Compact Planar Super-Wideband Antenna with Band-Notched Function

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Abstract **─** In this paper, the design of a novel printed monopole antenna is presented that operates across a super wideband frequency range (2.39 GHz to 40 GHz) and exhibits band-notch characteristic that is necessary to eradicate interference from WLAN systems operating between 5.15 GHz ─ 5.825 GHz. The prototype antenna consists of a radiating patch in the shape of an octagonal ring structure and embedded within ring is a rectangular strip. The antenna is excited through a microstrip feed-line and includes an elliptically shaped ground-plane that is defected with a dielectric notch in the vicinity of the patch. The proposed antenna's structure is simple to design and is relatively inexpensive to fabricate. In addition, it is compact in size with overall dimensions of 30 × 30 × 1.6 mm^3. The measured results confirm the impedance bandwidth cover a super wideband frequency range from 2.3 GHz ─ 40 GHz, for VSWR $\leq$ 2 that corresponds to a fractional bandwidth of 178 %. The radiation characteristic of the proposed antenna is approximately omni-directional.

Index Terms **─** Band-notched antenna, monopole antenna, microstrip fed antenna, and planar structure.

I. INTRODUCTION

Recent development in wireless technology use multiple communications standards to enable various systems, e.g., satellite, ultra-wideband (UWB), and WLAN systems, to operate through a common platform. Such communication systems necessitate the integration of various sub-systems and require the use of a single antenna to enable wireless communication. The antenna therefore needs to be designed so that its impedance bandwidth is sufficiently wide enough to cover the operating frequency of multiple wireless communication systems. In fact, since the Federal Communications Commission (FCC) launched the bandwidth defined between 3.1 GHz – 10.6 GHz for UWB usage [1-12], the UWB technology has become the most promising candidate for the short-range, high-speed indoor data communications. Since printed monopole antennas have attractive features, namely: (i) relatively

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large impedance bandwidth, (ii) ease of fabrication using conventional MIC technology, and (iii) acceptable radiation properties, hence these types of antenna find application in UWB systems [2, 3]. Unfortunately, within the UWB frequency band coexist other wireless narrowband standards such as WLAN bands (5.15 GHz – 5.35 GHz and 5.725 GHz – 5.825 GHz), which are likely to interference with the operation of UWB systems. This necessitates the need for additional functionality from UWB systems, i.e., a stop-band filter to mitigate the interference from such systems. However, this requirement would unnecessarily increase the size of UWB systems. In order to save space, the UWB antennas posses a notch function across the band 5.15 GHz – 5.825 GHz that would provide the solution. Band-notched UWB antennas with various filtering techniques have been recently proposed, which include: using H-shaped conductor-backed plane [4], cutting two modified U-shaped slots on the patch [5], inserting two rod-shaped parasitic structures [6], embedding resonant cell in the microstrip feed-line [7], using a fractal tuning stub [8], utilizing a small resonant patch [9], and using a MAM and genetic algorithm [10].

In this paper, a new single band notched super wideband (SWB) antenna is presented that uses a radiating patch consisting of an octagonal ring, in which is embedded a rectangular-shaped strip. The ring determines the center frequency of the notch band. The structure was optimized using a commercially available EM simulation tool, and the antenna was fabricated and its performance was verified.

II. ANTENNA STRUCTURE

The proposed monopole antenna was printed 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 super wideband antenna. The antenna design is terminated with a 50 Ω SMA connector for signal transmission and reception. The width of the feed-line was fixed at 2.8 mm, which corresponds to a characteristic impedance of 50 Ω. The optimal 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 immediately below the octagonal ring patch. Within the patch is embedded a rectangular strip whose dimensions determine the frequency of the required notched band. Figure 2 shows the three steps employed to implement the antenna structure. The first step includes the radiating patch in the form of an octagonal ring, and ground-plane in the shape of a semi-circle. In the second step the ground-plane is defected with a semi-elliptical notch, which is located just below the octagonal ring. In the third step a rectangular strip is disposed vertically within the ring as shown in Fig. 2.

