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DESIGN OF A DUAL-BAND REJECTION PLANAR ULTRA-WIDEBAND (UWB) ANTENNA

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Abstract: A novel Slotted-Decagon-Shaped (SDS) antenna is presented for Ultra Wide Band (UWB) applications. This antenna has two slots; the first one is printed on the lower side, and the second on the upper side of the conducting patch. The feeding technique used to feed this antenna is a 50Ω strip line. Return losses, bandwidth, radiation pattern, and, gain of the presented SDS antenna are tested. These characteristics denote it fitting for UWB wireless communication systems. The SDS antenna was fabricated and tested at the laboratories of the Iraqi-ministry of science and technology and the result shows a fine agreement between simulation and measured S_{11}. The SDS antenna has a compact size of 19.3mm×36mm×1.6mm. Measured results show that the SDS antenna has favorable properties of S_{11} less than −10 dB and a quasi-stable gain of 2 to 4.5 dB over UWB, with the exception of the notched WiMAX (3.3-3.7 GHz) & WLAN (5.1-5.8 GHz) bands.

Keywords: *WiMAX, WLAN, UWB, VSWR, PCB.*

1. Introduction

Ultra-Wideband (UWB) is a foundation for several different wireless communication technologies. In 1896, the first UWB Communications framework was made to interface two mailing stations in excess of a mile separated.

Pulse Broadcasting was used by the United States armed forces in the 1950s to hide an image, radar, and stealth communication [1]. It's also why UWB has resulted in an increase in antenna design, with both new potential and difficulties [2]. UWB systems have an unprecedented opportunity to influence communication systems, the enormous bandwidth available, and the potential for a very low-cost operation that leads to widespread use, all present a unique opportunity for UWB technology to influence the way people interact with communication systems [3]. Moreover, UWB transmission rates are incredibly low. It gives a strong and secure interchanges framework in view of the energy levels [4]. Since the motivation radio UWB signal transmission is at baseband, it is modest and easy to run. Between 3.1 GHz and 10.6 GHz, the Federal Communications Commission (FCC) distributed UWB applications in February 2002 [3, 4]. The FCC Judgment has determined that UWB systems can employ any signal that occupies UWB frequency range [4]. Therefore, UWB covers all impulse radios and everything else that meets all the UWB specifications [5].

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Impulse radio-based UWB systems are capable of transferring data at a higher pace than narrowband frequency carriers. To avoid interference, certain UWB applications must reject unwanted frequency ranges employing discrete band-stop filters [6]. The main challenge in building UWB antennas is to give a wide transmission capacity while saving a high addition and extraordinary radiation productivity [7]. Over the preceding decade, various scholarly approaches have been employed. Radiation patch or ground plane slot arrangements are the most often utilized ways for rejecting undesired frequency bands and lowering antenna size [8]. In addition, the UWB antenna design introduces extra challenges [9].

The 5-6 GHz band, as appointed by the FCC, is additionally utilized by other existing narrowband administrations, for example, IEEE 802.11a WLAN and HIPERLAN/2 WLAN, which use UWB development [10]. In general Interoperability for Microwave Access (WiMAX) is used in a couple of nations all through Europe and Asia. It is between 3.3 GHz and 3.7 GHz. Only one band will be ejected per notch structure. Many slot layouts are necessary to generate multiple notched bands [11]. The purpose of this work is to present a compact UWB antenna with dual-band indents carved into the emanating patch to give scored band attributes [12]. The antenna is compact in size- and ranges a UWB frequencies are 3.1 to 10.6 GHz. WiMAX (3.3-3.7 GHz) and WLAN (5.1-5.8GHz) are two groups [13]. An antenna model was designed, , and analyzed to demonstrate this notion; The suggested work is divided into components. Section 2 discusses the antenna geometry, Section 3 Discusses the results, and Section 4 covers the conclusions of this work.

2. Design and Performance of Antennas:

The proposed SDS design consisted of a Decagon-Shaped patch with side length of 6.2mm, and 0.035mm thickness. Figure 1 illustrates the proposed SDS antenna with two adjusted slots. The SDS was designed on a standard FR4 substrate with a relative permittivity (ε_r) of 4.3, a tangent loss (tan δ) of 0.02, and dimensions of (42 x 36 x 1.6) mm^3. The dimensions of the ground plane are (19.3 x 36 x 0.035) mm^3. The patch antenna is equipped with 50-ohm microstrip feed line that matched the characteristic impedance of the coaxial cable. Table 1 presents the optimized values of the antenna parameters. These parameters are determined by a comprehensive parametric study using CST-Studio software.

