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Compact Monopole Circular Shape Ultra Wide Band Microstrip Patch Antenna for Wireless Applications

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Abstract: The paper proposes a compact monopole antennas structure suitable for Ultra Wide-band (UWB) systems. The antenna configuration consists of a pair of compact circular radiating patches located on one side of the substrate, with a notched ground plane provided on the opposite side. The designed antenna has a compact size of 22 × 30 × 1.6 mm³. It successfully covers the complete Ultra-Wideband (UWB) frequency range while maintaining an isolation level of around -25 dB throughout the operating band. Furthermore, the antenna exhibits satisfactory performance with respect to reflection coefficient and radiation pattern. The proposed antenna attains wide bandwidth, constant gain and stable radiation characteristics over entire UWB and is applicable for wireless applications.

***Index Terms* -** Microstrip patch antenna, Ultra Wide band Antenna, Return Loss, Radiation Patterns.

I. Introduction

Ultra-wideband (UWB) technology is well suited for short-range, high-data-rate wireless communication and a wide range of other applications [1, 2]. Various monopole antenna configurations, including rectangular patches, circular printed monopoles with stepped structures, and different slot and tapered-slot designs with tuning patches, have been reported for compact UWB antennas [3-6]. Several monopole antenna geometries have been reported in the literature for compact UWB antenna designs. An orthogonal placement of antenna elements in UWB diversity antennas effectively reduces mutual coupling while maintaining a compact design. [7-10]. The use of decoupling structures between radiating elements significantly enhances isolation. Parasitic meander lines placed between antenna elements further help in reducing mutual coupling. A compact monopole circular shape UWB Microstrip patch antenna has been proposed to improve wideband isolation beyond -25 dB while maintaining a compact size of 22 × 30 mm².

II. Antenna Design

This work proposes a compact circular-inspired monopole patch antenna with dimensions of 22 × 30 × 1.6 mm³. The antenna operates over the complete UWB frequency band (2.0–11.0 GHz) and provides an isolation level of around -25 dB throughout the operating range. Furthermore, it exhibits satisfactory performance with respect to reflection coefficient and radiation pattern. The high-frequency response of the UWB band is controlled by introducing a rectangular notch at the central section of the ground plane. The width of the microstrip feed line is set to 1.5 mm to maintain a 50 Ω impedance. Employing these design strategies allows the antenna to operate over the UWB range with consistent impedance matching. Theproposed UWB antenna was realized on an FR-4 substrate of thickness 1.6 mm, with relative permittivity 4.4 and a loss tangent of 0.024. The complete antenna dimensions are provided in Table 1.

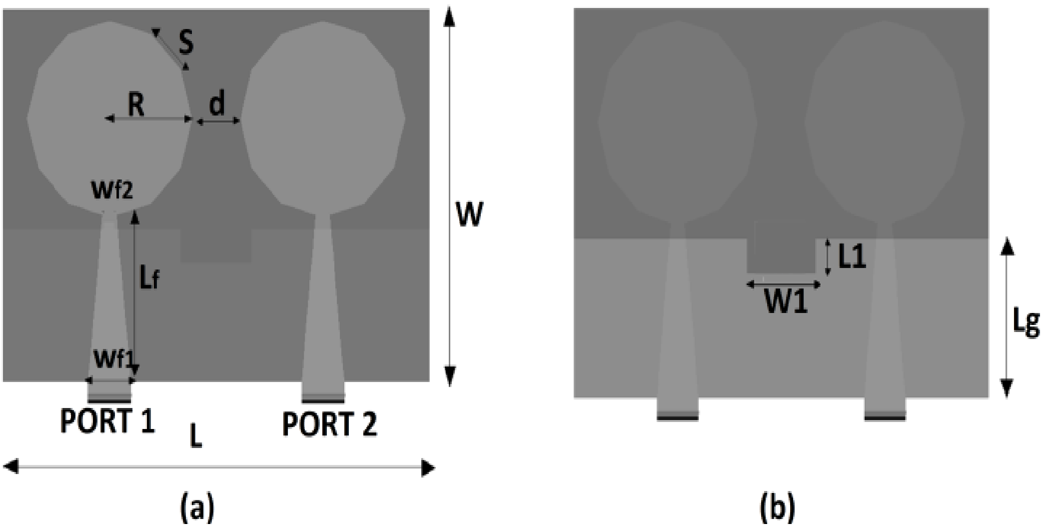


Figure 1. Proposed Circular Shape Microstrip Patch Antenna (a) Radiator (b) Slotted Ground Plane

