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A Monopole UWB antenna with Triple Band-Notched functions

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Abstract. This study introduces a novel planar monopole antenna designed to operate across three distinct frequency bands for wireless communication applications. The antenna is constructed on a 38 x 38 mm^2 epoxy substrate made of heat-resistant (FR-4) material. Its design effectively mitigates interference arising from Wi-MAX (3.3 GHz - 3.7 GHz), WLAN (5 GHz - 6 GHz), and the X-band satellite communication uplink band (7.9 GHz - 8.4 GHz). To achieve band rejection characteristics, three slots are strategically integrated into the radiating element. The antenna design is fine-tuned through electromagnetic simulation using Ansoft HFSS software. Subsequently, a physical prototype of the antenna is manufactured and tested. The antenna's operational bandwidth spans from 3.1 GHz to over 11 GHz, exhibiting excellent radiation properties. Both simulated and measured results affirm the suitability of the proposed antenna for portable devices.

Keywords: patch antenna, UWB, Slots, band notching.

1. Introduction

Radio frequencies spanning from 0.3 to 300 GHz have garnered considerable attention for their significance in clinical applications. This interest arises from their ability to penetrate deeply and provide high spatial resolution. Wideband antennas play a crucial role in this context. The Ultra-Wideband (UWB) spectrum is particularly relevant for microwave imaging applications, especially after the Federal Communications Commission (FCC) allocated the UWB (Ultra-Wideband) band from 3.1 to 10.6 GHz for commercial use. These microwave frequencies are safe, non-ionizing, and painless.

In the realm of microwave imaging radar, the antenna is a pivotal component. Antennas are essential in communication systems. Designing an antenna with broad impedance bandwidth, compact size, stable radiation characteristics, and cost-effectiveness is a challenging task. Various shapes can be employed to achieve super-wideband characteristics, including rectangular [5], square [6], circular [7], triangular [8], pentagonal [9], curved [10], hexagonal [11], and more.

Another significant challenge is the interference that can occur between UWB and existing narrowband wireless communication systems like Wi-MAX (3300 to 3600 MHz), WLAN (5150 to 5850 MHz), satellite communication C-band (3900 to 4200 MHz), and X-band (7400 to 8400 MHz). Solutions such as filters have been proposed to mitigate this interference, but they often lead to increased cost, complexity, and size. Numerous simple and cost-effective techniques have been suggested in the literature, including the use of split ring resonators in the radiating element or ground plane [8], complementary split ring resonators [17], the addition of parasitic elements [16], defected ground structures [7], full stubs [10], and various slot configurations [6], [9], [11], [13], [14], [15].

In an effort to detect cancer in its early stages, an octagonal-shaped UWB monopole antenna is designed. This microstrip patch antenna is situated on a 29 x 27 x 1.6 mm^3 FR4 substrate and is fed by a strip line. The impedance bandwidth of the proposed antenna covers the range of

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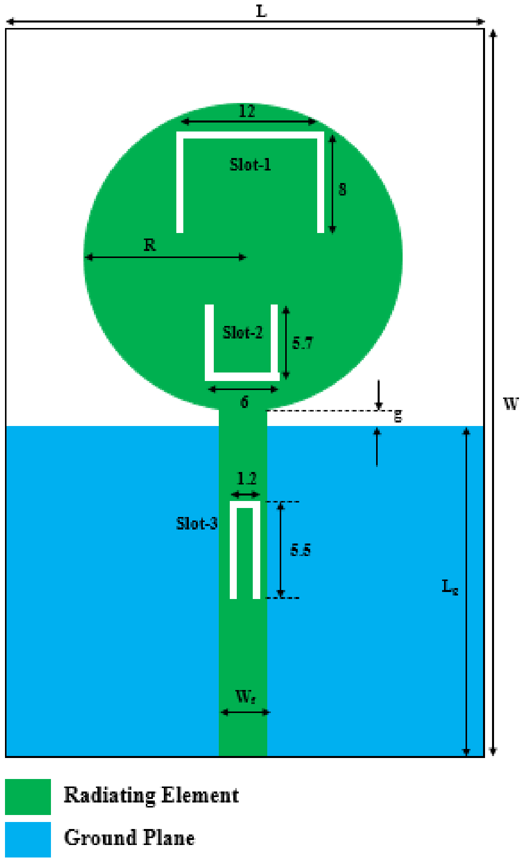
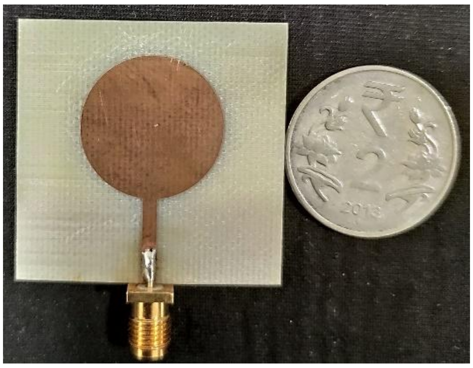
Research paper Volume 11, Sp.Iss 6 , 2022

