



DESIGN AND FABRICATION OF A MONOPOLE ANTENNA WITH DUAL-BAND NOTCHED CHARACTERISTICS USING TWO C- SHAPED SLOTS AND SIR SLOT

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Abstract

For wireless applications, a compact microstrip monopole is designed, produced, and measured based on C slots and etched Stepped Impedance Resonators (SIRs). This antenna functions with two C slots with SIR slot at 3.1 and 3.9 GHz bands, respectively, and displays bi-direction and omnidirectional radiation patterns in the E and H-planes. The WiMAX band spans from 2.63 to 3.16 GHz, while the C-band spans from 3.32-4.21 GHz. The antenna's size is a mere $30 \times 20 \times 1.6 \text{ mm}^3$. With a dielectric constant of $\epsilon_r = 4.4$, a loss tangent ($\tan \delta$) = 0.015, and a thickness of 1.6 mm, the antenna on a FR4 substrate exhibits an impedance bandwidth ranging from 2.23 GHz to 6.9 GHz, according to the observed data. In the end, the simulations are validated by fabricating and measuring the antenna that was projected.

Keywords : Monopole, Microstrip, WiMAX, WLAN, UWB antenna, Decagon patch, dual band-notched

I. Introduction

Planar microstrip antennas with tolerable physical parameters are necessary for modern wireless communication systems [I, VII-IX, XIII]. Antennas for radio frequency (RF) transmission can incorporate many frequency bands into a single microstrip antenna. Its primary function is to integrate and divide signals of varying frequencies in communication networks. Recent years have seen significant

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technological advancements in microstrip passive devices, spurred by the need for more efficient and effective communication systems. The small size, simple structure, low cost, and great performance characteristics of these passive devices are all thanks to microstrip technology and its unique qualities. It is attracting a lot of attention from researchers because of its potential utility in future UWB applications. Hence, various planar microstrip antennas with various geometries have been experimentally characterized [IV- X].

Existing wireless communication systems, including high data rate WLANs for IEEE 802.11a running, will be interfered with by UWB systems operating in the frequency range of 3.1 to 10.6 GHz.

WiMAX bands are typically at 2.5/3.5/5.5 GHz, while WiFi are at 2.4/5.2/5.8 GHz. So, as mentioned in [II, IV], a UWB antenna is needed with the ability to stop both single and dual bands.

In response to the need for ultra-wideband antennas operating in these frequency bands, a number of band notch techniques were developed, each with its own unique slot shape, by making a cut in the patch, as described in references [II-V]. Other described methods in the literature, such as in [V,VI, XVII], include using different types of resonators and parasitic linked devices to reject a band. It is common practice for microstrip antennas to have two rejection bands, one for desired frequencies and one for undesirable ones. For WiMAX and WLAN applications, this work primarily aims to achieve two notched frequency bands by integrating two C slots and SIR slot into the radiation patch. It is also demonstrated how the slots produce a notch band at WLAN and WiMAX frequencies.

The sections of this article describe the simulated antenna parameters and the geometry of the monopole antenna. The results of the experiments and simulations are discussed in Section 3. Sections 4 and 5 concludes the paper with its broad conclusions and future scopes respectively.

II. Antenna Design

Figure 1 shows the simulated decagon antenna using input impedance of 50Ω , which was achieved by using the optimized design and configuration with Ansoft HFSS 15.0 on a FR4 substrate with a dielectric constant of 4.4, thickness of 1.6 mm, and loss tangent of 0.015.

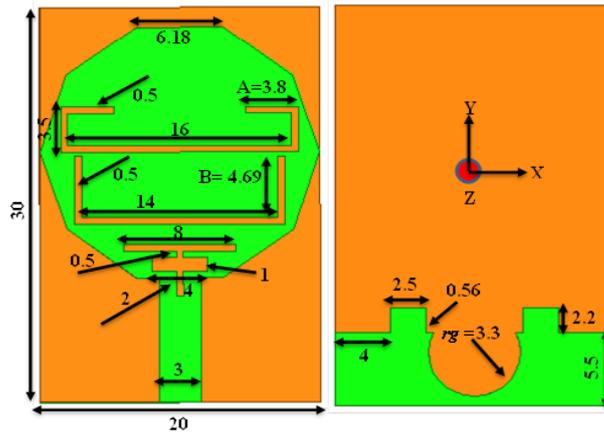


Fig.1. Structure of the antenna with decagon radiation patch, two C-shaped slots, SIR slot, two cross slots and circularly engraved in the ground plane (units: mm).

