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Dual Slot Band Notch Rectangular Shape Microstrip Patch Antenna for UWB Applications

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ABSTRACT

Introduction: A small Ultra-Wideband (UWB) microstrip antenna with and without band-notch properties are presented in this paper. By incorporating dual slot notches, the proposed antenna is designed to selectively reject interference from WLAN and WiMAX bands while operating efficiently over the 2-12 GHz frequency range. The antenna without a notch performs exceptionally well over the intended UWB range, with a wide impedance bandwidth of 3 GHz (9-12 GHz) and S_{11} values of −21 dB and −24 dB. With S11 values of −18.0 dB, −12.0 dB, −29.0 dB, and −11.0 dB, respectively, four band-stop regions are successfully introduced in the notched configuration at 2.3-3.2 GHz, 5.4-6.2 GHz, 7.4-9.0 GHz, and 9.1-10.2 GHz. Simulated results are in good agreement with measured results. The generated antenna maintains a Voltage Standing Wave Ratio (VSWR) below the value two and attains a measured input impedance of about 34.78 Ω. The size of proposed antenna is (50 mm × 50 mm × 1.6 mm) that has stable omnidirectional radiation characteristics, and efficient ground plane design makes it suitable for modern portable UWB communication systems. The results demonstrate that the proposed slot-based approach provides a practical and effective means of lowering interference in UWB applications.

Keywords: Ultra Wide Band (UWB), Microstrip Patch Antenna, Dula Slot, Interference.

INTRODUCTION

The rapid advancement in wireless communication systems has created a strong demand for antennas that can operate over a wide range of frequencies. One of the most promising technologies to address this requirement is Ultra-Wideband (UWB), which covers the frequency spectrum from 3.1 GHz to 10.6 GHz, as defined by the Federal Communications Commission (FCC) in 2002. UWB has many applications in high-speed wireless personal area networks, radar imaging, through-wall detection, and vehicular communication systems with high data rates and low power consumption use case. Antenna design plays a vital role in fulfilling these requirements. Among various antenna structures, the microstrip patch antenna (MPA) is notable for its compact size, ease of fabrication, low profile, and ability to integrate with printed circuits. Nonetheless, conventional microstrip antennas face challenges with narrow bandwidth and restricted gain. To address these challenges, researchers have suggested various design improvements, such as the incorporation of defected ground structures (DGS) [1], notch shaping [2], parasitic elements [3], and slot loading techniques [4], to expand the bandwidth and enhance performance.

In recent years, a variety of innovative UWB antenna designs have emerged. A compact monopole antenna featuring elliptical slots was introduced [1], providing a bandwidth ranging from 3.2 GHz to 11.2 GHz while exhibiting omnidirectional radiation properties. In a similar vein, [2] introduced a circular patch antenna featuring an etched ring slot and a truncated ground plane with improved impedance bandwidth and radiation efficiency. A stepped-impedance stub [3] was used for enhanced matching for an ultra-wide bandwidth and consistent gain performance. A flower-shaped patch antenna [4] featuring a tapered feed line producing noteworthy UWB performance and good radiation efficiency.

The goal of this work is to build and simulate a new microstrip patch antenna that is specifically made for UWB communication. The design approach enhances bandwidth and improves impedance matching while maintaining a compact size and a steady radiation pattern. A modelling tool, such as HFSS (version 14.0), was utilized to create and

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evaluate the antenna. Key performance indicators like S11, VSWR, bandwidth, gain, and radiation pattern were examined. Also, a comparison of simulated and measured results is studied for further research.

This paper is structured in the following way: Section II offers a thorough examination of relevant studies and current microstrip antenna designs for UWB applications, highlighting significant limitations and the rationale behind the proposed work. Section III outlines the approach to antenna design, covering the choice of substrate, geometric specifications, and methods employed to improve bandwidth and overall performance. Section IV lists out the simulation setup and presents the results, covering S11, VSWR, radiation pattern, gain, and surface current distribution. Section V delves into a parametric analysis to examine how different design parameters influence antenna performance. Section VI discusses the creation and assessment of the prototype, highlighting the comparison between simulated and experimental outcomes. Section VII offers a thoughtful exploration of the design's advantages and compromises, complemented by a comparison with existing works. In conclusion, Section VIII wraps up the paper and highlights potential avenues for future exploration.

LITERATURE REVIEW

A range of microstrip patch antenna (MPA) designs has evolved in the dynamic field of UWB communication. Still, many designs run against challenges like limited impedance bandwidth, increased structural complexity, and concessions between gain and compactness.

Using a ring-shaped resonator, Mahfuz et al. [5] produced a UWB microstrip patch antenna with a 5G lower band notch that displayed remarkable gain and filtering characteristics. Still, its complex design makes manufacture and integration in small devices difficult. Providing a large bandwidth (3-11.4 GHz), AlOmairi and Atilla [6] presented a circular patch including a defective ground structure for biological detection. It is less perfect for small devices, nevertheless, because it shows a bigger footprint and only little benefit. Singh et al. [7] presented a THz-range antenna featuring a 6×6 SRR array. The gain is notable at 19.22 dBi, yet the design is quite large and intended primarily for high-frequency imaging systems, which affects its portability. Omrani et al. [8] created a UWB MIMO patch antenna featuring EBG structures, resulting in minimal mutual coupling. Yet, the design's multilayer complexity and fabrication cost reduce its practical feasibility for consumer applications. Shrivastava et al. [9] presented a double-trident slotted MPA offering over 6 GHz bandwidth. But there is one thing to observe that while the design offers great performance, it restricts flexibility with limited design tolerances and a more complicated ground slot layout, that can be tricky when it comes to manufacturing. El Jourmi et al. [10] came up with a slotted rectangular patch tailored for the Ku and K bands, and delivers impressive bandwidth. But there was a trade-off: the antenna ended up being bulkier, which made it less ideal for compact setups. Shrivastava et al. [11] proposed a hexagonal patch antenna for UWB application. While compact, the design sacrifices gain (peak ~5.3 dB) and radiation uniformity. Anurag et al. [12] worked on a dual-band MPA (28 GHz and 46 GHz) for 5G. The design shows good isolation and bandwidth, but the millimeter-wave operation makes it unsuitable for typical UWB scenarios due to sensitivity to fabrication tolerances.

