Dual-Polarized Microstrip-Fed Slot Antenna Design with Dual-Notch Filtering for Ultra-Wideband Communications

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***Abstract*—This paper aims to discuss the characteristics of a dual-port/dual-polarized MIMO slot antenna system with dual-band filtering for ultra-wideband (UWB) wireless communications. Its structure contains a pair of modified arc-shaped radiation stubs with a shared ground plane in a planar form. The stubs also contain W-shaped and open-ended rectangular slots. The ground plane of the suggested design contains an open-ended circular slot. The results indicate that the antenna operates at frequencies 3–10.7 GHz, fully covering the UWB spectrum. Additionally, two notched-band filtering characteristics have been achieved at 5.5 and 7.5 GHz to fully suppress the interfaces from other wireless systems such as WLAN and downlink of X-band satellite communication. The introduced design is examined in terms of its fundamental characteristics. It has been determined that sufficient scattering parameters, 3D radiations, efficiency, and gain levels are all achievable with the planned UWB antenna design. The proposed antenna system meets the requirements well for MIMO and diversity applications.**

Keywords*— *Dual-polarized antenna, MIMO slot antenna, notched-bands, Satellite systems, UWB systems, WLAN.

I. Introduction

Wireless communication technology using ultra-wideband (UWB) has gained a lot of attention for its inherent advantages, which include low power consumption and high transmission rates [1-2]. The frequency band of 3.1-10.6 GHz was allocated as ultra-wideband frequency ranges by the FCC [3]. Spectrum on this band interferes with some wireless communication systems, such as WiMAX, WLAN, and X-band satellite communication. As a result, UWB antennas must be capable of band-stopping [4-6]. In UWB communications, microstrip antennas are important, so their design has attracted a great deal of interest. Consequently, various UWB antennas with dual-notched bands and different geometries have been experimentally characterized [7-9].

We propose here a new polarization-diverse dual-element slot antenna system with the microstrip-line feeding technique and dual notched bands for UWB-MIMO applications. Its configuration contains a pair of modified radiation stubs with a shared ground plane in a planar form. It is constructed on an FR-4 epoxy with ε= 4.4, δ= 0.02, and an overall size of 34×34×1.6 mm^3. The simulation of the investigated antenna was evaluated using CST microwave studio 2020 [10]. The structure for this paper is as follows. Section II provides the proposed schematic diagram along with the design details for the suggested design. The fundamental characteristics and radiation performance of the introduced UWB-MIMO antenna design are investigated in Section III. The study's conclusion is presented at the end of this paper.

II. Design and Configuration Details

Figure 1 depicts how the introduced MIMO array is configured. As seen, it involves four modified U-shaped radiation stubs with a shared ground plane in a planar form constructed on the FR-4 substrate with a thickness (h_S) of 1.6 millimeter. Fig. 2 illustrates the design details of the modified radiation stub. The elements use 50 Ω microstrip feedlines and the proper dimensions of all parameters are listed in Table I.

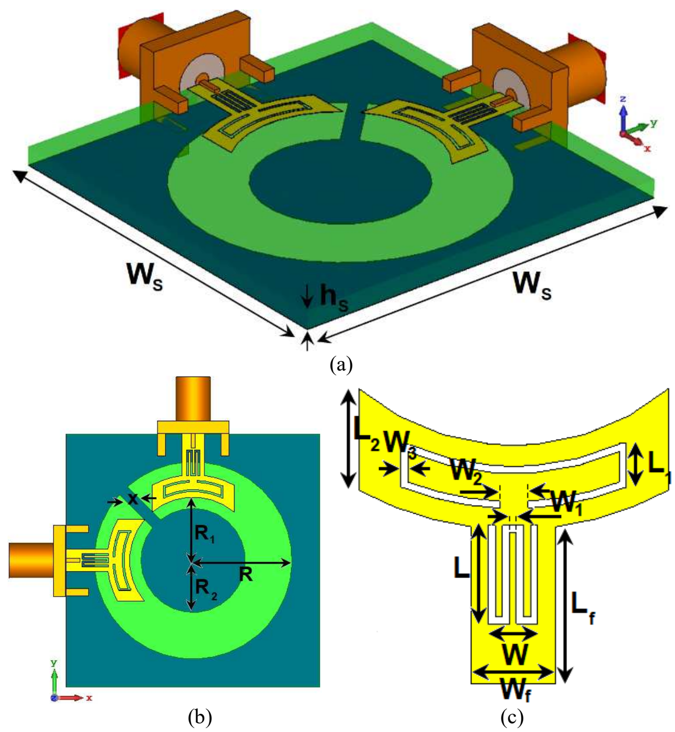


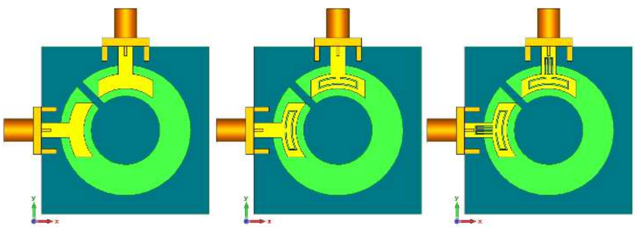
Fig. 1. (a) Side and (b) top view, and (c) the radiation stub of the investigated antenna schematic.

