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Dual Rectangular Band-Rejected for a Compact UWB Microstrip Log- Periodic Dipole Array Antenna using Rectangular Stubs



Abstract: - This paper presents a compact Ultra-Wideband Microstrip Log-Periodic Dipole Array antenna featuring dual rectangular band-rejected characteristics achieved through the integration of rectangular stubs. The proposed design suppresses interference from WiMAX [3.3 - 3.7] GHz and WLAN [5.2 - 5.8] GHz bands while maintaining a wide operational bandwidth [2.0 - 11.7] GHz with stable impedance matching and consistent radiation performance. The use of rectangular stubs enables precise control of band rejection without significantly increasing the antenna's size or complexity. Simulated and measured results demonstrate excellent agreement, with sharp gain drops at the rejected frequencies, confirming effective interference suppression. This design provides a practical solution for UWB communication systems, balancing compactness, performance, and fabrication simplicity.

Keywords: UWB microstrip antenna, Log-Periodic Dipole Array, rectangular band rejected, rectangular stubs.

I. INTRODUCTION

Ultra-wideband or UWB technology has recently become a focus in industry and research due to its high data rates, low power consumption, and precise localization abilities. This entails its applicability in various fields such as sensing systems, wireless communications, and radar imaging. UWB antennas are essential because they present wide bandwidth, defined by the Federal Communications Commission (FCC) as ranging from 3.1 GHz to 10.6 GHz. Nevertheless, UWB antennas often encounter problems with electromagnetic interference brought about by current narrowband communication.

These are why researchers have developed numerous types of UWB Patch antennas with embedding band-rejection features. By using these band-rejection characteristics, which are sometimes also called notch bands, it is consequently important to maintain wideband performance and at the same time minimize the level of interference coming from the narrowband services such as WiMAX [3.3-3.7] GHz, WLAN [5.15-5.825] GHz, and X-band satellite communications [7.25-7.75] GHz. UWB microstrip antennas with band-rejected characteristics can be obtained in several manners such as slots [1], parasitic elements [2], DGS (Defected Ground Structure) [3], EBG (Electromagnetic Band Gap) [4,5] and the use of metamaterials [6].

This paper proposes a compact design of a UWB-MLPDA (Ultra-Wideband Microstrip Log Periodic Dipole Array) antenna with rectangular dual-band rejection using rectangular stubs for rejection functionality. The structure of MLPDA is selected since they possess inherently broad bandwidths and compact sizes that are suitable for UWB systems. Inserting two pairs of rectangular stubs, each connected to the microstrip feed line to reject two specific frequency bands. The design proposed keeps a compact size while providing adequate band-rejection at WiMAX GHz and WLAN.

A major contribution of this work is the ability to design multiple bands rejected for a MLPDA antenna by employing rectangular stubs without incurring a huge change in size or design complexity. Because of its basic design, it can be readily fabricated using conventional PCB techniques, and yet the control of the rejected bands can be easily achieved through variations of stub length and position. This approach provides the design compromise between simplicity and improved performance, which allows for a wide range of UWB applications where interference suppression is the primary requirement.

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In the following sections, the basics of the antenna design, the principles behind the usage of rectangular stubs, the simulation environment, and the process of optimizing antenna parameters are described in detail. Lastly, we provide a simulation and experimental outcome of the invented design along with an elaboration on the efficiency of the band-rejection technique and several potential uses of the antenna.

II. DESIGN METHODOLOGY

The microstrip or printed log Periodic Dipole Array (LPDA) antenna emanates from the conventional wired LPDA, embodying its design principles for PCB integration. The wired LPDA incorporates a logarithmically spaced repeating dipole system for broadband capacitance, but the printed design uses etched paths on a non-conductive surface. This revision facilitates a condensed, cost-effective and simple integrative antenna configuration, exploiting the precision of PCB (Printed Circuit Board) manufacture. The Microstrip LPDA maintains the essential characteristics of its wired predecessor, offering broad frequency coverage while fitting seamlessly into modern electronic systems.