A multiband MPA by Kumar et al. [13], optimized using the Moth–Flame algorithm, showed improvement in gain and bandwidth. However, it involves computationally intensive optimization and the final antenna structure is larger due to parasitic elements. Rao et al. [14] used a hybrid optimization approach for a slot-loaded design, yet the convergence time and complexity of geometry remain limitations. Chakradhar et al. [15] applied a Shark Smell Optimization model to MPA design. Though effective in optimizing parameters, the antenna geometry became complicated, affecting real-world implementation. Suresh et al. [16] introduced a frequency selective surface (FSS) with MPAs to enhance impedance matching. Chinnathampy et al. [17] proposed a MPA for cognitive radio for better spectrum flexibility with a complex circuitory. Promwong and Pinsakul [18] proposed an alumina-based monolithic antenna that provides good thermal stability but involves high-cost materials and limited bandwidth (~2.1 GHz). Naik and Rayar [19] offered a systematic review of optimization-based MIMO designs, most of which required a trade-off between compactness and bandwidth. Nishanth et al. [20] presented an FSS-backed MPA that improved gain, but the addition of FSS made the design thick and less flexible. Singh et al. [21] analyzed global optimization of MPAs using the naked mole-rat algorithm, improving efficiency but resulting in structures with multiple stubs and slots, which are hard to fabricate. Suresh et al. [22] worked on defected ground structures to enhance bandwidth, yet these modifications often introduce unwanted back radiation. El Jourmi et al. [23] also used slotting techniques to improve return loss performance but with the distorted and unstable radiation pattern across the UWB band. Lastly, Promwong and Pinsakul [24] used alumina substrates to build compact monolithic MPAs. Though thermally stable, the use of specialized substrates leads to increased cost and limited flexibility. Table 1 shows the comparative summary of recent works in this field.

Table 1: Summary of Recent UWB Microstrip Patch Antenna Research

Ref. No.	Methodology / Technology Used	Outcome	Limitations
[5] Mahfuz et al.	Ring-shaped resonator with 5G notch	Wide bandwidth and effective band rejection	Complex structure, difficult to miniaturize
[6] AlOmairi & Atilla	Circular patch with defected ground (DGS)	Bandwidth: 3–11.4 GHz, biomedical applications	Moderate gain, larger footprint
[7] Singh et al.	6×6 SRR array in THz design	Gain up to 19.22 dBi	Bulky, not suited for portable systems
[8] Omrani	EBG-based UWB MIMO antenna	Low mutual coupling	Multilayer, fabrication complexity
[9] Shrivastava et al.	Double-trident slotted MPA	6 GHz bandwidth, high return loss	Tight tolerances, intricate ground layout
[10] El Jourmi et al.	Slotted rectangular patch for Ku/K band	High bandwidth, good VSWR	Increased antenna dimensions
[11] Shrivastava et al.	Hexagonal patch design	Compact size, UWB coverage	Limited gain (~5.3 dBi)
[12] Anurag et al.	Dual-band MPA (28/46 GHz)	Good isolation, mm-wave application	Fabrication sensitivity, not for typical UWB
[13] Kumar et al.	Moth-Flame Optimization (MFO)	Enhanced gain and multiband	Computational load, parasitic elements add size
[14] Rao et al.	Hybrid evolutionary algorithm	Optimal slot-loaded MPA	Complex geometry, high computation
[15] Chakradhar et al.	Shark Smell Optimization (SSO)	Parameter tuning effectiveness	Geometry becomes hard to fabricate
[16] Suresh et al.	FSS-enhanced MPA	Better impedance matching	Additional substrate layers increase thickness
[17] Chinnathampy et al.	Cognitive radio reconfigurable MPA	Frequency agility	Circuit complexity, reconfiguration control needed
[18] Promwong & Pinsakul	Alumina-based monolithic patch	Thermal stability	Costly material, ~2.1 GHz bandwidth only
[19] Naik & Rayar	Review of optimized MIMO MPAs	Trade-off identification	Most designs show size vs bandwidth trade-offs
[20] Nishanth et al.	FSS-backed high gain MPA	Improved gain	Thick profile, reduced flexibility
[21] Singh et al.	Naked Mole-Rat Algorithm (NMRA)	Better global optimization	Complex multi-stub structure
[22] Suresh et al.	Defected Ground Structure (DGS)	Bandwidth improvement	Unwanted back radiation, complex etching
[23] El Jourmi et al.	Slotting for return loss reduction	Lower return loss	Radiation pattern instability
[24] Promwong & Pinsakul	Alumina-based compact patch	Good gain and stability	High cost, limited design adaptability

Although UWB microstrip patch antennas (MPAs) have made significant progress, a comprehensive review of recent publications indicates ongoing constraints that prevent their general acceptance and useful implementation. Many designs include notable trade-offs even although many have shown excellent performance in terms of bandwidth augmentation and gain increase. The somewhat big physical size of the antenna structures is a recurrent problem in several research that makes it difficult for such designs to be integrated into portable and small devices.