TABLE. I. PARAMETER VALUES

Param.	W_S	L_S	W	L	W_1
Value, mm	65	65	1.75	3.5	0.25
Param.	L_1	W_2	L_2	W_3	R
Value, mm	1.6	1	3.6	0.25	13.25
Param.	R_1	R_2	L_f	W_f	x
Value, mm	8.25	7	5.6	3	1.5

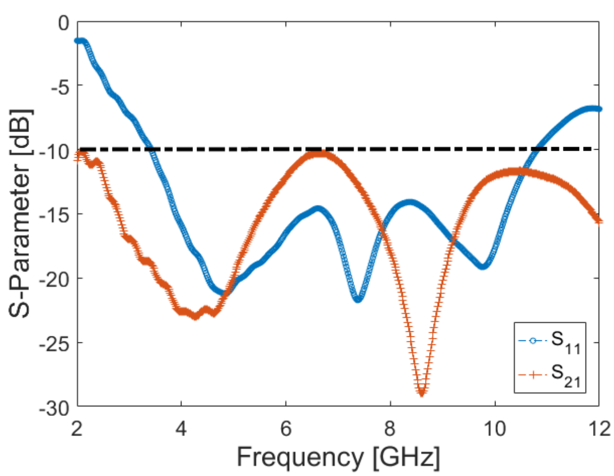
III. THE DESIGN'S ESSENTIAL CHARACTERISTICS

This section discusses the fundamental characteristics of the investigated diversity MIMO antenna for UWB applications. Various schematics of the introduced dual-polarized UWB slot antenna are illustrated in Fig. 2.

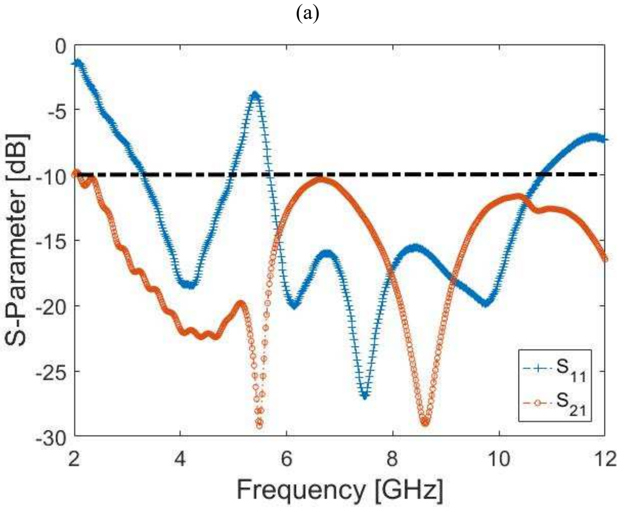


(a) (b) (c)

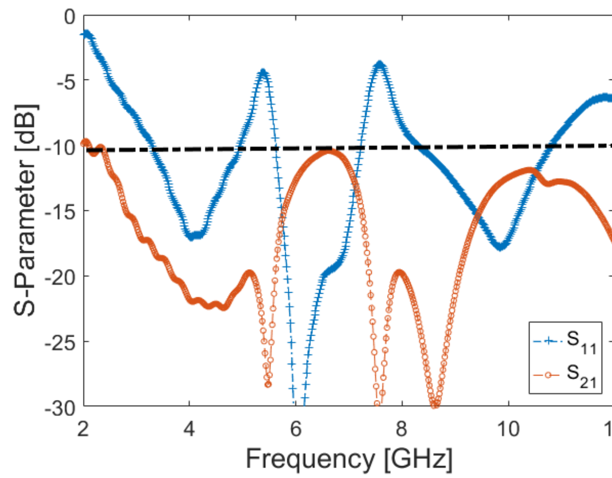
Fig. 2. Design evaluation: (a) the basic UWB slot antenna (b) modified design with open-ended rectangular ting, and (c) the suggested configuration.