TABLE 1 Dimensions of Proposed Circular Shape Microstrip Patch Antenna

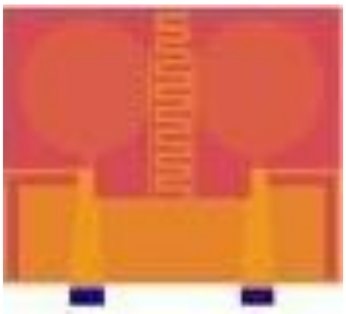
Parameters	L	W	L_f	W_{f1}	W_{f2}	R
Unit (mm)	22	30	10	3	1	5.8
Parameters	S	d	L_g	L_1	W_1	-
Unit (mm)	3	3.4	9	2	5	-

(a) Half Ground

(b) Middle Notch

(c) Meander Lines

(d) Side Stubs



(e) Inverted L shaped slits

Figure 2. Numerous Shapes of Proposed Microstrip Patch Antenna

Figures 2(a) - 2(e) illustrate the evolution of the ground plane configuration and its influence on impedance bandwidth and port isolation. Initially, a half-ground structure is employed to achieve the fundamental UWB impedance bandwidth. A central notch is employed to minimize surface current interaction between Port 1 and Port 2, thereby enhancing isolation between the antenna elements. The incorporation of meandered lines further broadens the operating bandwidth. Additionally, two narrow stubs are placed adjacent to the meandered lines to enhance isolation in the lower UWB frequency range. Finally, a pair of inverted narrow L-shaped slots is etched into the ground plane to suppress unwanted narrowband interference around the mid-frequency region (6.4 GHz).

III. Results and Discussions

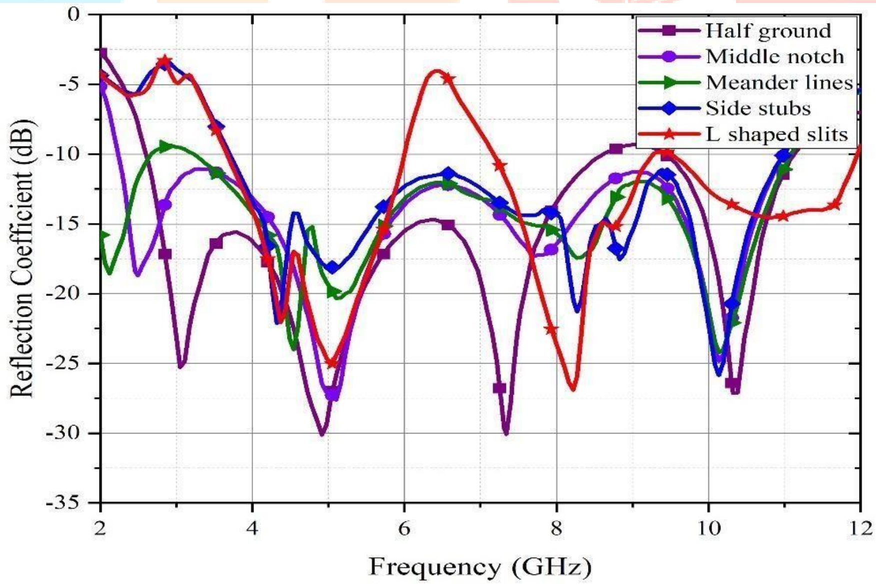


Figure 3 Reflection coefficient versus frequency graph for various ground structure of proposed antenna

Figure 3 illustrates that the initial half-ground configuration provides a wide impedance bandwidth extending beyond the UWB range. The inclusion of meandered lines contributes to further bandwidth enhancement by increasing the effective current path. When narrow stubs are added, the impedance bandwidth curve shifts toward higher frequencies. Nevertheless, the overall response still covers nearly the entire UWB spectrum, approximately from 3.7 GHz to 12 GHz.