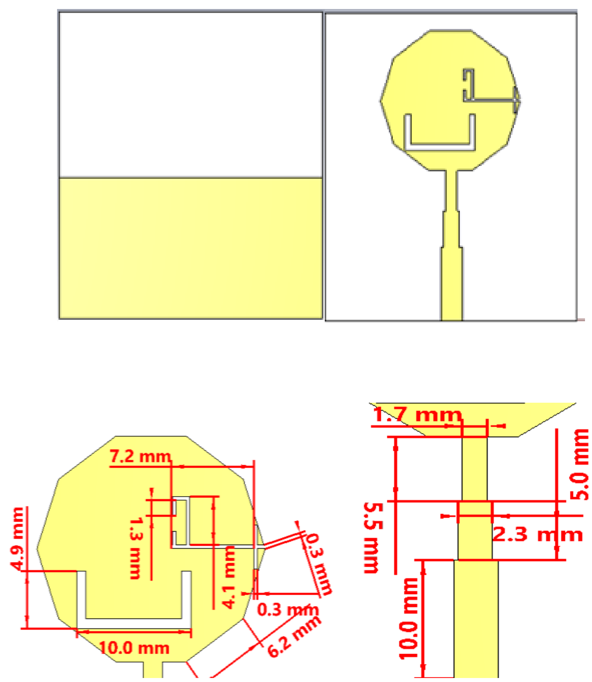


Figure 1. Proposed UWB antenna combinations

Table 1. The best value for antenna Parameters

Parameters	Value	Parameters	Value
L_S	42mm	W_f	3mm
W_s	36mm	t	0.035

L_g	19.3 mm	h	1.6mm
W_g	36mm	R	10mm
L_f	20.5mm	ε_r	4.3

The main problem in band notching implementation is determining the optimal location of notching structures in the feed line, radiating patch, or ground plane in order to properly omit the unwanted frequency bands. The proposed notching structures are oriented in order to generate the highest possible current density. The proposed antenna is analyzed with and without band notching functions. The first form UWB antenna is constructed, and the findings demonstrate that the suggested antenna covers a broad frequency range. Band notch functionality is accomplished by creating slots in the radiating patch. These notches act as band-reject filters to vanquish the unwanted frequency bands as shown in Figure 1. The band notches are implemented using the following formulas.

$$Fr = \frac{C}{4L\sqrt{\in eff}} \quad (1)$$

$$\in eff = \frac{(\in r + 1)}{2} \quad (2)$$

Where ***L*** represents the length of the first slot, ***Fr*** is the indent frequency, C is the speed of light, and ($\boldsymbol{\varepsilon_r}$) is the substrate's dielectric consistent.

Considering the second slot, the relationships listed below are used.

$$L_2 = \frac{\lambda g}{2} \quad (3)$$

$$\lambda g = \frac{c}{fr\sqrt{\varepsilon eff}} \quad (4)$$

Where $\boldsymbol{L_2}$ indicates the slot length, $\boldsymbol{\lambda g}$ is the wavelength of the targeted frequency.

2.1. Structure with Notches for 3.5, 5.5 GHz

The suggested UWB patch antenna performance has been investigated. CST Microwave Studio software is used to create and simulate the antenna. First starting with simulating the conventional circular patch UWB monopole antenna and obtained a VSWR of less than 2 and a S_{11} less than - 10 dB for the entire UWB frequency range (3.1–10.6 GHz). Second, create a notch on the main radiating patch at a center frequency of 5.5 GHz. Figure 3 presents the surface current distribution for proposed structure. As seen in Figure 3, the VSWR values obtained are greater than 2 in frequency range of (5.1-5.8) GHz, indicating that the antenna demonstrated a notched band over WLAN.

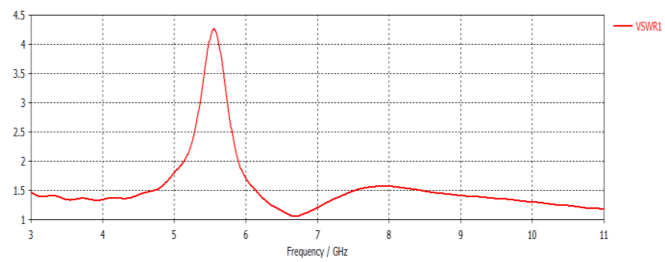


Figure 2. Demonstrates the influence of 5.5 slot length on VSWR.