(a)



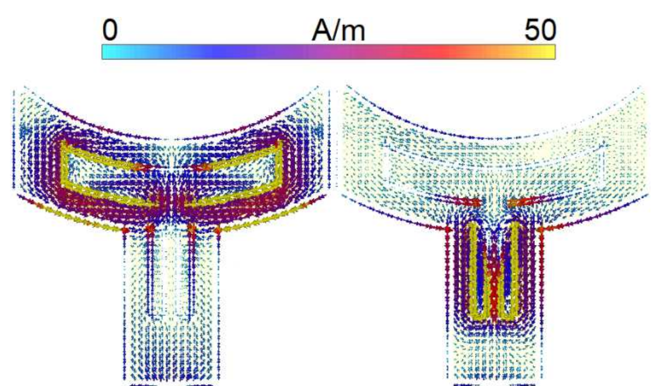
(b)



(c)

Fig. 3. S-parameter results for various configurations at (a) Fig. 2 (a), (b) Fig. 2 (b), and (c) Fig. 2 (c).

As can be seen that the basic design schematic [Fig. 2 (a)] is composed of 50-Ohm microstrip lines and arc-shaped stubs in the top layer and an open-ended circular slot in the ground plane [Fig. 2 (b)]. In the next step, compact open-ended rectangular rings have been inserted onto the radiation stub to generate the first filtering notch. Finally, W-shaped slots were cut in the top layer to create the second filtering band [Fig. 2 (c)]. The S-parameter results for this evaluation [Figs. 2 (a-c)] are provided and discussed in Figs. 3 (a-c). The results indicate that the suggested MIMO design offers an ultra-wide impedance bandwidth band supporting 3–10.7 GHz of the UWB frequency range [Fig. 3 (a)]. In addition, two notched bands have been achieved at 5.5 GHz and 7.5 GHz suppressing the interfaces from various wireless systems. As discussed in Figs. 3(a) and 3 9(b), the first notched-band at 5.5 GHz was achieved by inserting the rectangular open-ended ring slot while the W-shaped slot generate the second notched band. Moreover, As shown, the resonators of the introduced design exhibit low mutual couplings which makes it suitable for MIMO communications [11-12].



(a) (b)

Fig. 4. Distribution of the surface currents at (a) 5.5 and (b) 7.5 GHz.

The current distributions of the radiation stub at the centre of the notched frequencies are represented in Fig. 4. As illustrated, the embedded open-ended rectangular-ring slot inside the arc-shaped stub is significantly active at the first notched band of 5.5 GHz. Moreover, at the second filtering frequency of 7.5 GHz, as opposite-direction currents are confined within the W-shaped slot in the feedline, the electromagnetic energy cannot completely radiate outward, resulting in the notch function [13-14]. This verifies the impact of the filtering elements on creating the notched bands. Figure 5 depicts the simulated efficiencies over the operation range. As seen, sufficient results are discovered for the antenna. Apart from the notched frequencies, the antenna provides better than 80% and 70% radiation/total efficiencies. Besides, the efficiencies fall sharply in the notched frequencies. The maximum gain characteristic also has the same variation trend. As illustrated in Fig. 6, the gain value of the investigated antenna is approximately 3.5-5.5 dBi. In the frequency-notched bands, the antenna gain levels plummet up to -1 dBi, which can eliminate the electromagnetic compatibility issues among UWB systems and the interfacing wireless devices of WLAN and X-band systems [15-16].

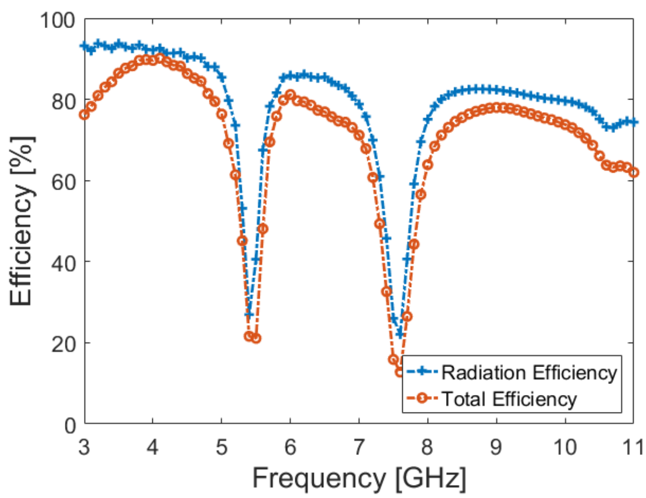


Fig. 6. Efficiency results of the element.