Figure 4 illustrates the variation in isolation for different ground configurations, with the isolation remaining below -15 dB across the UWB band. It can be observed that the incorporation of meandered lines significantly improves isolation over most of the UWB range, except within a lower-frequency region of approximately 1.0 GHz bandwidth. This limitation is further addressed by introducing stubs, which enhance isolation in that region. Overall, the results confirm that the antenna maintains satisfactory performance throughout the entire UWB spectrum.

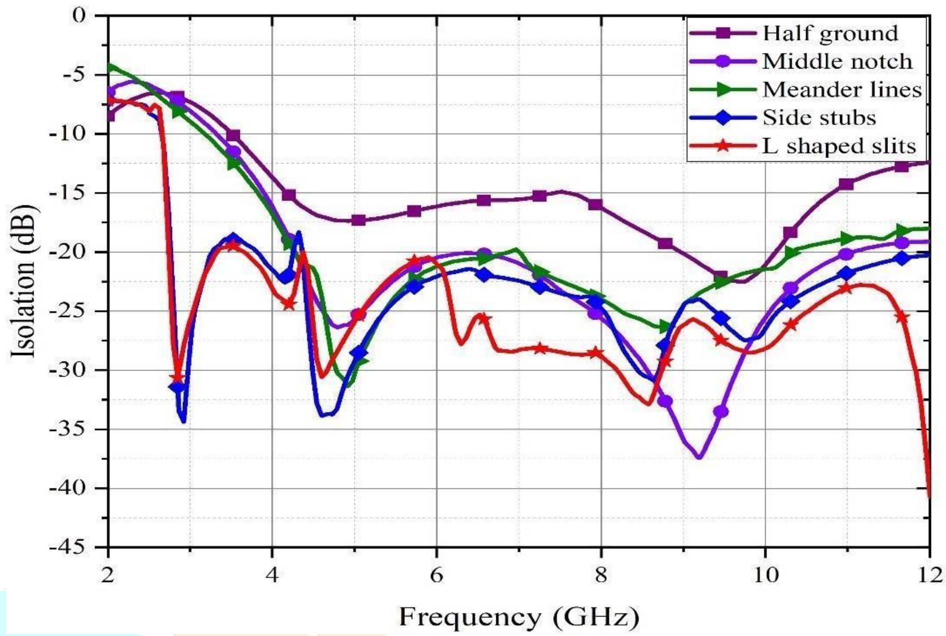


Figure 4 Isolation versus frequency graph for various ground structure of proposed antenna