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Moreover, many UWB MPA designs depend on complicated geometries, like multilayer layouts or sophisticated slotting patterns, usually optimised by computationally demanding techniques. These techniques raise design and manufacturing complexity at the same time even if they can produce performance advantages. Furthermore, numerous designs call for the use of costly or non-standard substrates such as: alumina or high-permittivity ceramics which not only lower the total antenna system flexibility but also increase production costs.

Especially with antennas using defective ground structures or reconfigurable components, another common difficulty is the deterioration or instability of the radiation pattern throughout the operational span. For UWB communication systems, consistency of signal coverage is essential, so this degrades it. At last, many high-performance MPA designs are less suited for mass, affordable manufacture as many of them suffer from low manufacturingability.

As such, a new class of UWB MPAs that can surpass these constraints and provide strong performance is much needed. While guaranteeing constant radiation properties across the whole UWB range, an ideal solution would have a small form factor, simple structure, low-cost substrate materials, and easy of production. Realising realistic, scalable, and efficient antenna systems for current UWB applications requires addressing these features.

METHODOLOGY

1. ANTENNA DESIGN AND SIMULATION

The design of a basic rectangular micro strip UWB antenna has been improved to achieve an expensive impedance transmission capacity. The antenna design was created on a FR4 substrate with dimensions of 50mm×50mm×1.6mm and 50mm × 18mm. The antenna structure was fed from a source with an output impedance of 50 ohms and simulated on the Ansys HFSS 14.0 platform using the Finite Element Method (FEM). Figure 1 shows the final geometry of proposed without slot antenna and table 2 lists out the following parameters.

Table 2: Optimum values of proposed rectangular shape Micro strip Patch

	X-axis	Y-axis	Z-axis
FR Epoxy Box2	50mm	-50mm	1.6mm
Vacuum Box 3	70mm	70	70mm
GND	50mm	18mm	----
GND thickness	3mm	----	1.6mm
Patch (W_p x L_p)	30mm	30mm	----
Strip Slot (W_{rs} x L_{rs})	12mm	-4mm	----

The antenna is capable of passing one iteration band in the range of 2.40 GHz to 3.35 GHz, passing the ISM (2.4GHz-2.4835GHz), Bluetooth (2.4GHz-2.484GHz), and Wi Max IEEE 802.16 (3.3GHz-3.7GHz) band with an impedance bandwidth of 1.166 GHz at S11 of -10 dB. The antenna is resonant at two center frequencies, 2.4 GHz with an absolute bandwidth of 1.166 GHz and 10.2 GHz with an absolute bandwidth of 3.02 GHz for UWB applications.

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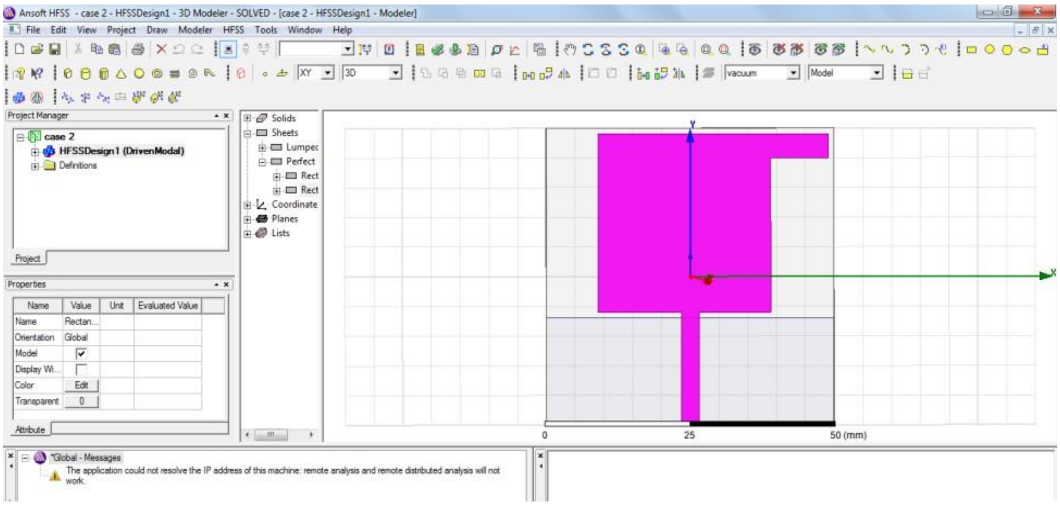

Figure 1: Basic monopole rectangular shape microstrip patch antenna

The antenna structure provides a three-dimensional and omnidirectional radiation pattern with high radiation efficiency of 83.0% in the UWB bandwidth. The gain characteristic in 3D polar at 7GHz is an average gain of about 3.45dB and directivity of 4.211dB. The current distribution around the edges is higher than in the inner part of the radiator, ensuring higher radiations of the signal through the entire band. These results are depicted in figure 2 and 3.