The design has been initiated with a trapezoidal geometry on an FR-4 substrate. The FR4 substrate was chosen since it is commonly used in electronic applications with a relative permittivity (ϵ_r) of 4.3 and a tangent loss of 0.025. The thickness of the substrate (h) was uniformly kept at 1.5 mm throughout the design. Simulation of the antenna were done in CST Studio. The antenna is made of dipole elements placed over the substrate. The placement of these dipoles was guided by a logarithmic function to compute the length (L) and width (W) of each element, keeping the top and bottom of the antenna.

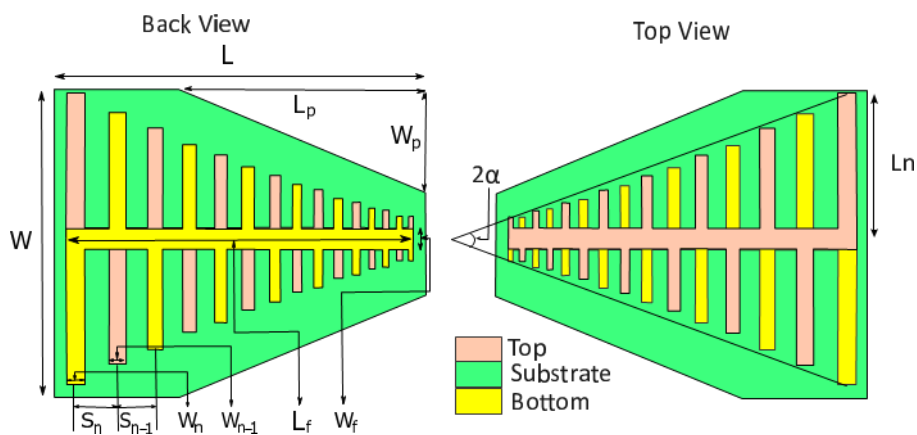


Fig. 1. Geometry of the proposed UWB-MLPDA antenna.

To achieve the UWB-required impedance matching, a predetermined distance S_i was used to separate the dipole elements. Using a scaling factor τ , additional adjustments were made to the dipoles L_i , W_i , and separation distance S_i to maximize the antenna's performance within the desired frequency range. By applying the following formulas [7], this improvement guaranteed the antenna's efficacy and efficiency in both signal transmission and reception:

$$\tau = \frac{S_{n-1}}{S_n} = \frac{L_{n-1}}{L_n} = \frac{W_{n-1}}{W_n} \quad (1)$$

This equation is used to compute the aperture angle α :

$$\alpha = \tan^{-1} \left(\frac{1-\tau}{4\sigma} \right) \quad (2)$$

The spacing constant σ is given as:

$$\sigma = \frac{S_n}{2L_n} \quad (3)$$

Additionally, the design incorporates two microstrip feed lines, positioned on the top and bottom of the antenna. These feed lines are essential for providing effective signal transmission and reception, as depicted in Figure 1. The optimized parameters for the antenna design are summarized in Table 1.

Tab. 1. Parameters of the final UWB-MLPDA antenna design.

Parameter	Value (mm)	Parameter	Value (mm)	Parameter	Value (mm)
L	75	W_f	4	T	0.86
W	60	L_p	50	L_{15}	26.3
h	1.5	W_p	20	S_0	1
N	15	w_1	1	A	10.63
L_f	70	S_1	0.6	Σ	0.18
t	0.035	L_p	50		

The finalized design of the UWB-MLPDA antenna is illustrated in figure 2, displaying its key components, including the deliberately placed dipole elements, a trapezoidal geometry, and an integrated SMA connector.