3.1-15 GHz, encompassing the entire UWB band, making it highly suitable for microwave imaging. Simulation tests are conducted to assess its capability to identify breast cancer [16].

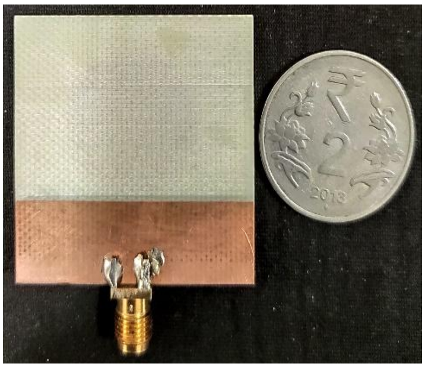
2. STRUCTURE OF ANTENNA:



(a)



(b)



(c)

Fig. 1. (a) Geometry of the proposed antenna for cancer detection. All dimensions are in mm. Prototype antenna (a) Front view (b) Rare view..

The proposed design for a circular model planar monopole antenna is implemented on a low-cost Heatproof 4 substrate measuring 38 x 38 mm² (with εr = 4.4 and tang γ = 0.019), and having a thickness of 1.6 mm. The development of this antenna began with the adoption of a circular patch structure, featuring a circular patch with a diameter of 10.2 mm. The incomplete ground plane accompanying the patch has a length of 11.5 mm. To feed the antenna, a 50 Ω stripline, measuring 12 mm in length and 2 mm in width, is employed.

The proposed antenna design is subjected to simulation using the electromagnetic simulation software, High-Frequency Structure Simulator (HFSS). The structure of the antenna is depicted in Figure 1, while the key parameters are outlined in Table 1. The lower cutoff frequency, denoted as "fL," for this broadband antenna, is determined using the following formula.

ISSN PRINT 2319 1775 Online 2320 7876
 Volume 11, Sp.Iss 6 , 2022

Table 1: Design specifications of the circular monopole Antenna

Design Specification	Dimensions(mm)
L	38
W	38
g	0.5
Wf	2
L_g	11.5
R	10.2

3. Results and Discussion

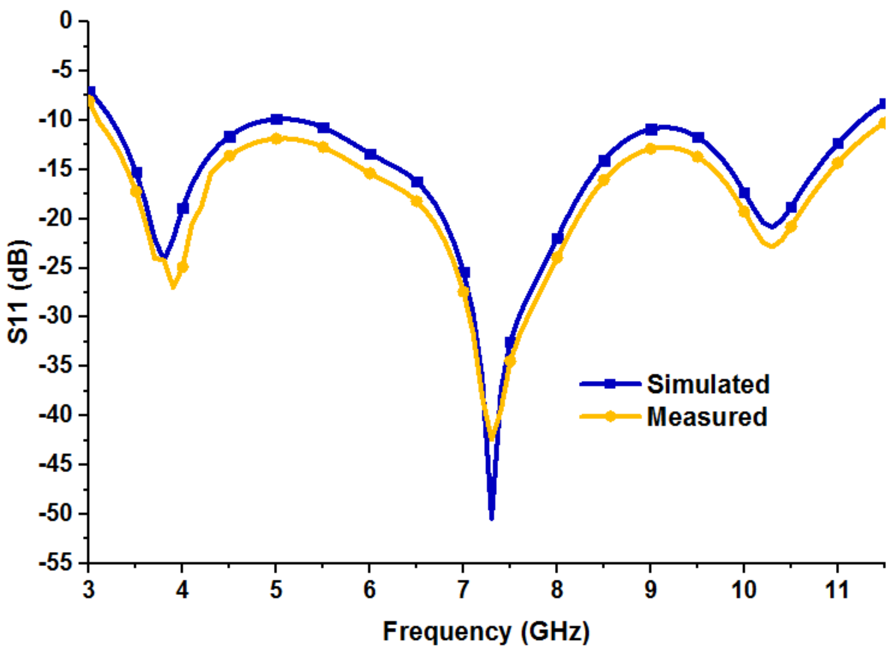


Fig. 2. S11 of the UWB antenna without band notching characteristics.