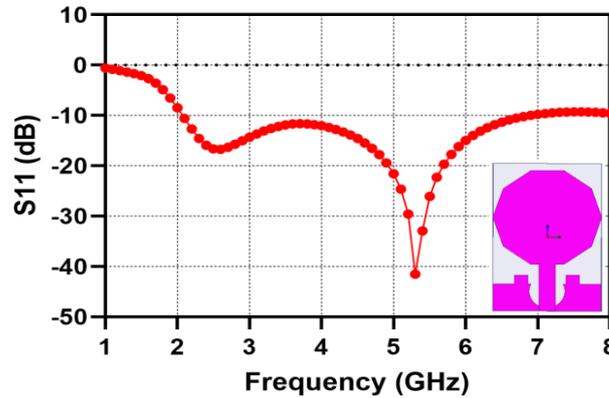


Fig. 2. Simulated scattering responses of the monopole antenna before slots etching on the patch.

Fig. 2 depicts simulated input reflection of the monopole antenna before slots etching on the patch, as reference study, in which no significant notches are appeared. In order to enhance the antenna's impedance bandwidth, the bottom side of the substrate has a circular notch etched into the ground plane, and the top side is a rectangle feedline feeding a typical Decagon monopole radiator. With dimensions of 30 x 20 mm², the monopole antenna packed a punch. As depicted in Figure 2, the slot based on stepped impedance resonators (SIR) and C-shaped slots were etched after a feedline microstrip width of 3 mm was selected for 50 Ω impedance throughout a bandwidth of 2.23 GHz to 6.9 GHz, which met the requirements of WLAN, WiMAX, and C bands. More details about SIR mathematical equations, ratios, types and variations are detailed in [XIX-XXII].

III. Effect of Design parameters

A parametric study is a straightforward method for creating small microstrip-fed monopole slot antenna that works for ultra-wideband (UWB) applications and has dual-band notch features and multi-resonance performance. The suggested antenna

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design has a number of degrees of freedom, which offer a degree of operational flexibility. Design parameters allow for this to be accomplished. The ground plane notching radius, radiator slot dimensions, and radiator slot location are only a few of the design characteristics that greatly impact antenna performance.

A. Effect of the length of the slots

See how changing the slot values (A and B in Fig.1) impacts the band-range impedance matching in Figs. 3 and 4. The movement of the slots toward lower frequency with increasing slot length values is shown in Figs. 3 and 4.

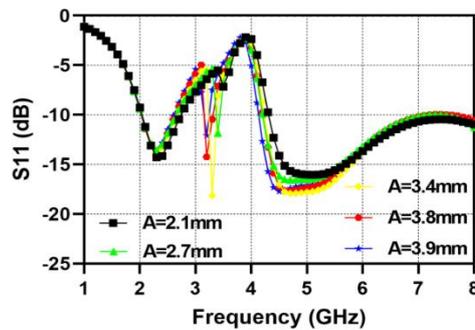


Fig. 3. Simulated S11 response of the proposed antenna with changing slot length values

A.

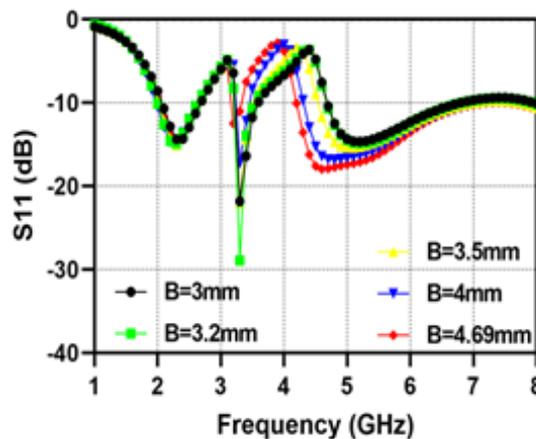


Fig. 4. Simulated S11 response of the proposed antenna with changing slot length values

B.