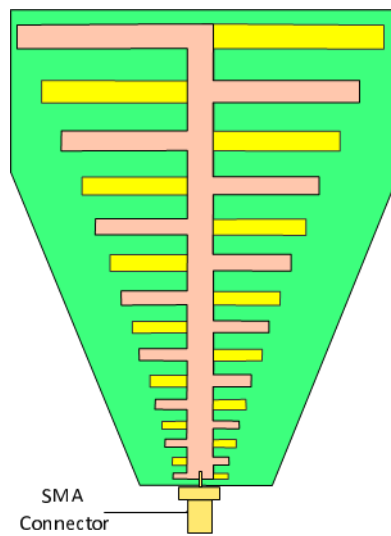


Fig. 2. The geometry of the final proposed UWB-MLPDA antenna

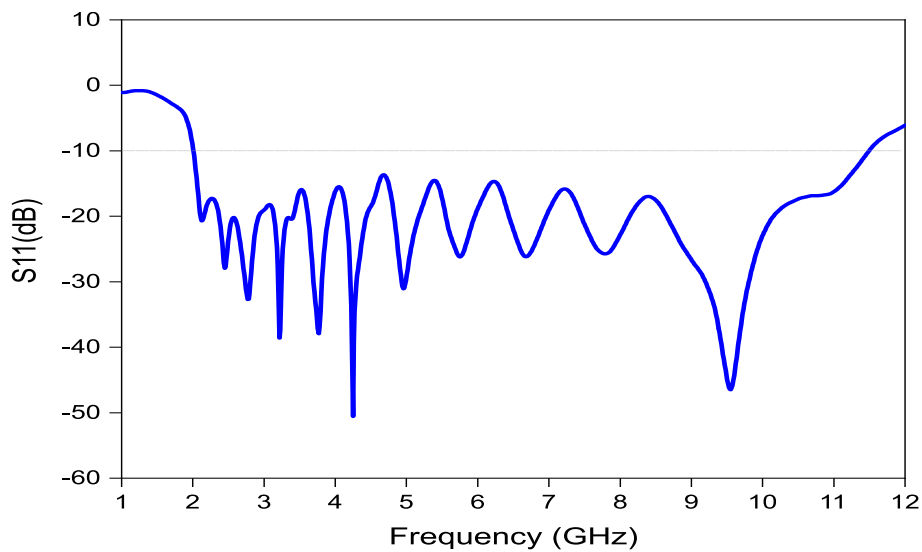


Fig. 3. Reflection coefficient of the proposed UWB-MLPDA

The figure 3 presents the magnitude of the reflection coefficient S_{11} for the proposed UWB-MLPDA design, illustrating its impedance matching across a frequency range of 1 to 11.7 GHz. In this figure, the antenna exhibits

excellent impedance matching from approximately 2 GHz to 11.48 GHz, where the S_{11} value stays below -15 dB, signifying minimal reflection and efficient power transfer. This wide range covers the entire UWB spectrum [3.1 - 10.6 GHz].

III. UWB-MLPDA DESIGN WITH DUAL BAND REJECTED

To solve the problem of interference in UWB communications, it is necessary to eliminate the unwanted bands. The traditional method used to suppress this potential interference is by connecting the antenna to cut-band filters, which increases the cost of these antennas and degrades their performance and characteristics. The alternative solution is the ability to cut one or more narrow bands under license from applications that already exist in the UWB spectrum without altering the fundamental characteristics by integrating resonators into the same structure.

To address the UWB spectrum and to mitigate interference from the existing narrow-band applications, a simple technique is proposed, which is to add stub elements to the active region of the antenna. This method explains the practice of adding a tuning part on the antenna itself, which may suppress undesirable bands of frequencies and preserve the operability of the UWB band.

Careful choice of the design of the additional element makes it possible to suppress the operation of unwanted devices emitting in the proximity frequencies with no detrimental effects on the performance of the miniaturized antenna.

A. Surface current analysis

To determine the active region in the rejection spectrum of this antenna using surface current analysis [10], a full evaluation of the current patterns on the antenna components at the center frequencies F_n of the band, which will be rejected, is required. The center frequency F_n is calculated using the equation:

$$F_n = \frac{F_{up} + F_{down}}{2} \quad (4)$$

In a MLPDA antenna, the surface current changes across the dipoles as a function of frequency, where different dipoles resonate at different wavelengths. By analysing the topography of the current distribution, the areas of amplified electrical force suggest dynamic polar magnets. By looking at how things propagate through different sound levels, we can determine exactly which sounds the special antenna chooses not to pick up.

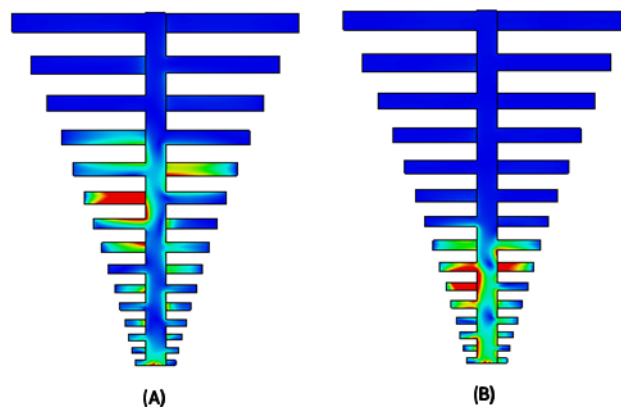


Fig. 4. Surface current of the proposed UWB MLPDA antenna at (a) F_{n1} and (b) F_{n2} .

