Design of an Ultra-Compact MIMO Vivaldi Antenna with Dual Band-Notched Features Tailored for UWB Applications

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Abstract:

This abstract describes a novel ultra-wide band (UWB) multiple-input multiple-output (MIMO) Vivaldi antenna with dual band-notched features. The antenna has a compact size of 26 x 26 mm², improved ground plane, and T-shaped slot for increased port isolation. Two split ring resonators (SRR) are added for dual notches to filter WLAN and X-band interference. Experimental results show an impedance bandwidth from 2.9 to 11.6 GHz, with notches at 5.3-5.8 GHz and 7.85-8.55 GHz. The MIMO antenna exhibits low mutual coupling, stable gain, and is suitable for UWB MIMO system applications. The research contributes to Investigating Band-Notched Vivaldi Antennas

l. Introduction

Normalized Radiation Pattern Analysis of MIMO Antennas. The consistency between simulated and measured radiation patterns validates the design. In terms of gain, the UWB MIMO antenna, without the SRR ring, exhibits stable gain. However, the proposed band-notched MIMO antenna experiences a sharp decrease in gain within the notched band. This highlights its suitability for Effective Band-Notched MIMO Vivaldi Antenna for UWB Communication

Moving to analysis diversity, the envelope correlation coefficient (ECC) is a crucial metric. The ECC, calculated from S-Parameters using the formula (2), is depicted in Fig. 11. Notably, The ECC remains consistently low across the entire impedance bandwidth, indicating excellent diversity characteristics for the MIMO antenna in practical applications.

ll. Antenna Design Analysis

The study explores various UWB MIMO antennas, emphasizing band-notched characteristics. The proposed MIMO Vivaldi antenna on a substrate with a thickness of 0.762 mm Ta-conic RF-35 substrate, has dimensions of 26 x 26mm². Fed by two 502 micro-strip lines, it integrates a Optimized Parameters of the MIMO Vivaldi Antenna and Four SRRs optimized were determined using A soft HFSS, with simulated values provided in millimetres.

lll. Design Process

The design process Dual-Notched MIMO Vivaldi Antenna involves four evolutionary iterations, each aimed at improving specific aspects. The initial antenna (Antenna I) is a dual-port Vivaldi design. In the second iteration (Antenna 2), a rectangular slot is etched on the ground plane to reduce mutual coupling between individual elements. The third iteration introduces a T-shaped slot on the ground plane to further enhance port isolation by reducing surface current between two ports.

In the final iteration, two different Split Ring Resonators (SRRs) are added near each micro-strip line. The larger SRR has a length of Smaller SRR has a length of 12.4mm. The purpose of adding SRRs is to suppress narrowband interference from WLAN and X-band communication satellites, leading to improved notched characteristics. The comparison Comparative Analysis of S-Parameters Across Four Evolutionary Antennas shows enhancements W impedance bandwidth and mutual coupling at low frequencies, particularly due to the T-shaped slot on the ground plane.