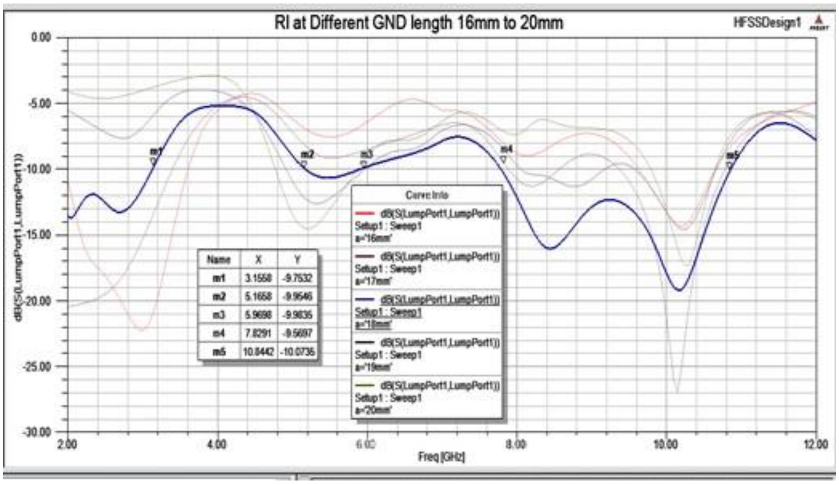

Figure 2: Variation of S_{11} with frequency of proposed microstrip patch antenna

The second proposed design of a Micro strip UWB antenna features a band notch characteristic and a rectangular radiator with a length of 30mm. The antenna is designed on a FR4 substrate with dimensions of 50mm×50mm×1.6mm and ground dimensions of 50mm × 18mm. The design was optimized through parametric characterization and simulated using the Finite Element Method (FEM) on the Ansys HFSS 14.0 platform. The optimal design parameters for the monopole rectangular Micro strip Patch antenna, and the final geometry of the antenna is shown in Figure 1.

The study focuses on the design of a radiator with feed mechanism for UWB applications. The partial ground plane was estimated using parametric studies and optimized for band notch characteristics using multiple simulations on the Ansys HFSS 14.0 platform. The radiator design is capable of passing two bands in the range of 2.1 GHz to 3.1 GHz, including ISM, Bluetooth, and Wi max IEEE 802.16. The radiator is resonant at two center frequencies, 2.6 GHz with Absolute Bandwidth 1.0 GHz, and 10.2 GHz with Absolute Bandwidth 3.0 GHz.

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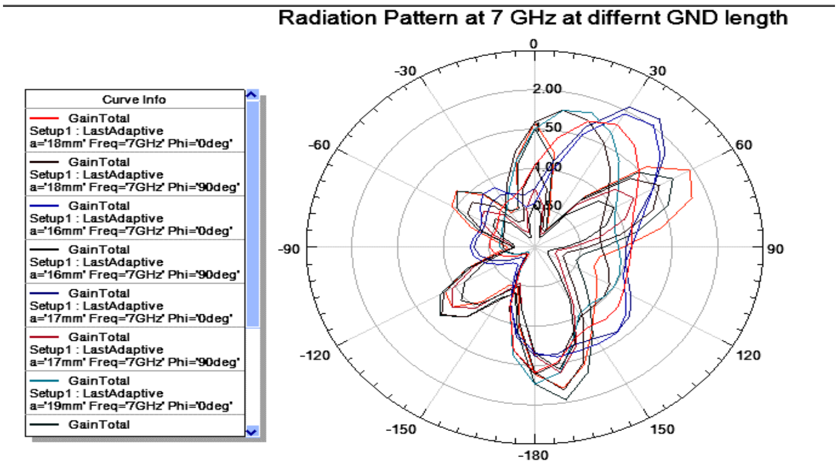

Figure 3: Radiation Pattern of proposed antenna at different ground length (L_g)

The radiator's far field radiation pattern plots in figure 3 show that it provides a three-dimensional and omnidirectional radiation pattern with high radiation efficiency in UWB. Surface current distribution plots show that the radiator around the edges has higher current distribution than in the inner part of the radiator, ensuring higher radiations of the signal through the entire bands. The design also measures gain and directivity in 3D Polar at 7GHz, with an average gain of about 2.64 dBi and directivity 3.436 dB. Radiation efficiency, radiated power, and incident power are measured at 7GHz, with an average of 82.5% and 69% and 99.0% respectively

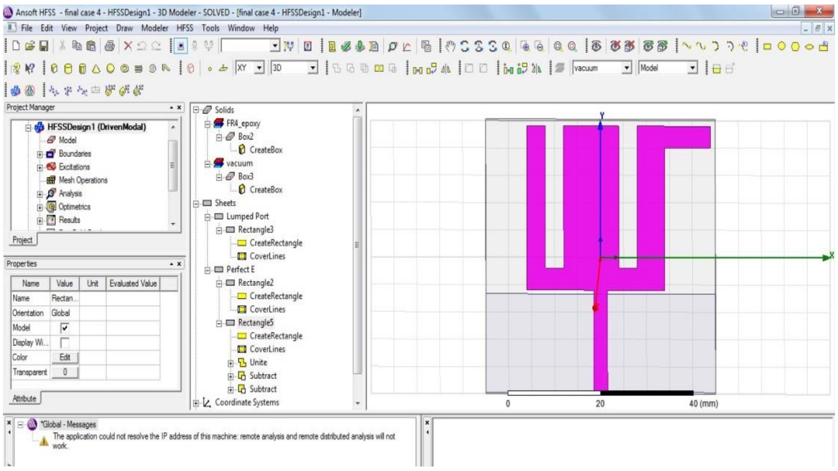

Figure 4: Proposed dual slot band notch rectangular shape microstrip patch antenna

