Diamond Shaped Ring Antenna for UWB Applications with Inherent Band-Notched Functionality

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Abstract **─** In this Letter, a novel printed monopole antenna design is described that operates across a wideband frequency band and exhibits band-notch characteristic necessary to suppress interference signals. The prototype antenna consists of a radiating patch in the configuration of a diamond shaped ring that has attached within it an inverted T-shaped resonant structure that controls the notch frequency. The antenna is excited with a microstrip feed-line and includes an elliptically shaped ground-plane that is defected with a dielectric notch in the vicinity of the patch to enhance the antenna's impedance bandwidth. The antenna exhibits an inherent stop-band function at the WLAN frequency band. The proposed antenna configuration is simple and compact with dimensions of 30×30×1.6 mm^3. The measured impedance bandwidth exceeds the Ultra-Wideband (UWB) spectrum defined between 3.06-15.96 GHz, for VSWR≤2 that corresponds to a fractional bandwidth of 135.6%. The radiation characteristic of the proposed antenna is approximately omni-directional.

Index Terms **─** Band-notched antenna, microstrip fed antenna, monopole antenna, UWB.

I. INTRODUCTION

Latest progress in wireless technology employs several communication standards to enable various systems; e.g., satellite, ultra-wideband, and WLAN systems, to operate over a common platform. Such systems necessitate the integration of various sub-systems and the use of a single antenna to enable wireless communications. The antenna therefore needs to be designed so that its impedance bandwidth is sufficiently wide enough to cover the operating frequency spectrum of multiple wireless communication systems. UWB systems have a 10 dB bandwidth of 7.5 GHz between 3.1-10.6 GHz as defined by Federal Communications Commission (FCC). Such systems have become the de facto standard of high data rate, high capacity and low power transmission for short range indoor applications. In fact, the effective isotropic radiated power spectral density of UWB is restricted to -41.3 dBm/MHz [1]. Since printed monopole antennas have attractive characteristics including: (i) relatively large impedance bandwidth, (ii) ease of manufacture using conventional Microwave Integrated Circuit (MIC) technology, and (iii) acceptable radiation properties, hence these types of antenna find application in UWB systems [2-7]. The UWB spectrum includes within it other wireless narrowband standards, such as WLAN bands (5.15-5.35 GHz and 5.725-5.825 GHz) that will interfere with the operation of UWB systems. Hence, to avoid interference, the UWB systems need to employ filters with stop-band functionality. Unfortunately, the inclusion of filters would unnecessarily increase the overall size, weight and cost of the UWB systems. In order to save space, UWB antennas possessing a notch function across the band 5.15-5.825 GHz would provide the solution. Several band-notched antennas have been recently proposed for UWB systems including: using H-shaped conductor-

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backed plane [8], etching two modified U-shaped slots on the patch [9], inserting two rod-shaped parasitic structures [10], embedding a resonant cell within the feed-line [11], using a fractal tuning stub [12], and utilizing a resonant patch [13].

In this paper, a novel WLAN band-notched antenna is proposed for UWB applications that uses a radiating patch consisting of a diamond shaped ring structure in which is embedded an inverted T-shaped resonance element. The diamond ring determines the center frequency of the notch band.

II. ANTENNA STRUCTURE

The proposed monopole antenna was constructed on a low-cost commercial FR-4 substrate with relative permittivity of 4.4, tanδ=0.02 and thickness of 1.6 mm. Figure 1 shows the geometry of the proposed UWB antenna. The antenna is terminated with a 50 Ω SMA connector for signal transmission and reception. The width of the feed-line is fixed at 2.8 mm, which corresponds to a characteristic impedance of 50 Ω. The optimized dimensions of the antenna are shown in Fig. 1. The antenna's structure includes a ground-plane with a notch in the shape of a semi-ellipse in the vicinity of the radiating patch. Within the patch is embedded an inverted T-shaped resonance element.