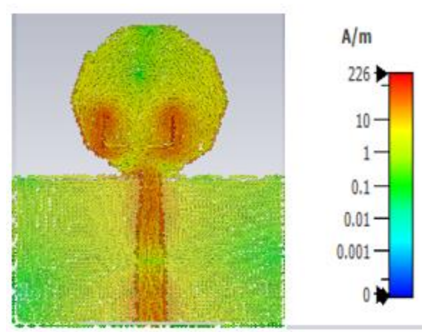


Figure 3. Surface Current Density for 5.5 GHz

Thirdly, the second structure is optimized for notch generation at 3.5 GHz. The developed antenna incorporates a notch to suppress undesirable frequencies centered on 3.5 GHz. The proposed structure's surface current density is depicted in Figure 4. Figure 5 illustrates the antenna's simulated VSWR over the entire UWB. Likewise, the outcomes show a VSWR more than 2 at (3.3-3.7) GHz, demonstrating that the proposed antenna showed band rejection over WiMAX (3.5 GHz)

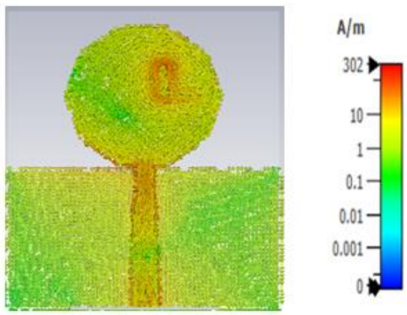


Figure 4. Surface Current Density for 3.5

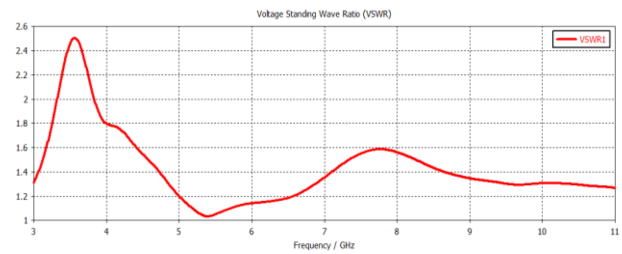


Figure 5. Demonstrates the influence of 3.5 slot length on VSWR.

3. Discussion of the Results

The following subheadings will be discussed in this section.

3.1. Reflection Coefficient

The reflection coefficient (S_{11}) indicates the percentage of power reflected back from the antenna input to the excitation port. It is expressed as a decibel (dB) value and can be calculated as follows:

$$S11 = -20\log_{10}\left|\frac{Zin - Zo}{Zin + zo}\right| \qquad (5)$$

where Z_{in} is the proposed antenna's input impedance and Z_o denotes the 50 SMA connector's characteristic impedance. The SDS antenna simulated results with and without notches are presented in Figure 6.

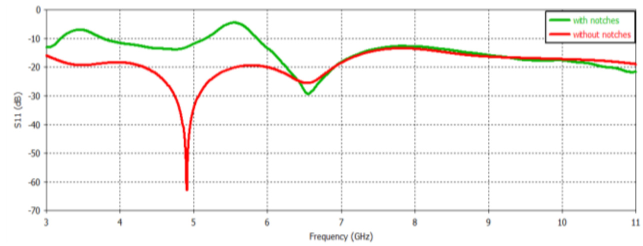


Figure 6. (S_{11}) return loss curves with and without notches.

3.2. Voltag Standing Wave Ratio

The VSWR ratio is defined as the difference between the maximum and minimum voltages in the transmission feed line of the antenna. Figure 7 compares the simulated performance of the proposed SDS antenna with and without notches. Without notches, the proposed antenna has VSWR of less than 2 across the whole UWB frequency range. While at 5.5 and 3.5 GHz, VSWR exceeds 2 due to the influence of the notches. This shows that the notch filters parameters have been adjusted to ensure sufficient spectrum rejection in the WLAN (5.1–5.8 GHz) and WiMAX bands (3.3-3.7GHZ).

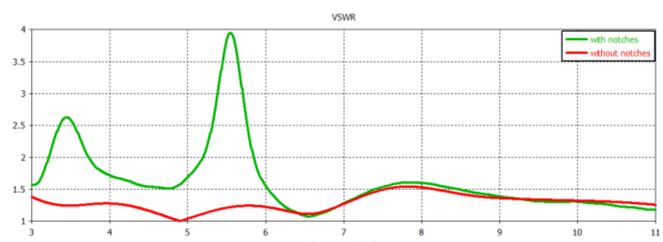


Figure 7. shows the VSWR curves (with and without notches).

3.3. The Gain

At 3.5 GHz and 5.5 GHz, the gain of the SDS antenna drops to less than 1.5 dB because of the notches impact. This shows the band suppression in the WiMAX (3.3-3.7 GHz) and WLAN (5.1-5.8 GHz). Outside these bands, the antenna gain increases dramatically to maximum of 4.5 dB at 9 GHz. Figure 8 illustrates the proposed SDS antenna gain-bandwidth with and without dual-band notches.