As illustrated in Figure 3, our design takes into account the value at $A = 3.8$ mm in order to obtain the required antenna notched band. In addition, the bandwidth and center frequency of the rejected band are affected by the change in A. Consequently, the impact on WiMAX range at low frequencies is represented by the first C-shape. Additionally, the antenna's input reflection for various slot length values (B in Fig.4) is displayed in the figure. Consequently, the second C-shape represents the impact on WLAN range at higher frequencies, which is evident in the higher band. Our design

takes into account the slot value at $B = 4.69$ mm in order to obtain the antenna's notched band, as illustrated in Figure 4.

B. Effect of the radius of rg

Furthermore, to ensure proper bandwidth adaptation, the values for the antenna's higher band notched parameters can be controlled reasonably by referring to the values of rg as depicted by Figure 5, which show the radius of the small circular on the ground plane (see Fig. 1). For this calculation, we will use $rg = 3.3$ mm.

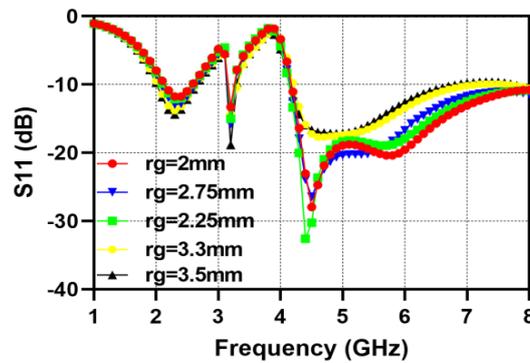


Fig. 5. Simulated variation of S11 with frequency based on change of radius of the circular values rg .

C. Effect of the position slots

The design monopole antenna's simulated input reflection is shown in Figure 6. Applying the upper C-slot for WiMAX (2.63-3.16 GHz) yielded the first notched band, as depicted in the Fig.6, with a center frequency of 3.1 GHz. The design monopole antenna's simulated input reflection is shown in Figure 7. The lower C-slot for WLAN (3.32-4.21 GHz) was used to obtain the second notched band, which has a center frequency of 3.9 GHz, as illustrated in the figure. Applying dual C slots with lower SIRs is necessary to achieve dual notched bands.

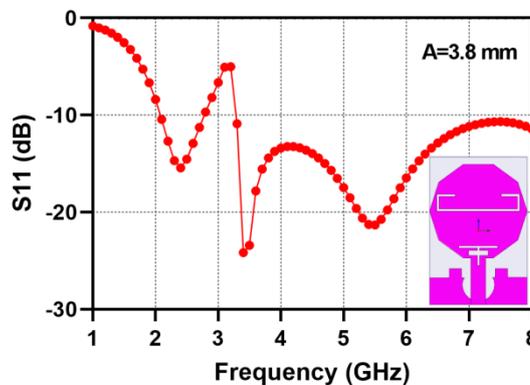


Fig. 6. Simulated return loss of the proposed antenna with the upper C slot and SIR slot only.

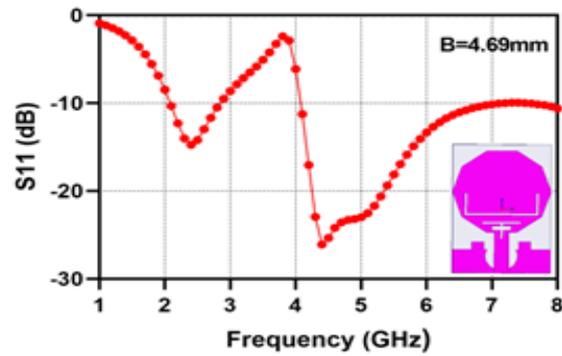


Fig. 7. Simulated return loss of the proposed antenna with the lower C slot and SIR only.