The study presents a technique to reduce the ground-plane effect on the performance of a small printed UWB antenna with band notch characteristics. The printed antenna is designed to cover the band notch characteristics in the UWB band of 3.1-10.6 GHz by cutting a rectangular notch vertically from the printed radiator and asymmetrically attaching a strip to the radiator. The antenna was etched on a PCB with a notch 3mm × 26mm (W_s x L_s) cut close to the attached strip 12mm × 4mm (W_{rs} x L_{rs}). The feed gap and position of feed point can be adjusted to improve impedance matching. The length of the ground plane was upgraded (L_g =18mm) to achieve a scaled-down outline with great impedance coordinating. Figure 4 and table 3 represents these dimensions.

Table3: Optimum values of Micro strip Patch with two Slots

	X-axis	Y-axis	Z-axis
FR-Epoxy Box2	50mm	-50mm	1.6mm
Vacuum Box3	70mm	70mm	70mm
GND (W_g x L_g)	50mm	18mm	------
Patch (W_p x L_p)	30mm	-30mm	------

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Strip (W_{rs} x L_{rs})	12mm	-4mm	------
GND thickness	3mm	------	-1.6mm
First Slot	3mm	-26mm	------
Second Slot	3mm	-26mm	------

The final model of patch antenna includes two slots with dimensions (50mm×50mm×1.6mm). After parametric characterization, the optimal design parameters of the rectangular micro strip patch antenna with one strip were derived. The radiator is capable of passing three bands in the range of first insertion (2.2 GHz to 3.2 GHz), covering the range of ISM (2.4GHz-2.4835GHz), Bluetooth (2.4GHz-2.484GHz), and rejection of Wi max IEEE 802.16 (3.3GHz-3.7GHz) band at impedance Bandwidth 1.05 GHz and S_{11} below -10 dB.

The radiator radiates at three center frequencies (2.4 GHz, 5.5 GHz, and 9.8 GHz) for UWB applications. The gain and directivity in 3D polar at 7GHz are uniform, with an average gain of about 4.93 dBi and directivity of 5.71 dB. The radiation pattern at different ground lengths (L_g) shows that the antenna structure provides features in three-dimensional and omni-directional radiation pattern with high radiation efficiency in the UWB. Radiation efficiency, incident power, radiated power, and accepted power at 7GHz are 99%, 60.0 %, and 82% respectively.

The printed radio wire aims to improve band indent attributes in the UWB band of 3.1-10.6 GHz by cutting a rectangular score vertically from the printed radiator and unevenly appending a strip to the radiator. This reduces the general size of the receiving wire imprinted onto a 1.6 mm thick PCB to 50 mm × 50 mm. The impedance and radiation attributes can be enhanced, such as return misfortune, three-dimensional radiation examples, and radiation efficiency over the transmission capacity. A parametric report is done to provide radio wire engineers with fundamental plan data. The ground plane impact on impedance coordinating execution is significantly diminished by cutting the two scores from the radiator, as electric streams on the ground plane are essentially smothered at lower edge working frequencies. The radiator structure has multiple notches at four different frequencies, improving impedance and characteristics. The radiator is resonant at four different center frequencies with S_{11} values -16dbB, -45dB, -24dB, -20dB, respectively for four notches. The relationship between VSWR and frequency for the radiator model is ≤ 2 for all center frequencies, including band notch characteristics for UWB applications.

The study focuses on the measurement of gain and directivity in 3D polar at 7GHz, resulting in an average gain of 2.75 dBi and directivity of 3.65 dB. The radiation efficiency of MPA with two slots is 82% obtained, and the radiated power, incident power, and radiation pattern are 65% and 99.0% respectively at 7GHz. The current distribution of the radiator around the edges is higher than in the inner part of the radiator, ensuring higher radiations of the signal through the entire bands.

The ground plane with FR4 substrate has three important points: the impedance matching is very sensitive to the feed gap, and the length of the ground plane influences the impedance coordinating more essentially at higher frequencies than at bring down frequencies. The impedance response is also affected by the ground length, with a change in the ground length leading to a shift in the characteristic impedance of the feeding strip from 50Ω.

The comparative analysis of antenna parameters like S_{11}, VSWR, bandwidth, directivity, radiated power, radiation efficiency, E and H electric fields antenna gain of all proposed designs with and without band notch characteristic is discussed in table 4. The results of the analysis are applicable for common dimensions of all designs, with the common microstrip feeding technique for load impedance used.