The figure 4 illustrates the surface current distribution at the center frequencies F_{n1} and F_{n2} , corresponding to the WLAN and WiMAX bands, respectively. The visualization reveals distinct areas of concentrated current, highlighting a pair of dipole elements associated with each center frequency.

B. The first band rejected (WLAN)

A rectangular stub S_1 is introduced into the design. This stub is added to the top microstrip feed line, extending from the edge of the substrate by a distance d_{S1} . The stub has a length of L_{S1} and a width of W_{S1} . The key idea

behind this modification is to exploit the rectangular stub's ability to influence the antenna's frequency response by creating a band stop above -10 dB as illustrated in figure 5.

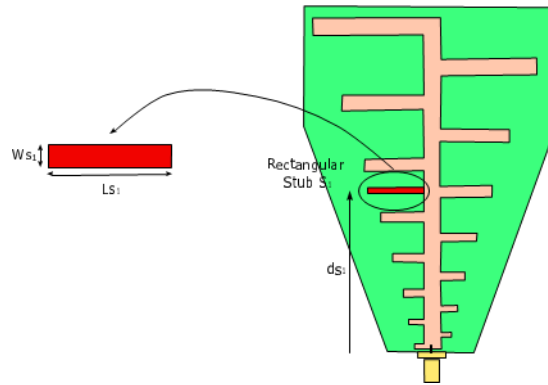


Fig. 5. Geometry of the design adding the first rectangular stub S_1 .

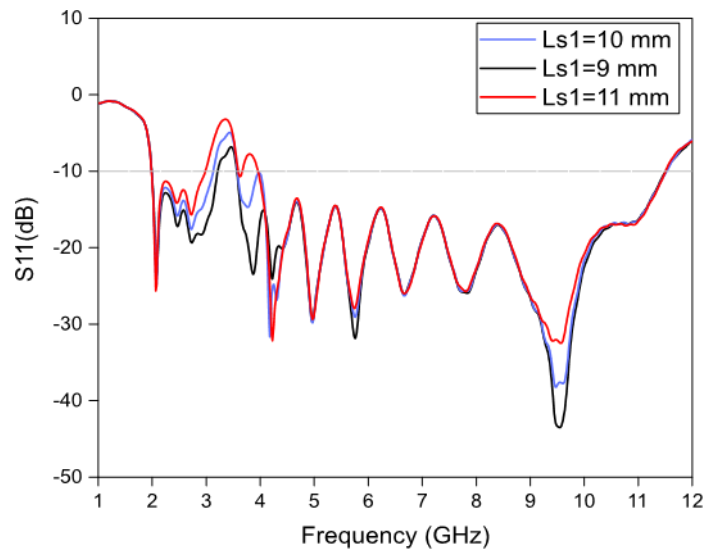


Fig. 6. S_{11} of the UWB MLPDA antenna with Stub S_1 for different values of L_{s1} .

The figure 6 illustrates the frequency response of the UWB MLPDA antenna with varying values of L_{s1} . As the value of L_{s1} increases, the rejected frequency shifts to lower values, indicating that L_{s1} plays an important role in controlling the resonance and rejection characteristics. This suggests that adjusting L_{s1} can be an effective method for fine-tuning the band rejection performance of the design. This relationship can be expressed mathematically as:

$$F_n = \frac{c}{L_{s1} \sqrt{\epsilon_{eff}}} \tag{5}$$

and ϵ_{eff} is the effective dielectric constant given by:

$$\epsilon_{eff} = \frac{1 + \epsilon_r}{2} \tag{6}$$

C. Rectangular band-rejected

Conventional band rejection methods are capable of reducing interference but often suffer from low selectivity, making them ineffective for rejecting wide interference bands. This limitation has sparked interest in the design of UWB antennas with well-defined rejection characteristics, which are essential for handling interference from unwanted bands [5].