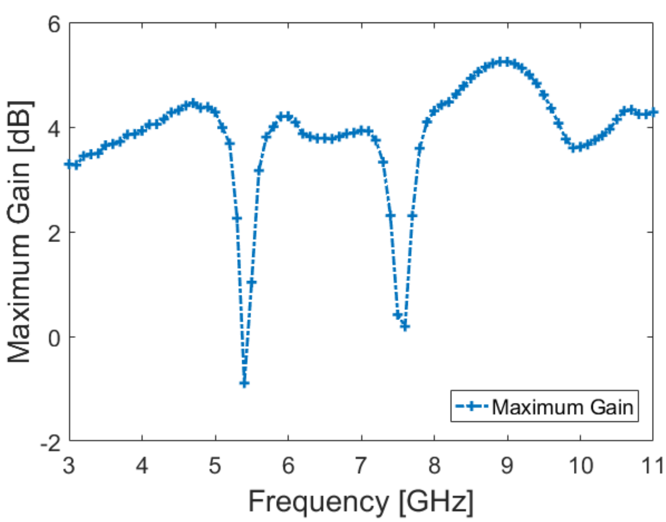


Fig. 7. Maximum gain characteristic of the single-element antenna.

3D radiation behaviour of both antenna elements at the different frequencies (including 4, 6.5 and 9 GHz) of its operation is represented in Fig. 7. It is evident from the plot that the antennas provide Omnidirectional radiations. Meanwhile, we observe well-defined diversity property for the proposed dual-port slot antenna design which supports different polarizations covering different sides of the antenna substrate [17-18].

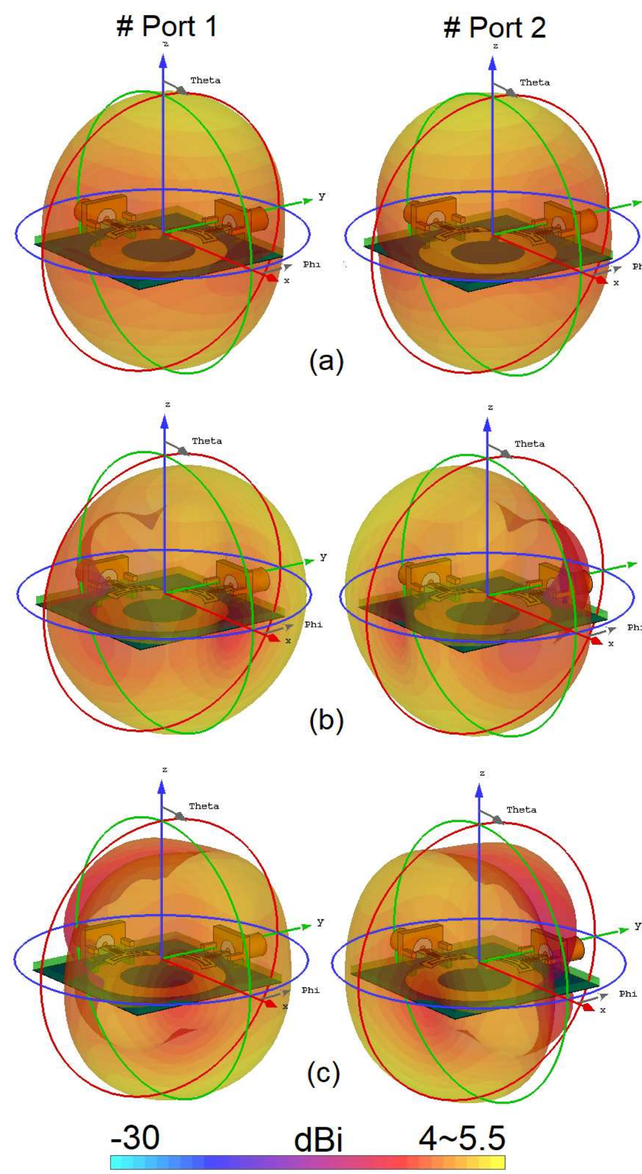


Fig. 7. 3D antenna radiations at (a) 4 GHz, (b) 6.5 GHz, and (c) 9 GHz.

IV. Conclusion

A new UWB-MIMO microstrip slot antenna with polarization diversity and dual notch bands is designed and studied in this paper. The configuration of the design contains a pair of modified slot antennas with a common ground plane arranged in a low-cost FR4 substrate. The radiation element is composed of a modified arc-shaped stub W-shaped and open-ended rectangular slots. The working principle of the antenna is explained in detail. The antenna elements offer good characteristics and cover 3-10.7 GHz with two notched filtering bands at 5.5 and 7.5 GHz. In addition, it exhibits good radiation, MIMO performance, and diversity function.

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