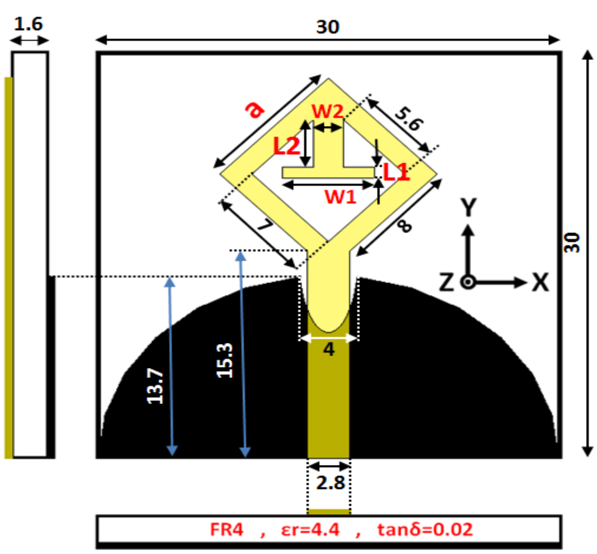

Fig. 1. Geometry of the proposed antenna (optimized dimensions in mm).

The notched band defined between 5-6 GHz is determined by the dimensions of this resonance element. Figure 2 shows the three steps employed to implement the antenna structure. The first step includes the radiating patch in the configuration of a diamond shaped ring, and a truncated ground-plane in the shape of a rectangle. In order to extend the impedance bandwidth to cover the UWB spectrum, in the second step the rectangular ground-plane is modified into a semi-elliptical shape with a semi-elliptical notch next to the patch. The notch-band is created by adding an inverted T-shaped resonance element, as the third step in Fig. 2 depicts. The antenna's VSWR response in Fig. 2 is wider than previous antennas [2-21].

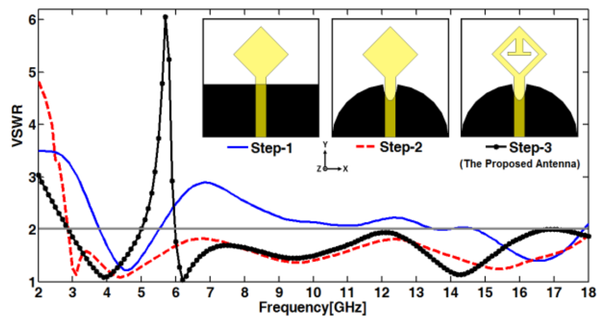

Fig. 2. Simulated VSWR characteristic of the antenna in the various steps to create the final proposed structure.

III. SIMULATION AND MEASUREMENTS RESULTS

In this Section, the affect of the various parameters on the band-notched antenna are studied. Numerical and experimental results of the impedance bandwidth, radiation characteristics, gain, surface current distribution, and group delay are presented and discussed. The affect of the various parameters defining the proposed UWB antenna are studied by changing them one at a time while keeping all others fixed. Full-wave analysis on the proposed antenna configuration was performed using Ansoft HFSS (ver 11.1). As shown in Fig. 3, the width (W1) of the inverted T-shaped resonance element affects the antenna's notch frequency. However, the thickness of the inverted T-shaped element (W_2) greatly affects the frequency of the notch band as shown in Fig. 4.

The thickness of the horizontal section (L_1) and vertical section (L_2) of the inverted T-shaped element also affects the notch's center frequency as shown in Figs. 5 and 6, respectively. L_1 and L_2 changes the notch frequency by approximately 1 GHz, for L_1 change between 0.8-1.5 mm and L_2 change between 3.5-4.5 mm.

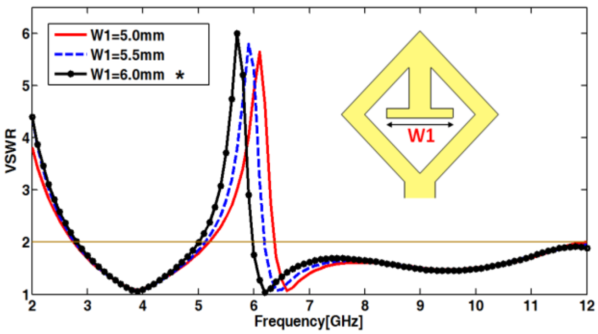

Fig. 3. Simulated VSWR characteristics of the proposed antenna for various dimensions of parameter W_1.