The use of upper and lower C slots with SIR slot to create the two notched bands is clearly demonstrated in Figures 6 and 7. You can alter the dual band notched characteristics by adjusting the C slots and SIR lengths. The following equations can be used to determine the slot length:

$$L \sim \frac{C}{2f_{notch} \sqrt{\epsilon_{eff}}}$$

$$\epsilon_{eff} \sim \frac{1+\epsilon_r}{2}$$

IV. Results and discussion

The Ansoft simulation program (HFSS-v15) is used to model and fine-tune the antenna that is being suggested. Figure 1 shows the optimal dimensions of the antenna that was designed. Figure 8 displays the suggested antenna's input reflection, both in terms of simulation and measurement. Results from both the simulation and the measurements show a high degree of concordance. The front and back faces of the manufactured antenna are depicted in Figure 9. As shown in Figure 10, the predicted antenna was made utilizing a computer numerical control machine. In order to verify the accuracy of the simulation, the input reflection and impedance bandwidth were measured experimentally using an Arinst vector network analyzer.

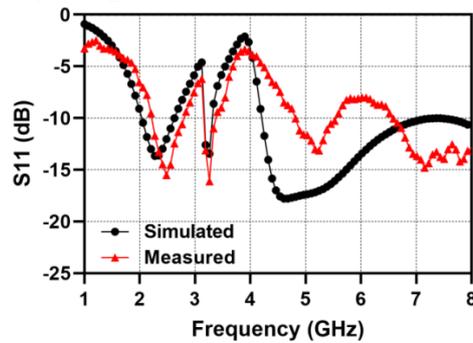


Fig.8. Simulated and measured input reflection of antenna.



Fig. 9. Antenna prototype

Figure 10 shows the E-plane and H-plane simulated radiation patterns of the proposed antenna at 3.1, 3.9, 5.6, and 2.6 GHz. On the horizontal plane, the suggested antenna looks like a monopole antenna, and on the vertical plane, it can produce far-field patterns that are omnidirectional and bidirectional patterns.

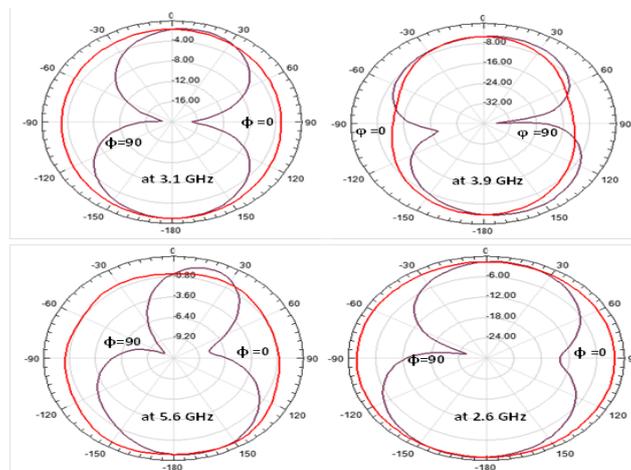


Fig.10. Radiation pattern of the antenna at 3.1,3.9,2.9,5.6 GHz with E-plane $\phi=90$, H-plane $\phi=0$.

The distribution of current at the upper and lower cutoff frequencies is illustrated in Fig. 11. The surface current is between the upper C-slot and the higher margins of the 3.1 GHz radiation zone, as can be seen clearly in Figure 11(a). This results in the first notched band since the overall radiation in this band is negligible. The surface current flows in the opposite direction from the lower C-slot to the inner margins of the 3.9 GHz radiation zone, as shown in Figure 11(b). This results in a second notched band since the radiation field in the first band is so little.