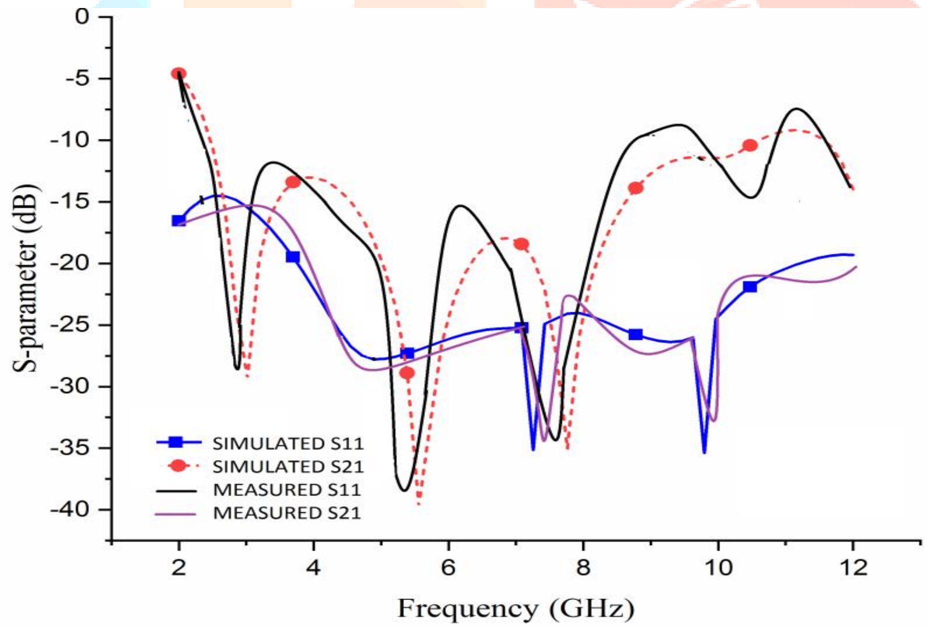
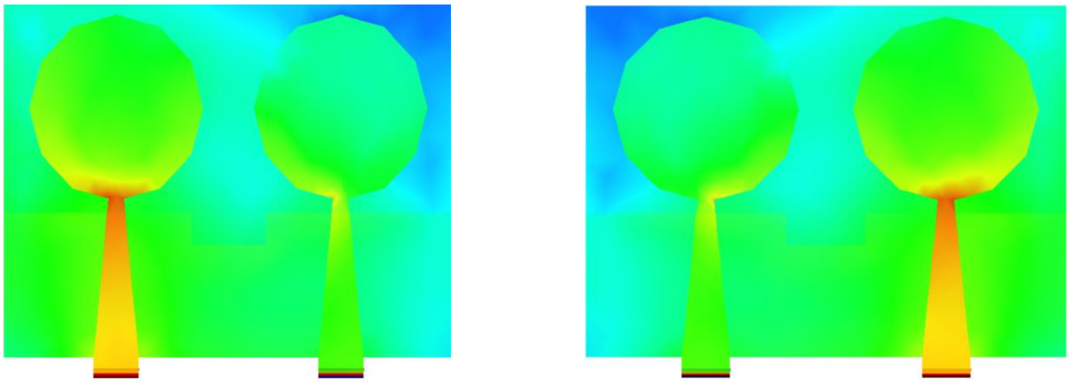


Figure 5 Simulated and measured S-parameter versus frequency graph of proposed antenna

Figure 5 presents the simulated S-parameters of the proposed antenna. Owing to the symmetrical arrangement of the radiating elements, both ports exhibit identical performance. For Port 1, the reflection coefficient (S_{11}< -10 dB) is achieved over the frequency range of 2.5 - 11 GHz, which extends beyond the complete UWB band. The isolation parameter (S_{21}< -15 dB, and below -25 dB across most of the operating range) indicates strong port decoupling, making the antenna well suited for UWB applications. Furthermore, the measured results of S_{11} and S_{21} closely match the simulated data, confirming the validity of the design.



(a) (b)

Figure 6. The surface current patterns of the proposed antenna at the resonant frequency of 5.5 GHz are presented for (a) Port 1 excitation and (b) Port 2 excitation.