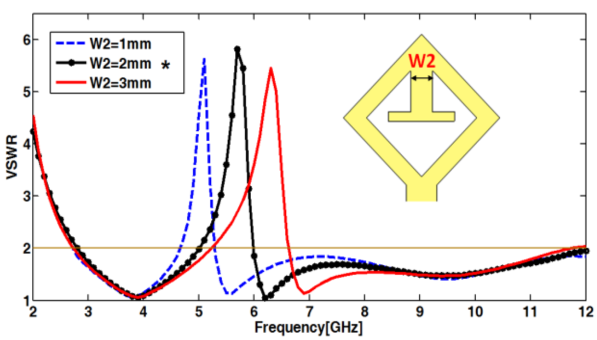

Fig. 4. Simulated VSWR characteristics of the proposed antenna for various dimensions of parameter W_2.

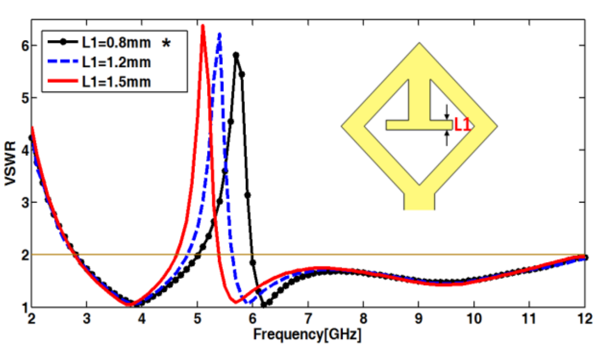

Fig. 5. Simulated VSWR characteristics of the proposed antenna for various dimensions of parameter L_1.

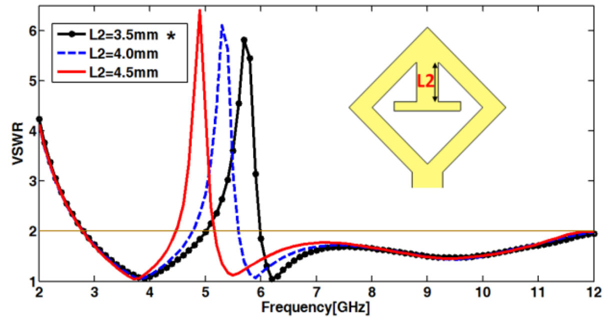

Fig. 6. Simulated VSWR characteristics of the proposed antenna for various dimensions of parameter L_2.

Figure 7 shows the simulated radiation patterns of the proposed antenna with the co- and cross-polarization in the H-plane (*x-z* plane) and E-plane (*y-z* plane). It can be observed that the radiation patterns in *x-z* and *y-z* plane are nearly omni-directional and bidirectional, respectively, at the frequencies of 3.8 GHz and 8 GHz. The measured and simulated gain of the proposed antenna over the antenna's operating bandwidth is shown in Fig. 8. The graph shows that the measured gain is optimum of about 4 dBi between 2-3.5 GHz and 10.8-11 GHz. The gain as required drastically drops across the notch band.

The process contributing towards the UWB and notch-band is explained by the current distribution density over the antenna.

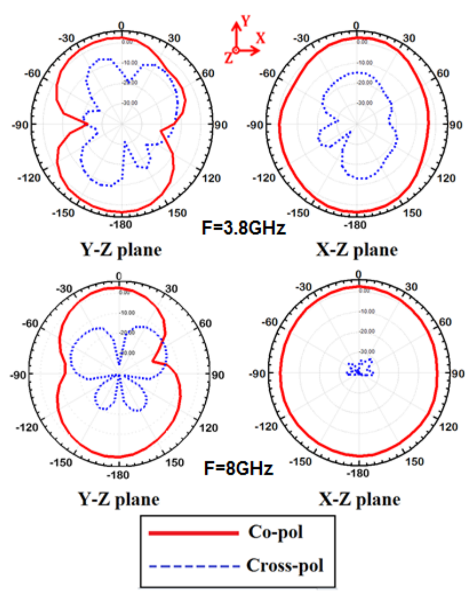

Fig. 7. Radiation patterns of the proposed antenna at: (a) 3.9 GHz, and (b) 8 GHz.

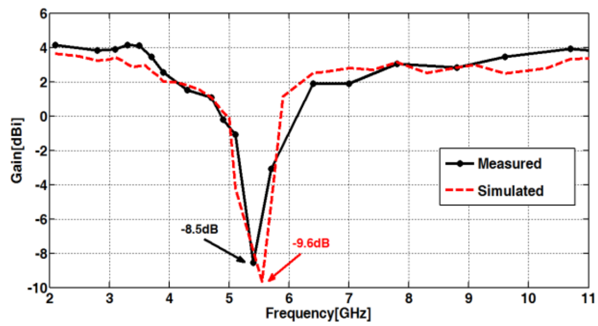

Fig. 8. Measured and simulated gain of the antenna.