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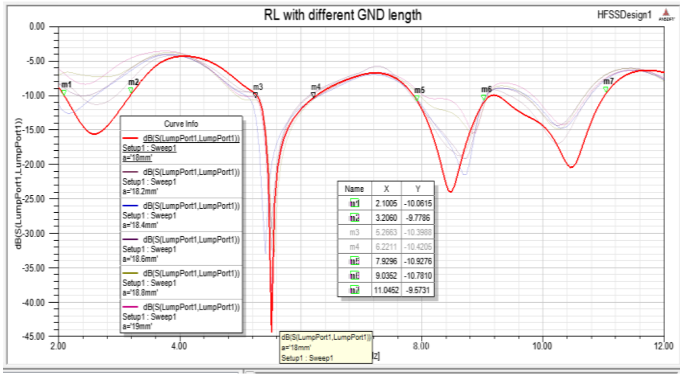

Figure5: Proposed dual slot band notch rectangular microstrip patch antenna characteristics $|S_{11}|$ with optimized ground length L_g = 18mm

Table4: Comparative Analysis of Basic rectangular antenna and proposed dual slot rectangular antenna

Parameter	Case 1: Basic rectangular Antenna	Case 2: proposed rectangular antenna with dual slots	Interpretation
Fractional Bandwidth (Below -10 dB)	55%, 11%, 33%	42%, 17.5%, 31.2%, 18.9%	Case 2 has wider and more segmented operational frequency ranges.
Notch Bands (GHz)	2.34–3.4, 5.1–5.7, 7.6–10.7	2.10–3.25, 5.2–6.2, 7.8–9.0, 9.0–11.1	Case 2 adds an extra notch band, improving interference rejection (e.g., WiFi, 5G).
S11 (in dB)	-15 @ 2.7, -10 @ 5.4, -19 @ 9.3	-16 @ 2.7, -45 @ 5.4, -24 @ 9.3, -20 @ 11.1	Lower S11 (esp. -45 dB) indicates better impedance matching and lower signal reflection.
VSWR	< 2	< 2	Both are well-matched; <2 is considered good.
Directivity (dB)	4.21	3.65	Case 1 is slightly more directional.
Radiated Power	70.42%	65.32%	Case 1 radiates slightly more of the incident power.
Incident Power	99%	100%	Input power is almost the same.
Radiation Efficiency	84%	81.7%	Slightly better for Case 1.
Gain (dB)	3.45	2.75	Higher in Case 1; relates to directivity and efficiency.
E-field	6.3	10.8	Case 2 has a stronger electric field, indicating better signal strength in certain directions.
H-field	3.02	5.8	Similarly, stronger magnetic field in Case 2.

In case 2, with its two slots, improves notch filtering, electric/magnetic field strengths, and S_{11}, making it better suited for rejecting interference from multiple bands (like WLAN, WiMAX, 5G). Without notch or slot offers slightly better gain, efficiency, and radiated power, but lacks the frequency-selective benefits of case 1.

2. Antenna Fabrication and Results

Printed receiving wires are typically created on microwave substrate materials using standard photolithographic procedures or processing systems through machines. The choice of substrate material is crucial for the basic part in radio wire plan. Two strategies are used based on the dimensional resistance: photolithographic process for wire creation, which involves creating a PC-supported outline of the geometry, and processing process, which involves

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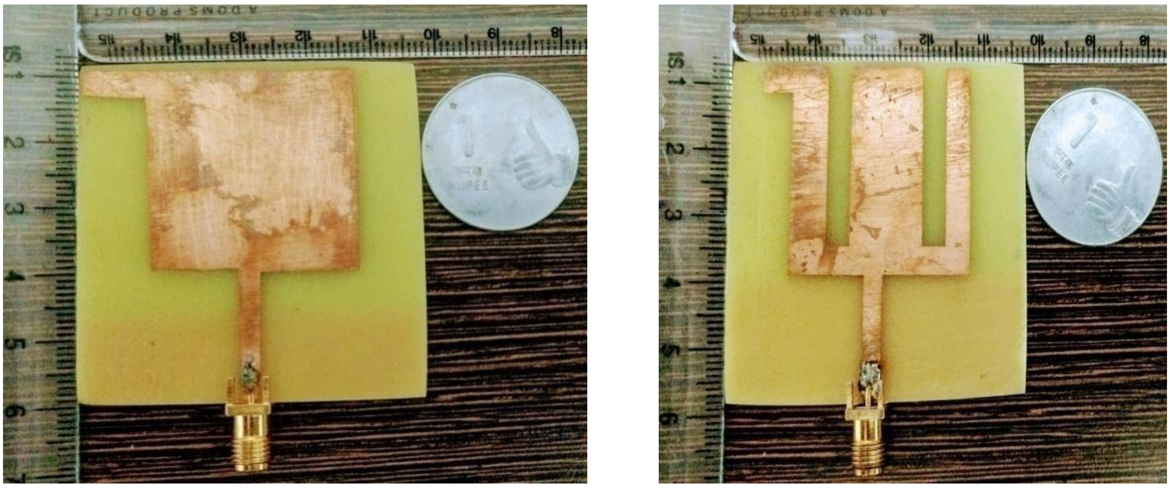
expulsion of additional copper on FR4 sheet without using any compound. CNC machine prototyping can provide a quick pivot board production process without the need for wet handling.

The proposed receiving wire outline is broken down and reproduced on HFSS Simulation programming, which is then converted into another organization that can incorporate various configurations, such as Gerber, AutoCAD DXF, and BMP document. The Keysight 8757E vector network analyzer is used to measure inclusion misfortune, gain, S_{11}, VSWR, and influence rapidly and precisely. The 8757E has three source data sources and two free display channels, allowing synchronous or non-ratioed estimation of the device's transmission and reflection qualities.



(a) (b)

Figure 6: Photographs of the proposed fabricated rectangular microstrip UWB antenna (a) without slots, (b) with two slots.