In order to achieve the best performance, a band with a high degree of selectivity is required to allow good rejection of interference. This can be accomplished by inserting an additional stub, which is configured to cover the same band, improves the degree of the notch, and enhances the interference rejection within the controlled frequency.

In the design, another rectangular stub S_2 is added. This stub is connected to the top microstrip feed line that extends d_{s2} from the substrate's edge, as showing in figure 7.

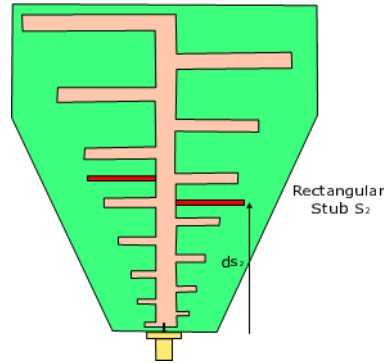


Fig. 7. Geometry of the design adding the second rectangular stub S_2 .

The figure 8 illustrates how the stub, which has length L_{s2} and width W_{s2} , forms a rectangular band that is rejected.

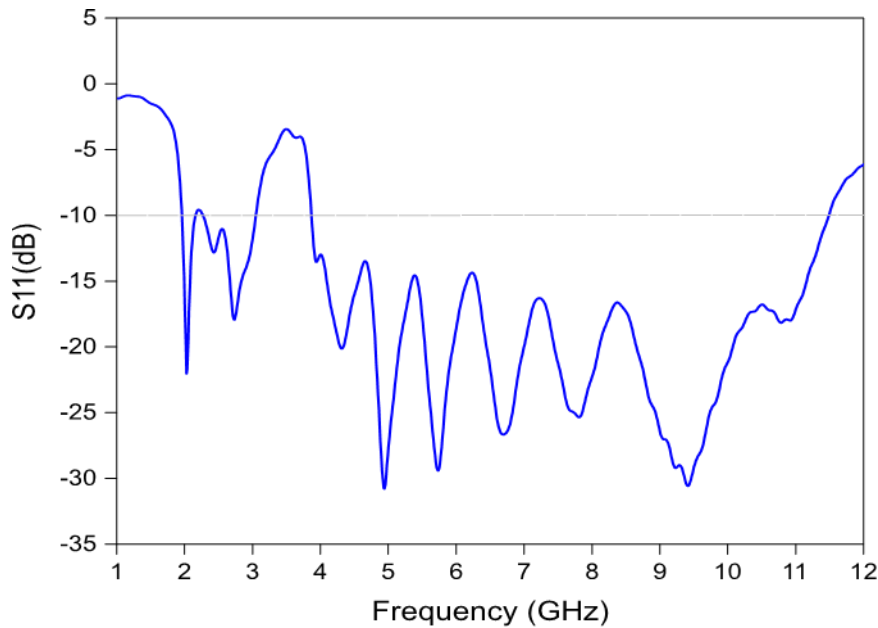


Fig. 8. Reflection coefficient of the proposed UWB-MLPDA with two stubs S_1 and S_2 .

D. Second band rejected (WiMAX)

To enhance the band-rejected performance, two additional stubs, S_3 and S_4 , are incorporated into the top microstrip feed line, as illustrated in figure 9. Stub S_3 is designed to generate a conventional band rejected, while stub S_4 introduces a rectangular band rejected, as demonstrated in figure 10. This configuration allows for precise control over the rejected bands, effectively suppressing interference at the WiMAX band.

Tab. 2. Final optimized stub's parameters.

Parameters	Value (mm)	Parameters	Value (mm)
W_{s1}, W_{s2}, W_{s3} and W_{s4}	0.8	L_{s3}	6.5
L_{s1}	11	D_{s3}	16.5