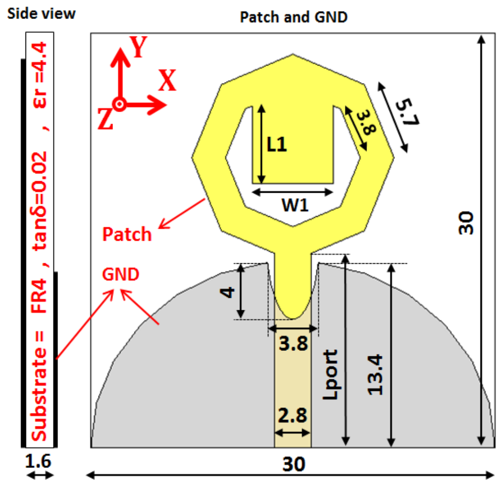
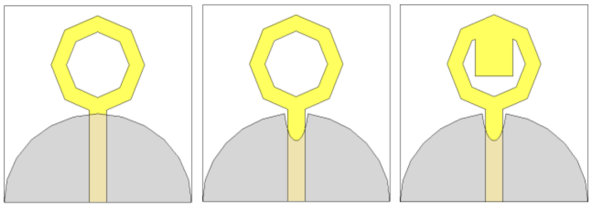


Fig. 1. Geometry of the proposed antenna (optimized dimensions in mm).

Figure 3 shows the microstrip antenna whose ground-plane is defected with a notch; provides a significantly wider impedance bandwidth match in comparison to the same antenna without the notch. In fact, super wideband impedance bandwidth is achieved between 2.39 GHz – 40 GHz, for VSWR ≤ 2. Also by inserting the rectangular strip within the octangular ring creates a narrow-band notch between approximately 5 GHz – 6 GHz.

III. SIMULATION RESULTS AND MEASUREMENTS

In this section, the affect of the various characterizing parameters on the band notched antenna are studied. Numerical and experimental results of the input impedance and radiation characteristics are presented and discussed. The parameters of this proposed antenna are studied by changing the salient parameters one at a time while keeping all other parameters fixed. Full wave analyses of the proposed SWB antenna configuration was performed using commercial software, i.e., Ansoft HFSS (ver11.1). As shown in Fig. 4, adjusting the width (W1) of the rectangular strip can affect the antenna’s notch frequency and to a lesser extend its bandwidth. The strip’s length (L1) also affects the notch’s center frequency as shown in Fig. 5. The change in the notch frequency is approximately 1 GHz for the length changing from 6.5 mm to 8.0 mm. Moreover, the length of the feed-line (Lport) plays an important role in the sharpness of the stop band. This effect is shown in Fig. 6, where the bandwidth and sharpness of the stop band frequency is controllable by changing Lport.



Step-1 **Step-2** **Step-3(proposed)**

Fig. 2. Steps to create the proposed antenna structure: Step-1 is Antenna-1 with octagonal ring shaped patch and semi-circular ground-plane, Step-2 is Antenna-2 with defected ground-plane, and Step-3 is Antenna-3 with a rectangular strip embedded in the octagonal ring shaped patch.

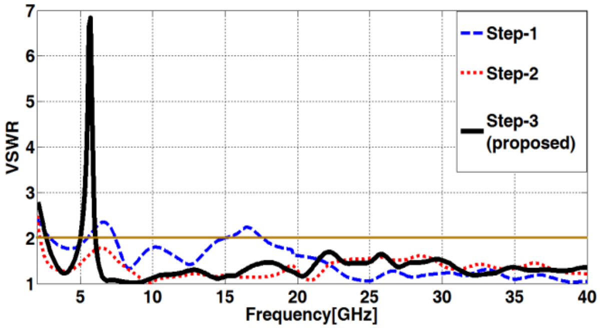


Fig. 3. Simulated VSWR characteristic of the antennas depicted in Fig. 2.

Figure 7 shows the simulated radiation patterns of the proposed antenna with the co- and cross-polarizations in the H-plane (x–z plane) and E-plane (y–z plane). It can be observed that the radiation patterns in the x–z and y-z planes are nearly omni-directional and bidirectional, respectively, at the frequencies of 5 GHz and 6.9 GHz.

