaped slot is introduced on the radiating patch to create a notched band from 3.3 to 3.6 GHz to minimize the potential interferences from WiMAX system. The modified antenna is suitable for numerous UWB applications.

References
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