Ds1	33.5	Ls4	5.5
Ls2	11.7	Ds4	20
Ds2	29		

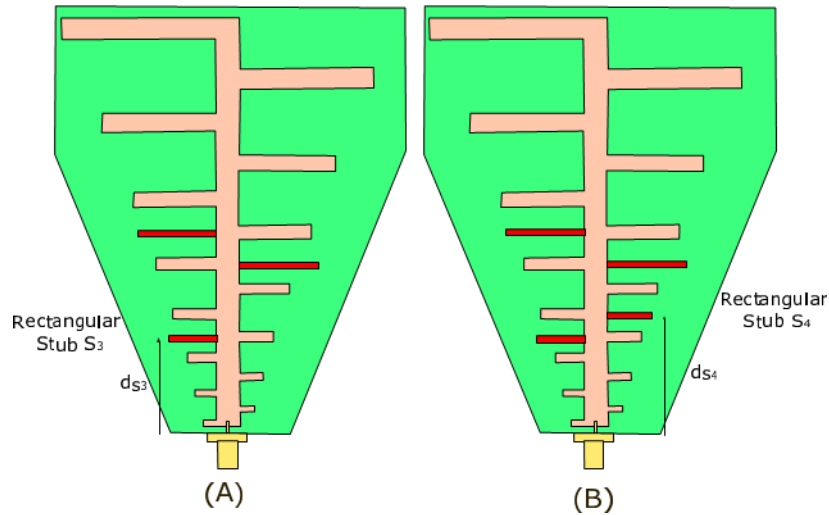


Fig. 9. Geometry of the design adding (a) the third rectangular stub S3, (b) the fourth rectangular stub S4.

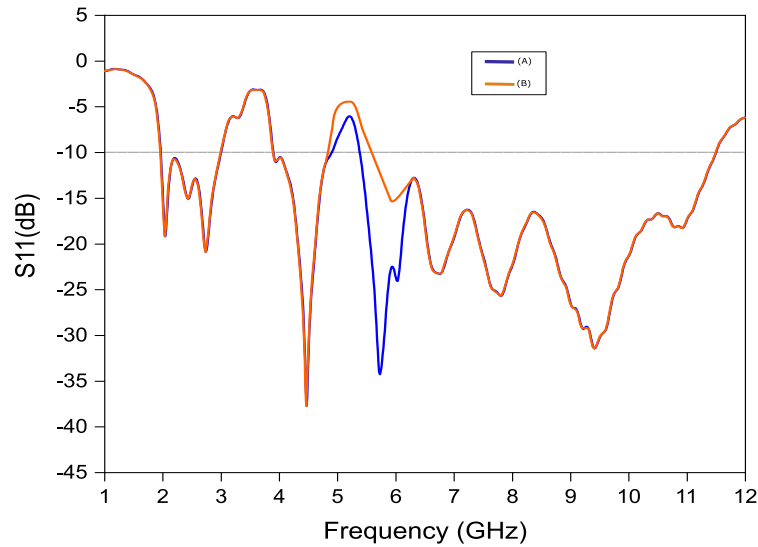


Figure 10. Reflection coefficient of the proposed UWB-MLPDA with stub S3, and S4.

The table 2 presents the final optimized parameters for the four stubs. These parameters are adjusted to fine-tune the antenna’s response, ensuring precise suppression of interference within the targeted frequency bands. Each stub is optimized to contribute uniquely to the overall design, balancing compactness with high-performance operation.

IV. FABRICATION AND MEASUREMENT

The proposed UWB-MLPDA antenna with WLAN and WiMAX bands rejected has been successfully fabricated using photolithography technique. The manufactured antenna’s top and bottom views are displayed in figure 10.

After soldering the SMA connector, the S_{11} parameter of the proposed antenna was measured using a Vector Network Analyzer (VNA). The figure 11 illustrates the measurement setup for evaluating the reflection coefficient with the VNA.

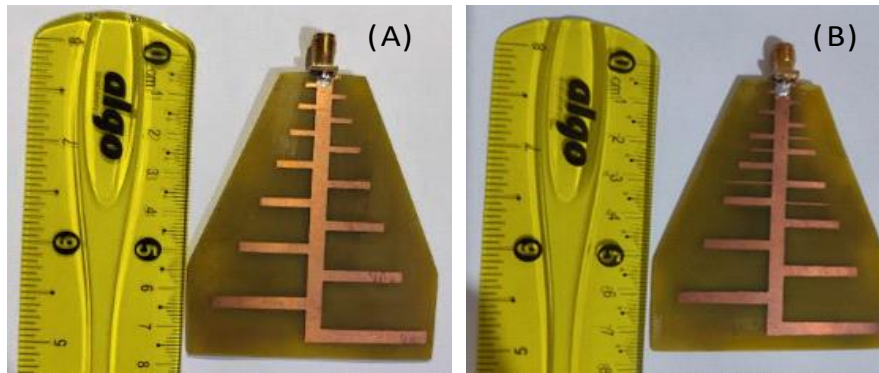


Fig. 11. Photo of the fabricated UWB-MLPDA antenna with dual rectangular rejected bands (A) Top view, (B) Bottom view.