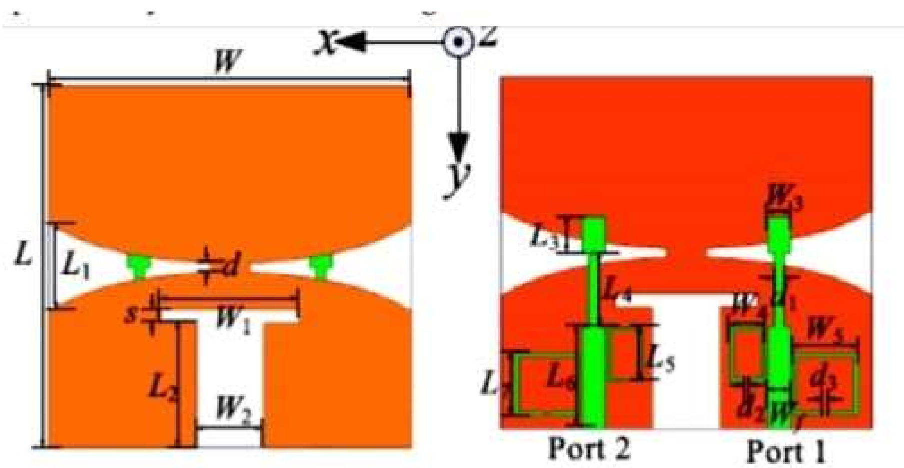

Fig 1.1: Configuration of the designed antenna (a) Top view (b) Bottom view

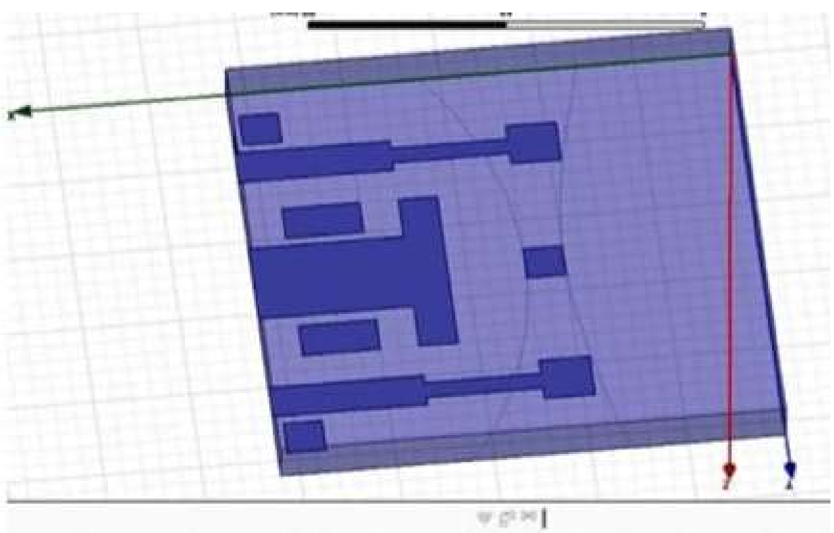

Fig 1.2: Design of MIMO antenna on HFSS platform

IV. Notched Mechanism

It seems like you're discussing Surface Current Distributions and Resonant Effects of Designed Antennas Operating at Various Frequencies, specifically 5.5GHz and 8.2GHz. The presence of different-sized Split Ring Resonators (SRRs) contributes to dual notched bands in the antenna's performance.

V. Parametric Study

The plot in Fig. 5 illustrates the impact of varying d_{1} on the s_{11} curve. With an increase in d_{1}, The notched central frequency gradually increases at low frequencies, whereas it remains stable at high frequencies remains relatively stable. Similarly, Fig. 5 depicts the influence of different d_{e} on the variation of S. As d_{e} increases, the notched central frequency at high frequencies gradually increases, whereas the notched central frequency at low frequencies remains essentially unchanged. This highlights that the notched performance of the designed antenna is primarily determined by the Split Ring Resonator (SRR). Additionally, it is evident that The notched band of the antenna can be flexibly controlled by adjusting the opening slot width of the SRR.