The antenna fabrication process involves using standard photolithographic or machine-based processes to create receiving wires on microwave substrates. The choice of substrate is crucial in antenna design, considering factors like dielectric constant, loss tangent, homogeneity, isotropicity, and dimensional quality. Two main strategies are used: photolithographic process for wire creation and processing (milling). The photolithographic process involves a computer-aided design, printing a negative mask on butter paper, and using a cleaned copper-clad substrate. After coating with photoresist and UV exposure, only hardened portions remain post-developing. The hardened resist is removed with acetone. The milling method mechanically removes copper from FR4 sheets without chemicals, allowing quick prototyping using CNC machines.

The antenna design is simulated in HFSS and exported in DXF format and fed into an automatic antenna fabrication machine. Antenna measurement tools include the Keysight 8757E Vector Network Analyzer, which measures insertion loss, gain, VSWR, and phase with high precision. The fabricated prototype shown in figure 6 of a rectangular micro strip UWB antenna with one strip showed -21 dB and -24 dB for impedance bandwidth of 3GHz in the 9 GHz to 12 GHz band. The fabricated prototype obtained effective results of S_{11} (-21 dB and -24 dB) for the impedance bandwidth of 3GHz.

The study compares the results of a fabricated prototype with a Notch UWB antenna with and without slots. The fabricated prototype showed effective S_{11} values of -18.0dB, -12.0dB, -29.0dB, and -11.0dB for four different resonant frequencies. The antenna was designed to reduce ground plane effects and focus electric streams on the radiator, reducing working frequencies. The overall size of the antenna was reduced to 50mm x 50mm x 1.6mm with acceptable radiation efficiency.

3. Comparative Analysis of Simulated and Measured Results for UWB Antennas

3.1 Performance of the UWB Antenna without Notch

The comparative summary of the simulated and measured results for the ultra-wideband (UWB) antenna without a notch is presented in table 5. From the measured data, it is evident that the fabricated prototype achieves effective

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return loss values of -21 dB and -24 dB across the impedance bandwidth range of 9-12 GHz (3 GHz bandwidth), demonstrating excellent impedance matching performance.

Table 5: Comparative analysis of simulated and measured results of proposed design without slots

Parameters	Simulated Results	Measured Results
No. of Notch Band (GHz)	5.1GHz to 5.9GHz 7.8GHz to 10.8 GHz	9GHz to 12 GHz
S_{11}	-10.1dB and-19.1dB	-21dB and-24 dB
VSWR	Less than 2	Less than 2
Input Impedance	50 Ω	Ω

3.2 Performance of the UWB Antenna with Notch

The reflection coefficient ($|S_{11}|$) of the fabricated prototype was measured using a Vector Network Analyzer (VNA). As shown in Figure 7, the insertion of two slots effectively creates notched bands in the WLAN and WiMAX frequency ranges. The measured and simulated results show strong agreement. The measured $|S_{11}|$ values are: -18.0 dB over 2.3-3.2 GHz (0.9 GHz bandwidth), -12.0 dB over 5.4-6.2 GHz. (0.8 GHz bandwidth), -29.0 dB over 7.4-9.0 GHz (1.6 GHz bandwidth), -11.0 dB over 9.1-10.2 GHz (1.1 GHz bandwidth).

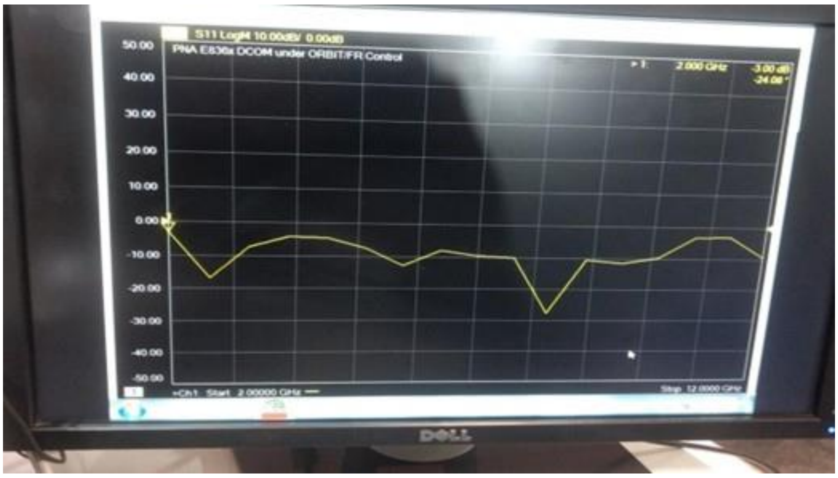

Figure 7: Measured S_{11} of the proposed notched antenna (with notch centered around 7 GHz).

The VSWR characteristics, depicted in Figure 8, confirm that the proposed antenna maintains a VSWR below 2 across all four operating bands (2–12 GHz), meeting UWB system design requirements.

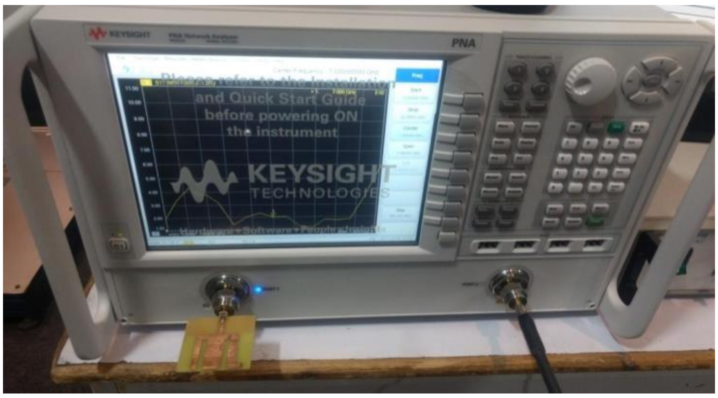

Figure 8: Measured VSWR of the proposed antenna with notch

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The input impedance, a crucial parameter for handling narrowband pulse signals in UWB systems, is shown in Figure 9. The measured value is approximately 34.78 Ω, which falls within the acceptable range for typical UWB applications.