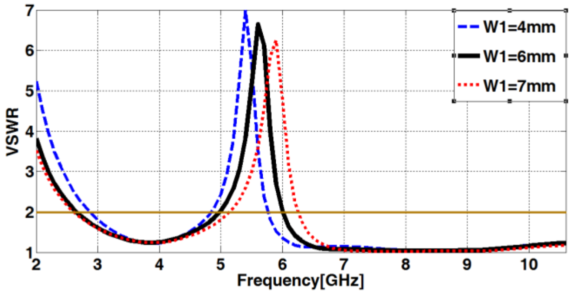


Fig. 4. Simulated VSWR characteristics of the proposed SWB antenna for various dimensions of W1.

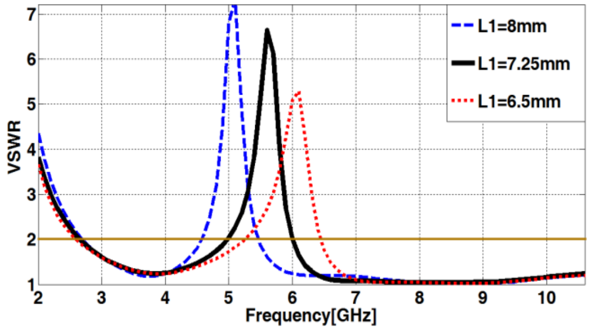


Fig. 5. Simulated VSWR characteristics of the proposed SWB antenna for various dimensions of parameter L1.

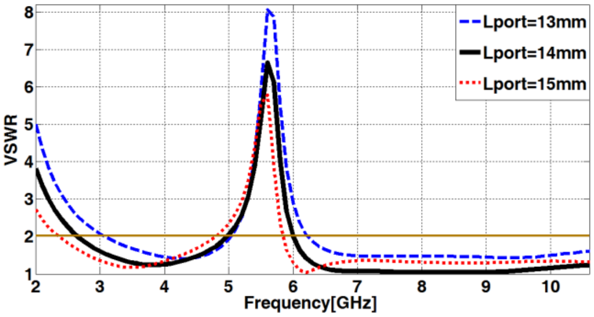


Fig. 6. Simulated VSWR characteristics of the proposed SWB antenna for various Lport lengths.

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 reaches a peak of around

3.5 dBi at 11 GHz. The gain as required drastically drops across the notch band.

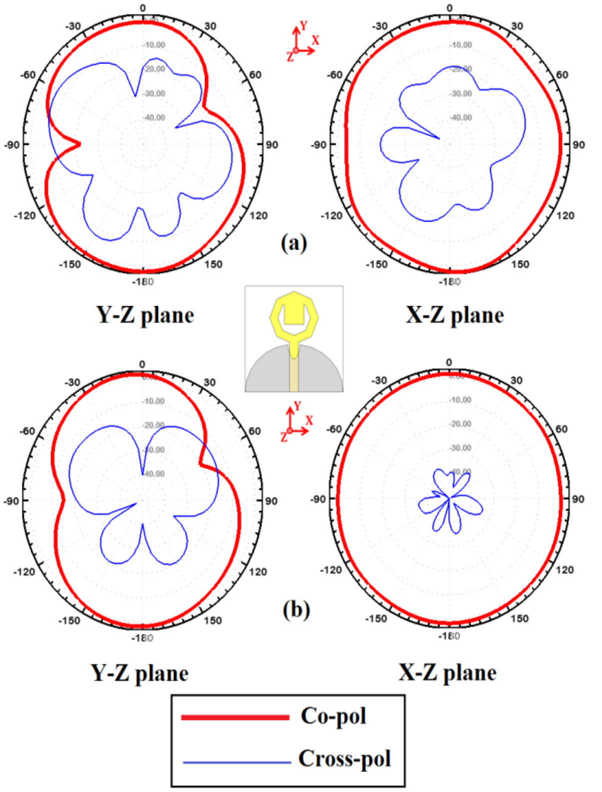


Fig. 7. Radiation patterns of the proposed antenna at (a) 5 GHz and (b) 6.9 GHz.