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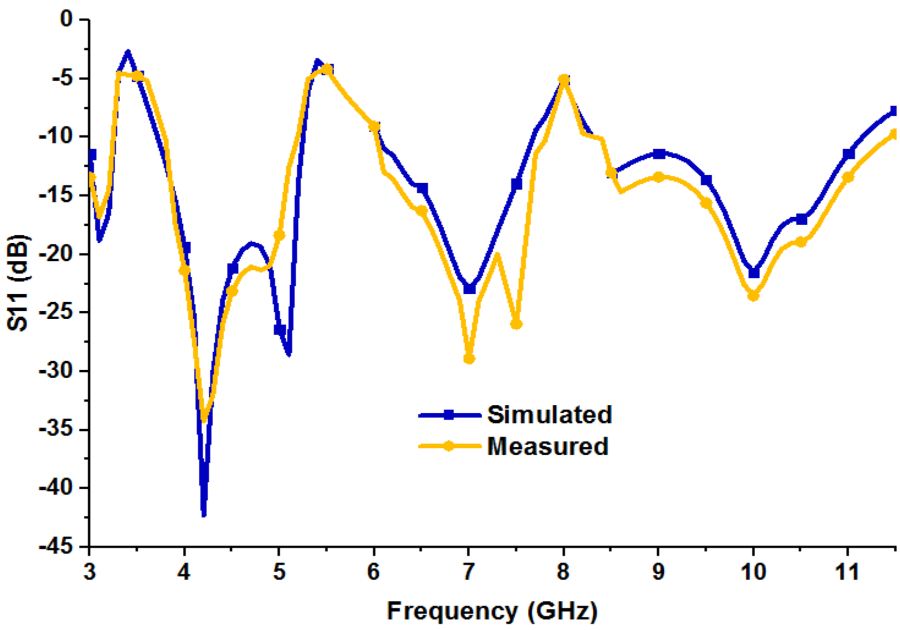

Fig. 3. S11 of the proposed UWB antenna with triple band notching characteristics.

The proposed antenna exhibits impressive impedance bandwidth, covering the frequency range from 3.1 to 11 GHz, effectively rejecting signals within three specific frequency bands associated with Wi-MAX, WLAN, and X-band, as illustrated in the figure. Furthermore, it demonstrates excellent radiation characteristics, a fact confirmed through both simulation and experimental results, shown in the figure.

Two-dimensional radiation patterns of the circular planar monopole antenna are tested in an anechoic chamber. The simulated and measured radiation patterns for the E-plane and H-plane in the passband at 3.0, 4.6, 6.9, and 10.3 GHz are presented in Figure 4. Remarkably, there is a close agreement between the simulated and experimental two-dimensional radiation patterns.

At 3.0 GHz and 4.6 GHz frequencies, the antenna exhibits nearly omnidirectional radiation patterns in the H-plane (the XZ plane). However, at 6.9 GHz and 10.3 GHz, due to the influence of higher-order resonances, the radiation patterns in the H-planes are less omnidirectional.

In the E-plane (the YZ plane), at 3.0 GHz and 4.6 GHz, the antenna shows a characteristic "bowtie" or bidirectional pattern. Nevertheless, at 6.9 GHz and 10.3 GHz, the antenna deviates from the "bowtie" pattern in the E-planes, primarily due to the presence of higher-order resonance modes.