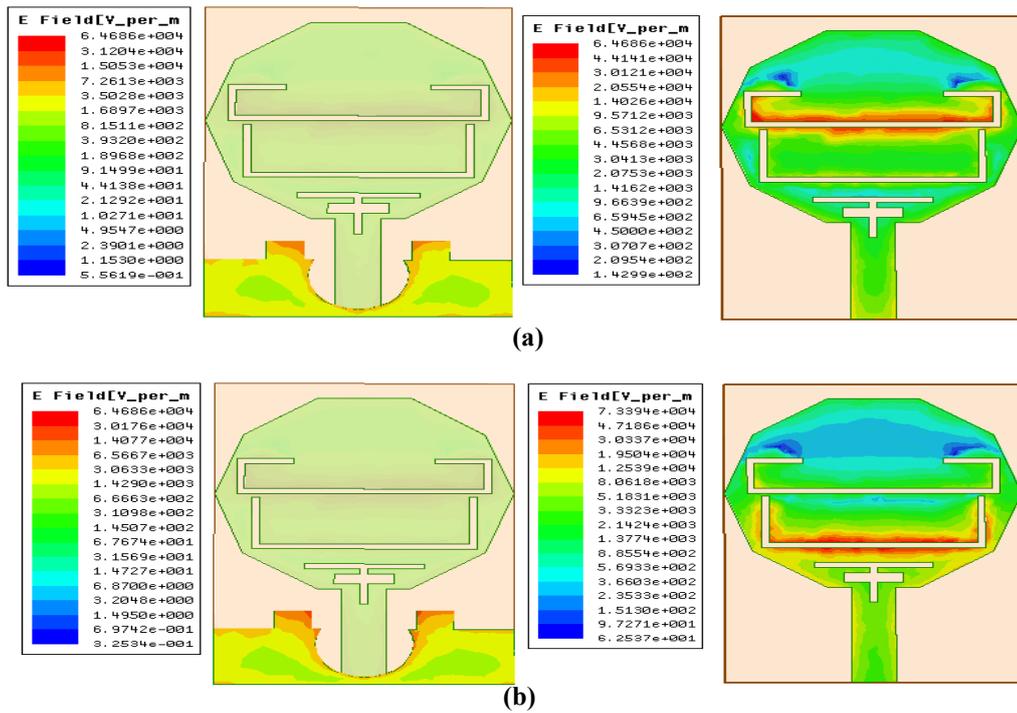


Fig. 11. Surface current distributions for radiation in upper and ground planes. (a) upper slot at 3.1 GHz (b) lower slot at 3.9 GHz.

V. Conclusions

An diminutive monopole antenna including two notch bands is showcased. For ultra-wideband (UWB) uses, this antenna was designed, built, and tested. Two C slots with SIR slot are used to provide dual band functionalities. The upper C slot is used to create the first notch band for WiMAX, which spans from 2.63 to 3.16 GHz and has a center frequency of 3.1 GHz. The second C slot is used to create the second notch band for WLAN, which spans from 3.32-4.21 GHz and has a center frequency of 3.9 GHz. The frequency range that this antenna covers, with a VSWR less than 2, is 2.23 to 6.9 GHz (102%).

VI. Future Trends

The design and fabrication of microstrip patch antennas with dual-band notched characteristics using stepped impedance resonators is expected to evolve toward greater adaptability and integration with emerging wireless technologies. Future research will likely emphasize reconfigurable and tunable notching mechanisms, enabling antennas to dynamically suppress interference across multiple frequency bands in real time. Advances in metamaterials, substrate innovations, and miniaturization techniques will further enhance performance while maintaining compact form factors suitable for wearable and biomedical applications. Additionally, the integration of artificial intelligence-

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driven optimization algorithms is anticipated to streamline antenna design, ensuring precise control of impedance and radiation characteristics. As 5G, 6G, and IoT systems expand, dual-band and multi-band notched antennas will play a pivotal role in mitigating coexistence issues, offering robust solutions for next-generation communication networks. Fractals, AI and other machine learning algorithm can be used to enhance the physical parameters of antennas [XII, XVIII]

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Conflict of Interest:

There was no relevant conflict of interest regarding this paper.

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