Fig. 12. Reflection coefficient Measurement of the proposed UWB-MLPDA antenna with dual rectangular rejected bands.

In figure 13, the measured and simulated S_{11} curves of the proposed UWB-MLPDA antenna are presented, showing very good agreement. The results confirm that excluding the rejected bands, the antenna design effectively passes only the permitted bands within the rectangular region exhibiting proper impedance matching range from 2GHz up to 11.7GHz. This indicates that the rectangular stubs are able to suppress the unwanted bands. Such Small variations in the measured and simulated results can be due to the soldering process of the SMA connector as well as fabrication tolerances.

The figure 14 depicts the proposed antenna, who have been able to achieve a stable gain performance of about 6 dBi on average across the frequency operating band. However, at bands that were rejected, the gain reduces significantly to -4 dBi at F_{n1} and -5 dBi at F_{n2} , thus indicating that band rejection is achieved. In addition, the measured and simulated gain value tendencies are in good agreement.

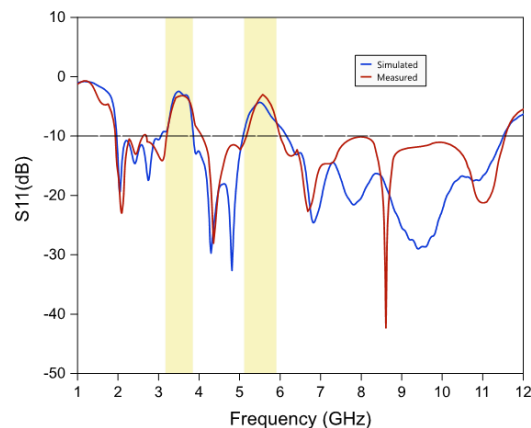


Figure 13. Simulated and measured S_{11} of the proposed UWB-MLPDA antenna with dual rectangular rejected bands.

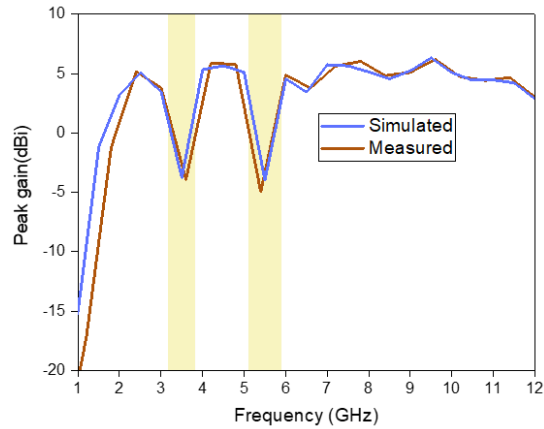


Fig. 14. Simulated and measured gain of the proposed UWB-MLPDA antenna with dual rectangular rejected bands.

Radiation patterns for the prototype UWB-MLPDA antenna in both measurements and simulations have been normalized and are graphed in figure 15. The results exhibit recognizable features of end-fire radiation at 2.4 GHz, 4 GHz and even at 10GHz. These patterns appear in the transverse (xz) plane (E-plane) and the longitudinal (yz) plane (H-plane) which indicates good performance at low, medium and high frequencies over the whole frequency range.

The distributions of current flow within the proposed MLPDA antenna on the two center frequencies F_{n1} and F_{n2} are depicted in figure 16. The current is mainly confined to Stub 1 and Stub 2, which largely accepts or rejects the first band. In the same manner, Stub 3 and Stub 4 have more currents, which indicate that they also accept or reject the second band. It is therefore clear from the findings that the stubs perform well in terms of band rejection features.