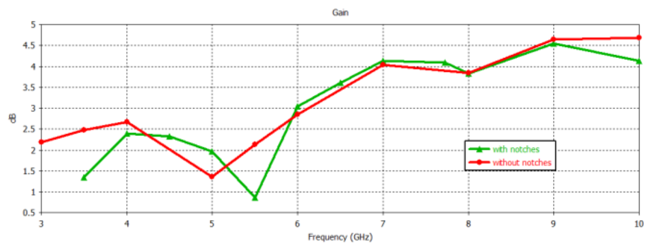


Figure 8. Gain of the UWB patch antenna with a band-notched pattern.

3.4. Surface Current Distribution

Microwave studio programming is utilized to analyze the radiation properties of the dual-band notched SDS UWB antenna at frequency of 4 GHz as shown in Figure 9. Figure 10 shows the 2D and 3D radiation patterns of the adjusted SDS antenna at frequency of 8 GHz.

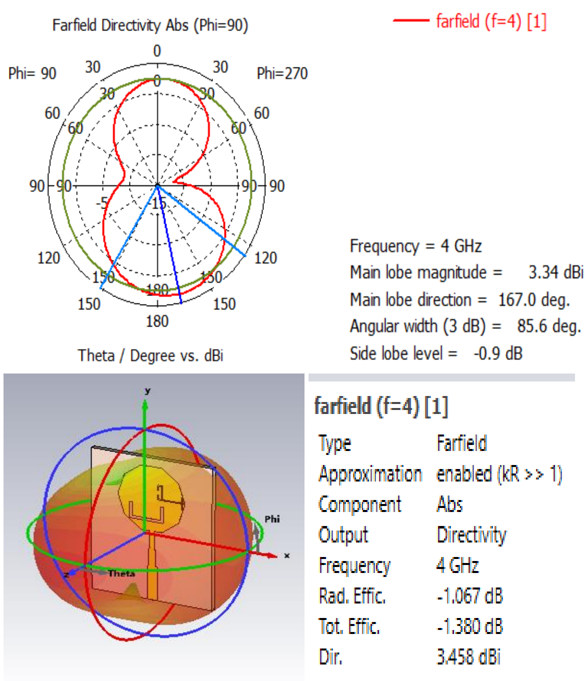
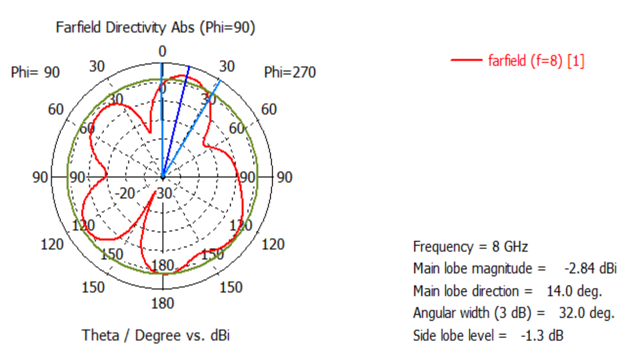


Figure 9. Radiation pattern at (4) GHz and (3D) view.



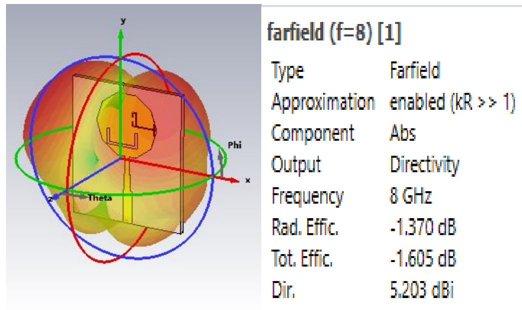


Figure 10. Radiation pattern at (8) GHz, and (3D) View.

4. Conclusions

In this work, a Slotted-Decagon-Shaped patch antenna is designed for double band rejections in the UWB frequency range. The proposed antenna is analyzed to have small-size, low-cost features, and then be implemented. The designed SDS have the feature of rejecting unwanted frequency bands, and its characterized as follows:

1. Microstrip Decagon-shaped patch antenna operating at UWB range at (3.1-10.6) GHz.
2. The antenna is compact in size, and easy to manufacture, it is implemented with dual-band notches, by etching slots for changing the current distribution at the patch, removing the interference, by rejecting the frequency ranges of, WIMAX at (3.1-3.8) GHz, WLAN at (5.1-5.8) GHz. the SDS antenna has a suitable performance in terms of, S11, VSWR, and gain. The rejection levels of the dual band-notched design have been compared with those available in the literature. The proposed SDS antenna shows acceptable band-notched characteristics in terms of radiation patterns, gain, and reflection coefficient.

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