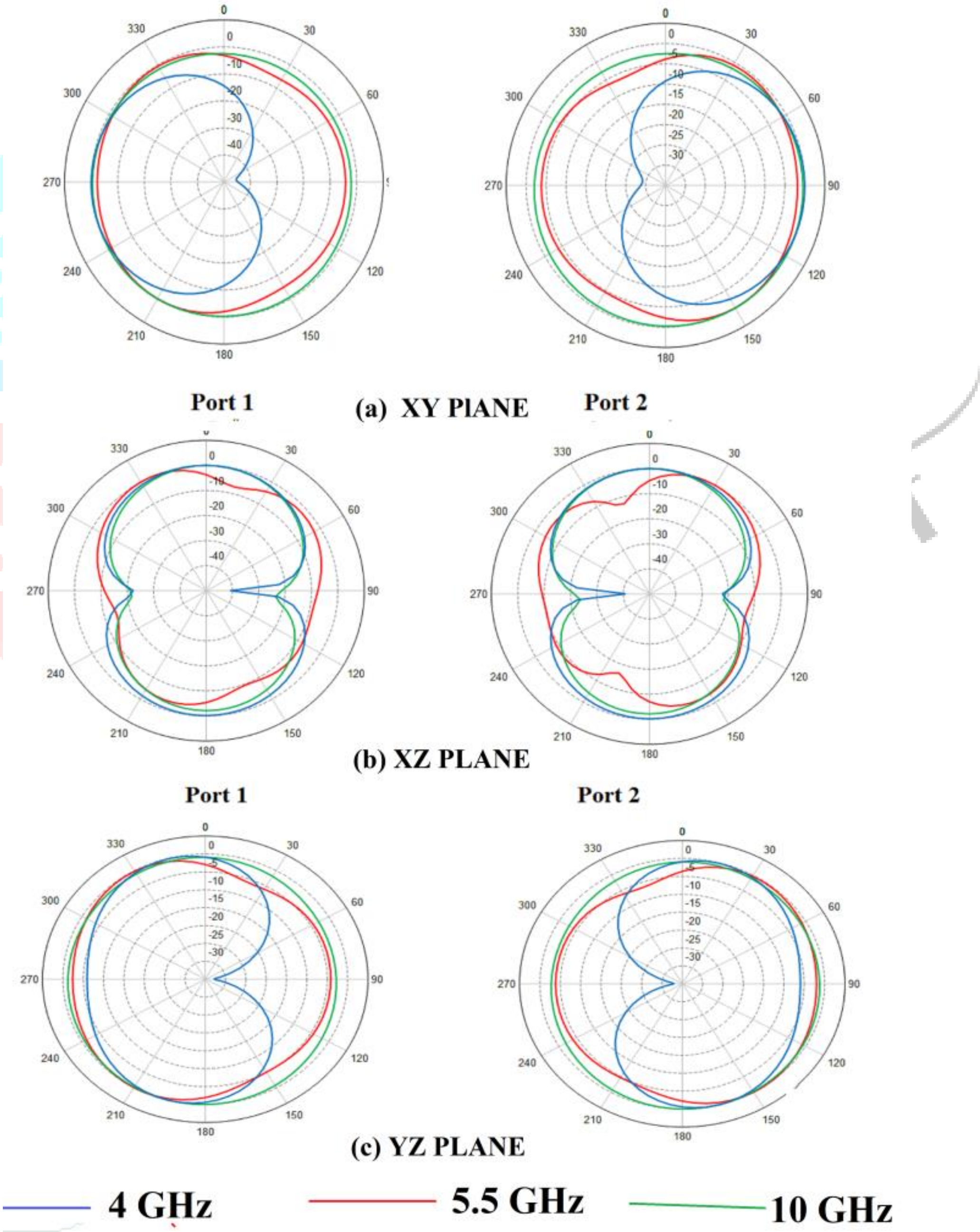


Figure 7. Figure illustrates the simulated radiation characteristics of the proposed antenna at 4.0, 5.5, and 10 GHz in (a) the x–y plane, (b) the x–z plane, and (c) the y–z plane

The isolation mechanism can be further explained through the surface current distribution shown in figure 6. Upon excitation of Port 1 while Port 2 is terminated with a 50 Ω load, most of the surface current is confined to the first radiating element, with very little interaction with the second element. This reduction in mutual coupling is attained by incorporating a rectangular cut in the central portion of the ground stub. Upon excitation of Port 2, negligible current appears on Port 1, demonstrating the strong isolation between the ports. The far-field radiation patterns at 4.0, 5.5, and 10 GHz, obtained through simulation, are presented in Figure 7, with individual excitation of Port 1 and Port 2 while the opposite port is terminated with a 50 Ω load. In the x–z and y–z planes, the radiation is generally omnidirectional, except at 4.0 GHz, where the main lobe shifts inward to 90° for Port 1 and 270° for Port 2. In the x–y plane, a quasi-omnidirectional characteristics is obtained. The figure clearly shows that the radiation characteristics of both ports are symmetrical but oriented in opposite directions.

IV. Conclusion

A compact UWB antenna comprising two circular shaped radiating elements has been proposed and analysed. For enhanced isolation between the antenna ports, a small rectangular slot is introduced in the ground plane. The antenna is designed to function over a wide frequency range of 2.5-11.0 GHz, thereby covering and exceeding the UWB band, with isolation better than -25 dB across most of the operating spectrum. Results for reflection coefficient, insertion loss, surface current distribution, radiation characteristics demonstrate satisfactory performance. The antenna also exhibits desirable characteristics, confirming its suitability for compact and portable for UWB and wireless applications.

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