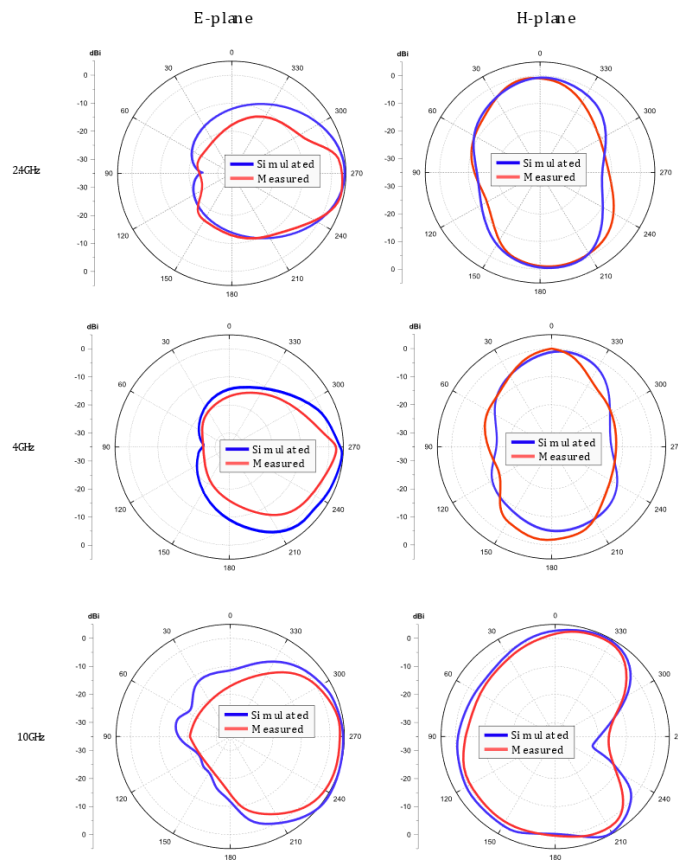


Figure 15. Simulated and measured Radiation pattern of the proposed UWB-MLPDA antenna with dual rectangular rejected bands in the E-plane and H-plane at 2.4, 4 and 10 GHz

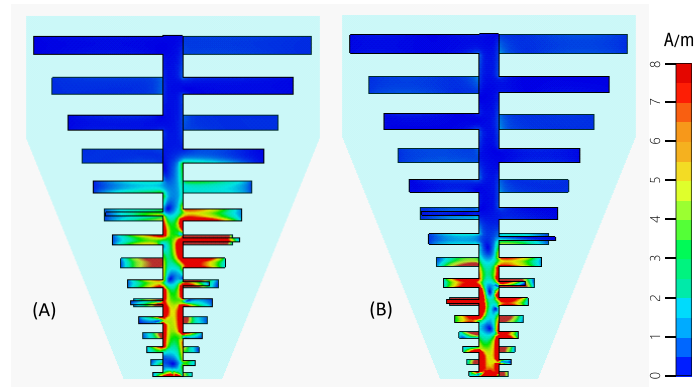


Fig 16. Surface current of the proposed UWB-MLPDA antenna with dual rectangular rejected bands (A) at F_{n1} , (B) at F_{n2} .

The presented structure represents a broad range of operating frequencies [2-11.7] GHz it is certainly the widest range of the antennas presented at similar sizes. Although it reaches a slightly lower average gain of 6 dBi, it provides a good interference rejection with high gain-reduction levels of -4 dBi and -5 dBi for both WiMAX and WLAN rectangular rejected bands, respectively. Unlike other techniques such as tapered and meander fractal geometries or parallel stripline-based designs, the use of rectangular stubs ensures both simplicity and reliability in fabrication. This balance of compactness, broad bandwidth, and effective band rejection underscores the design's suitability for modern UWB applications requiring precise interference suppression.

V. CONCLUSION

A compact UWB-MLPDA antenna with dual rectangular band-rejection characteristics to suppress the interference from WiMAX and WLAN bands is proposed in this paper. This design provides a wide operational bandwidth from [2 - 11.7] GHz with good impedance matching and constant radiation performance. The significant suppression of band gain in rejected bands confirms the effectiveness of interference rejection mechanism. There is good agreement between the simulated and experimental results with the slight differences being attributed to fabrication tolerances and connector problems. The proposed UWB-MLPDA antenna is characterized by its simple structure, compact size, and high performance, thus making it a good candidate for modern communication systems requiring efficient interference rejection with a wideband operation.

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