Figure 9 shows the current distribution at the notch's center frequency of 5.8 GHz which is intense over the feed-line, the diamond ring and the base of the inverted T-shaped element. The concentration is also strong in the ground-plane in the vicinity of the feed-line. The current emanating from the inverted T-shaped element flowing over the top of the ring is in the opposite direction to the current flow in the bottom half of the ring. This results in the attenuation at 5.8 GHz.

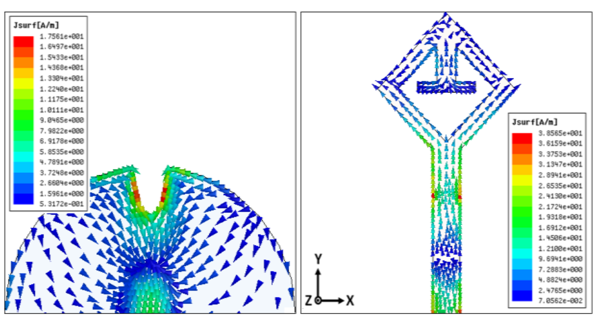

Fig. 9. Surface current distribution at 5.8 GHz over the defected ground-plane, feed-line and the patch.

Group delay is an important parameter in UWB antenna design, which represents the degree of distortion of pulse signal. To evaluate the dispersion performance of the proposed antenna, group delay was measured. The measured group delay between two identical antennas separated by 50 cm is shown in Fig. 10. The variation in the group delay is within about 2 ns, which verifies the proposed antenna is suitable for UWB communication systems. The measured VSWR, shown in Fig. 11, not only verifies its performance up to 15.96 GHz but also shows a close correspondence between the measured and simulated curves. The photograph of the proposed antenna is inset in Fig. 11. Both the impedance bandwidth and radiation patterns were measured by using the Agilent 8722ES network analyzer in its full operational span (3.06-15.96 GHz).

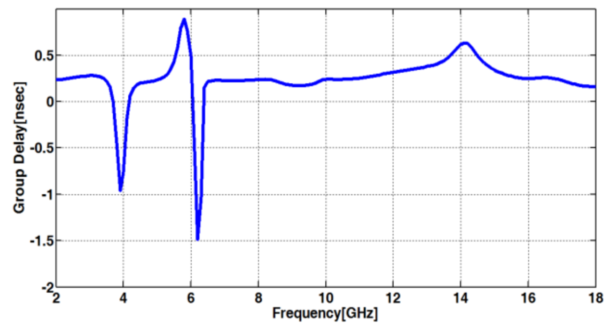

Fig. 10. Measured group delay of the proposed antenna.

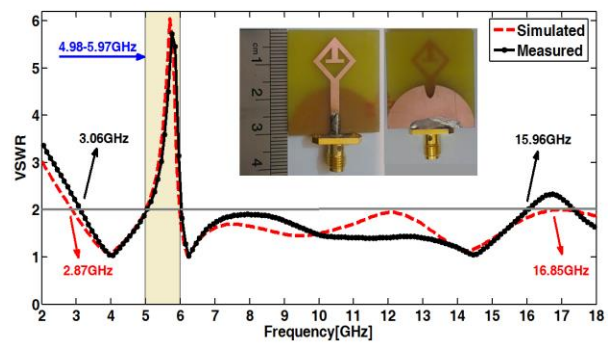

Fig. 11. Measured and simulated VSWR of the proposed optimized antenna. Inset is the photograph of the front and back side of the antenna.

IV. CONCLUSION

Proof of concept is reported of a novel compact printed monopole antenna for UWB application. The antenna has an inherent band-notch characteristic which is necessary to mitigate interfering signals with the UWB spectrum. The antenna has the following features: ease of pre-manufacture tuning of the notch-band, compact size, ease of fabrication and low cost. The measured results verify the antenna operation exceeds the UWB frequency range (3.06-15.96 GHz), rejection band between 5-6 GHz, and good radiation patterns across the UWB band. These characteristics make the antenna feasible for UWB wireless systems.

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