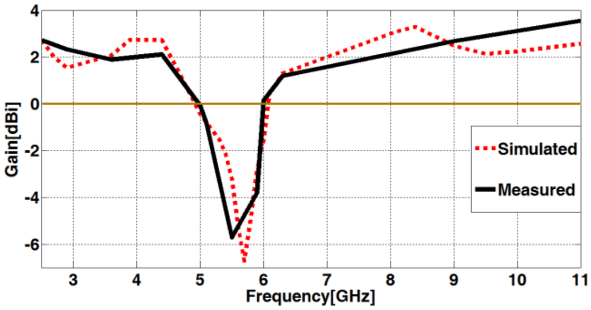


Fig. 8. Measured and simulated gain of the proposed SWB antenna.

The process contributing towards the SWB and notch band is explained by the current distribution density over the antenna. Figure 9 shows the current distribution at the notch's center frequency of 5.8 GHz, which is strong over the feed-line, the base of the octangular ring and the rectangular strip. The concentration is also strong over the defected ground-plane in the vicinity of the feed-line. The photograph of the proposed SWB antenna is shown in Fig. 10. The measured reflection-coefficient, shown in Fig. 11, verifies its outstanding performance up to 40 GHz. Both the impedance bandwidth and radiation patterns were measured by using the Agilent 8722ES network analyser in its full operational span (500 MHz – 40 GHz).

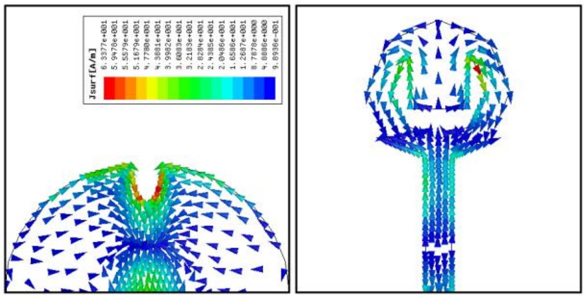


Fig. 9. Surface current density distribution of the proposed SWB antenna at 5.8 GHz over the defected ground- plane, feed-line, and the patch.

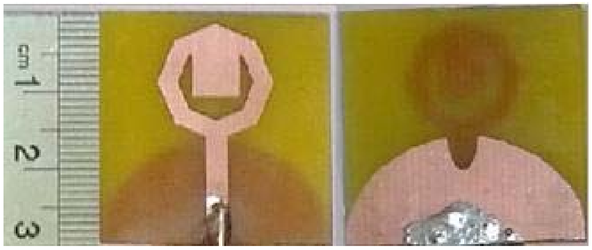


Fig. 10. Photograph of the front and back side of the SWB monopole antenna.

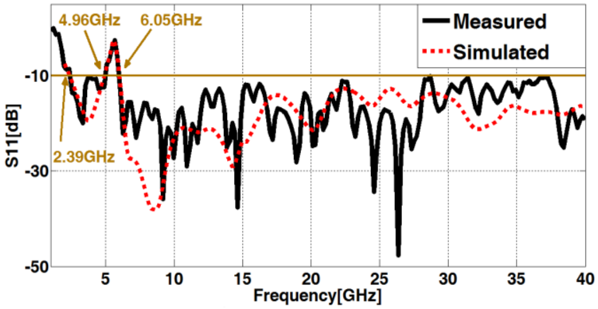


Fig. 11. Measured and simulated return-loss of the proposed antenna.

IV. CONCLUSION

Proof of concept is reported of a novel compact printed monopole antenna for super wideband applications. The antenna possesses a single band-notch characteristic necessary to mitigate interfering signals from WLAN systems. The proposed antenna has advantages of low-cost, compact size, and ease of fabrication. The measured results show an excellent 5 GHz – 6 GHz rejection band feature, super wideband performance (2.39 GHz – 40 GHz) and good radiation patterns in the UWB operating band. These characteristics make the antenna a viable choice for future SWB wireless applications.

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