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Research paper **Volume 11, Sp.Iss 6 , 2022**

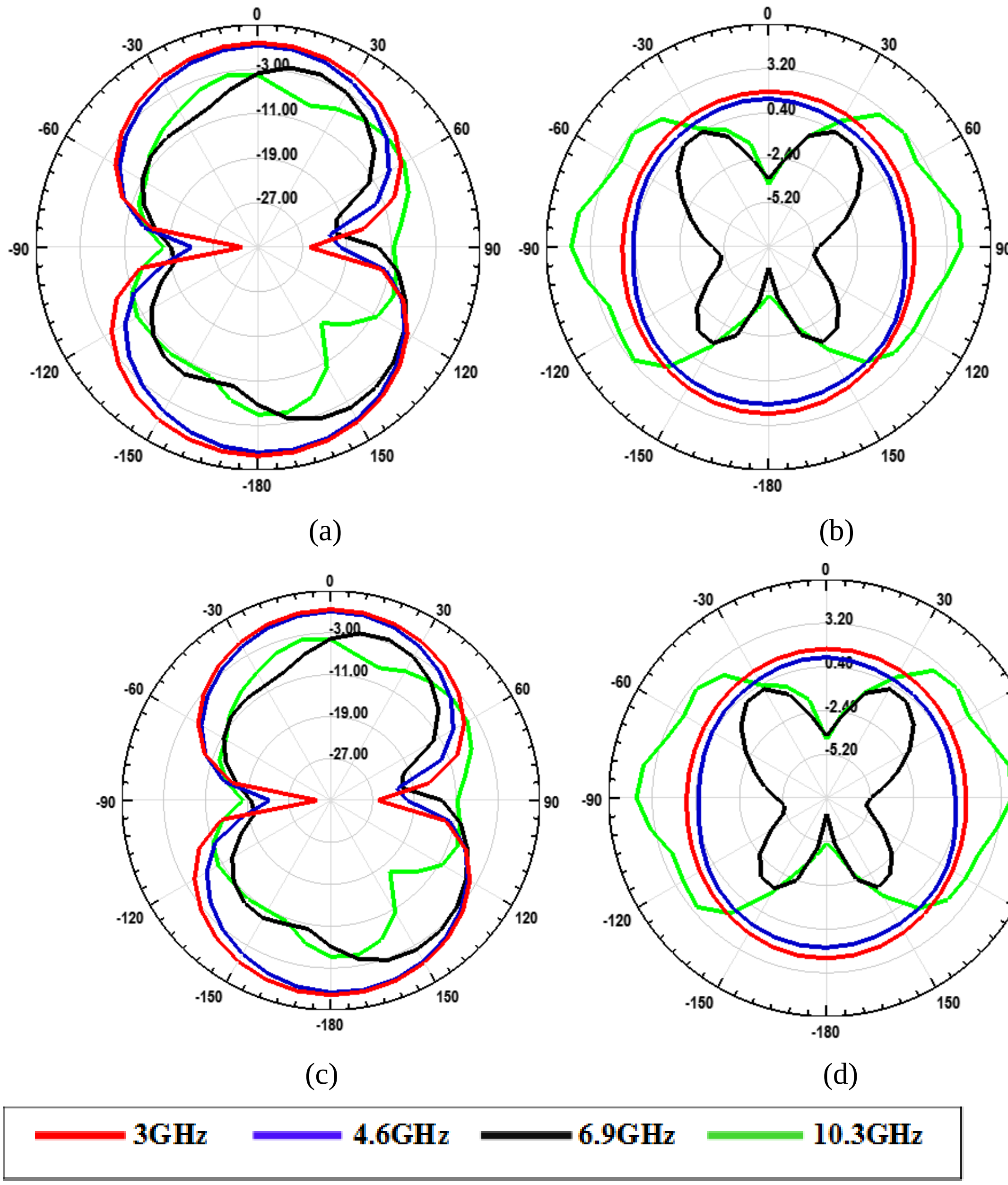

Figure 8 demonstrates that the proposed antenna produces omnidirectional radiation patterns in the H-plane, which is essential for mobile wireless devices to capture signals from various directions.

4. Conclusions

This paper introduces a triple-band notched circular planar monopole antenna. The antenna design features a circular patch, which is fed by a 50-ohm strip line feed. To achieve band-rejection capabilities, three U-shaped slots are strategically incorporated into the radiating element. The antenna exhibits triple band-notched characteristics, effectively rejecting frequencies in the ranges of 3200 - 3900 MHz (Wi-MAX), 5100 - 6000 MHz (WLAN), and 7500 - 8450 MHz (X-band).

Experimental results confirm the antenna's impressive impedance bandwidth, with S11 values consistently below -10 dB spanning from 3.1 to 11 GHz. Furthermore, the antenna exhibits strong gain and radiation efficiency across the entire operational band,

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including the notched frequency bands. Its omnidirectional radiation patterns affirm that the proposed UWB antenna is well-suited for portable UWB systems.

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