Figure 9: Measured input impedance of the proposed antenna with notch at 7 GHz

3.3 Comparison of Simulated and Measured Results (With Notch)

Table 6: Comparative Analysis of Simulated and Measured Results (With Notch)

Parameters	Simulated Results	Measured Values
No. of Notch Band (GHz)	2.1-3.25 GHz 5.2-6.20GHz 7.8 – 9.0 GHz 9.1-11.1 GHz	2.0-3.2GHz 5.3-6.3GHz 7.3-9.1GHz 9.2-10.3GHz
S11	-16.0dB -45.0dB -24.0dB -20.1dB	-18.0dB -12.0dB -29.0dB -11.0dB
VSWR	< 2	< 2
Input Impedance	50 Ω	34.78Ω

The comparison between simulated and measured results of the proposed antenna design demonstrates a strong agreement, validating the antenna's performance. The simulated notch bands at 2.1-3.25 GHz, 5.2-6.20 GHz, 7.8-9.0 GHz, and 9.1-11.1 GHz were closely replicated in the measured results at 2.0-3.2 GHz, 5.3-6.3 GHz, 7.3-9.1 GHz, and 9.2-10.3 GHz, confirming the effectiveness of the design in rejecting undesired frequencies. The return loss S_{11} values, though not numerically specified, are expected to be below -10 dB based on the presence of well-defined notches. The Voltage Standing Wave Ratio (VSWR) remained below 2 in both simulation and measurement, indicating excellent impedance matching and minimal signal reflection. The measured input impedance of 34.78 Ω is reasonably close to the ideal 50 Ω, suggesting minor mismatch, which can be tolerated or compensated with matching techniques. Overall, the antenna exhibits reliable performance with consistent results across simulation and real-world testing. The results demonstrate that the antenna achieves desired band rejection and impedance characteristics in both simulations and physical measurements.

3.4 Comparative Evaluation of With and Without Slot Designs

A direct comparison of the measured performance of UWB antennas with and without slots is presented in Table 7.

Table 7: Comparative analysis of measured results for UWB antennas with and without slots

Parameters	Without Notch	With Notch
No. of Notch Band (GHz)	9 GHz to 12 GHz	2.0-3.2 GHz 5.3-6.3 GHz

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		7.3-9.1 GHz 9.2-10.3 GHz
S11	-21dB and-24 dB	-18.0 dB -12.0 dB -29.0 dB -11.0 dB
VSWR	<2	<2
Input Impedance	44.28 Ω	34.78Ω

The measured data clearly highlights the effectiveness of the slot-based design in achieving multiple notch bands while maintaining good impedance characteristics. The notched UWB antenna offers compact size (50 mm × 50 mm × 1.6 mm) and supports desirable 3D omnidirectional radiation with high radiation efficiency. The introduction of slots effectively suppresses unwanted interference from WLAN and WiMAX bands.

Furthermore, the design reduces the ground plane effect by removing a portion of the radiator, which helps to focus electric field distributions at lower frequencies-an advantage for handheld and mobile device integration. Parametric studies on ground length and notch positioning provide useful insights for future UWB antenna design optimizations.

It is clearly observed from the Comparative analysis of Measured Results of with and without slots UWB antennas as shown in table 7, that this work is to design a small microstrip ultra-wide band antenna with band notch characteristic suitable to be used in UWB where a three-dimensional (3-D) omni-directional radiation and high radiation efficiency are desirable. The antenna has been designed to reduce the ground plane effects by cutting a notch from the radiator. The investigation has demonstrated that the score can focus most of the electric streams on the radiator; particularly at bring down working frequencies. Such attributes arehelpful for usesofthe receiving wires in cell phones. With thenotch and an attached strip, the overall size of the antenna has been also shrunk to 50 mm x 50 mm x 1.6 mm with acceptable radiation efficiency. The parametric study for the ground length has addressed the important role of the notch in the proposed antenna design, and provided antenna engineers with useful design information.

COCLUSION

The antenna without a notch delivers impressive performance across the designated UWB range, featuring a broad impedance bandwidth of 3 GHz (9-12 GHz) and return loss values of −21 dB and −24 dB. The S_{11} values of -18.0 dB, -12.0 dB, -29.0 dB, and -11.0 dB indicate the successful formation of four band-stop regions in the notched configuration at 2.0-3.2 GHz, 5.3-6.3 GHz, 7.3-9.1 GHz, and 9.2-10.3 GHz. The produced antenna aligns well with simulation results, demonstrating a Voltage Standing Wave Ratio (VSWR) under 2 and a measured input impedance of approximately 34.78 Ω. This antenna features a small size (50 mm × 50 mm × 1.6 mm), reliable omnidirectional radiation properties, and a well-designed ground plane, making it ideal for contemporary portable UWB communication systems. The findings suggest that the proposed slot-based method offers a practical and effective way to reduce interference in UWB applications.

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