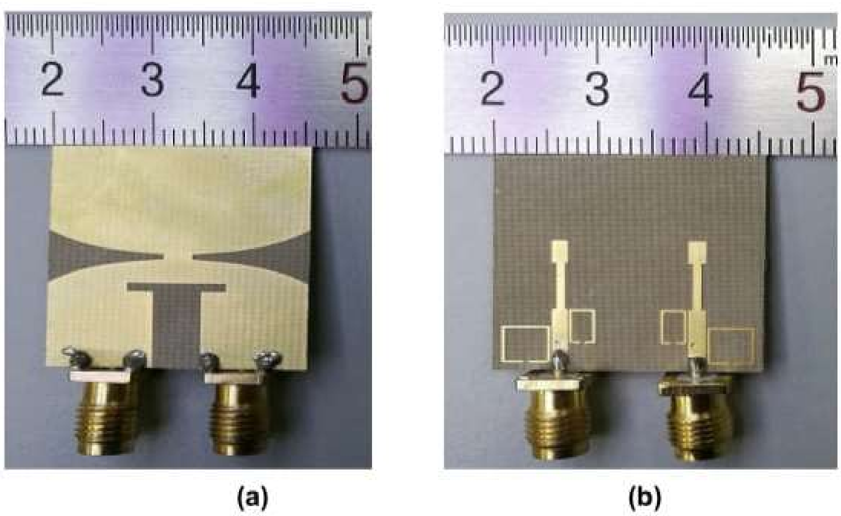

Fig 1.3: Fabricated photographs of the MIMO antenna (a) Top view (b) Bottom view

VI. Result And Discussions

Validating Practical Applicability and Accuracy of Simulations, we proceeded to construct the proposed antenna using the optimized dimensions established in section two. A visual representation Fabricated Band-Notched MIMO Antenna is provided through a captured photograph. Employing a vector network analyser, we carefully measured the S-parameters of the antenna, aiming for precise characterization of its performance. In pursuit of heightened accuracy, we conducted comprehensive tests on the antenna's radiation pattern and gain performance within the confines of a microwave anechoic chamber. This controlled environment ensures minimized external interference, enabling us to obtain reliable and robust results that align closely with the simulated expectations.

A. RETURN LOSS

In Figure 1.7, we present the experimental S-Parameters, including S11/S22 and S21/S12. A quick look at the graph reveals a strong agreement between the measured and simulated results. The proposed antenna boasts an impressive impedance bandwidth, spanning from 2.9 to 11.6 GHz, with S11 consistently below -10dB. Noteworthy are the two notched bands, covering 5.3-5.8 GHz and 7.85-8.55 GHz, aligning with the 5.5 GHz WLAN and 8.2 GHz communication satellites bands, respectively.

Throughout the entire frequency range (2 to 14 GHz), the measured transmission coefficient (S12 = S21) remains impressively low, consistently below -16dB.

The MIMO antenna demonstrates commendable port isolation, ensuring efficient signal transmission, while maintaining relatively low mutual coupling.

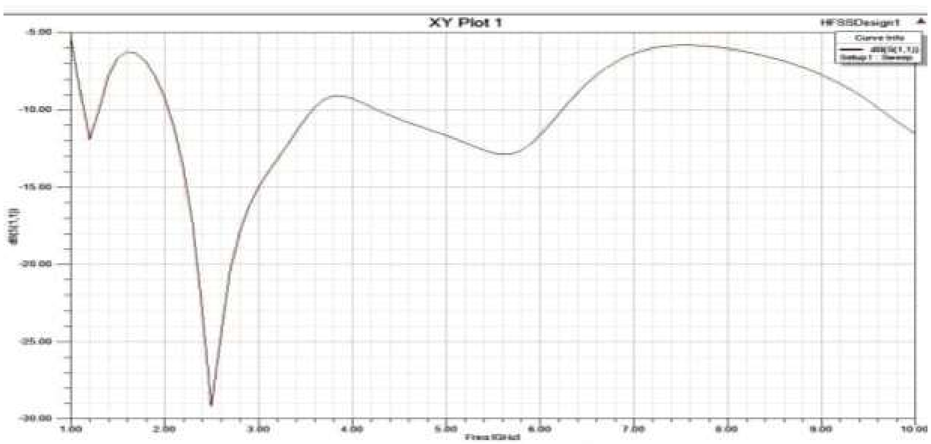

Fig 1.4:Return loss of MIMO antenna.

B. RADIATION PATTERN AND GAIN

Simulated and Tested Normalized Radiation Pattern of the Presented MIMO Antenna, with port 1 being fed and port 2 terminated with a 50Ω load. The alignment between Simulated and Measured Radiation Patterns of the Design serves as confirmation of the design's correctness, highlighting the consistency of performance. Notably, the proposed antenna demonstrates end-fire characteristics.

Fig 1.8 also illustrates the Gain of UWB and Proposed Band-Notched MIMO Antennas with Port 1 Excitation. In the context you're referring to, a UWB (Ultra-Wideband) antenna without an SRR (Split Ring Resonator) ring is simply a UWB antenna configuration that does not incorporate the SRR structure. This type of antenna design is optimized for UWB applications and does not utilize the specific resonant properties provided by SRR, The stability of the gain in MIMO antennas is maintained. while the gain of the designed band-notched MIMO antenna experiences a sharp decrease in the notched band. The experimental results show that the designed MIMO antenna is well-suited for UWB communication applications, offering excellent characteristics in band notching.

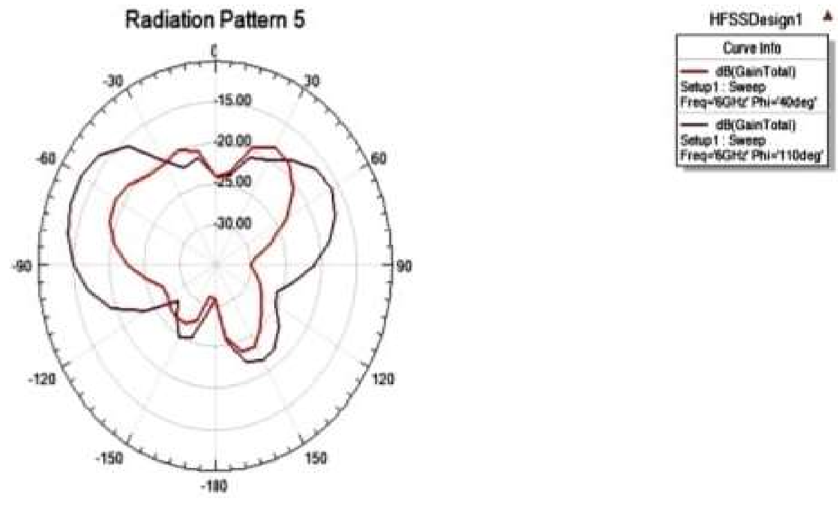

Fig 1.5 : 2-D radiation pattern of MIMO antenna

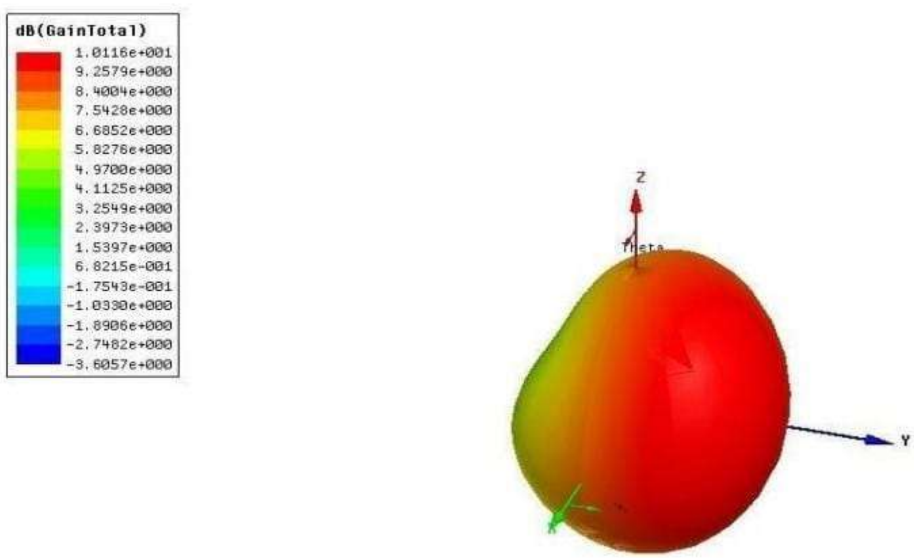

Fig 1.6: 3-D radiation pattern of MIMO antenna

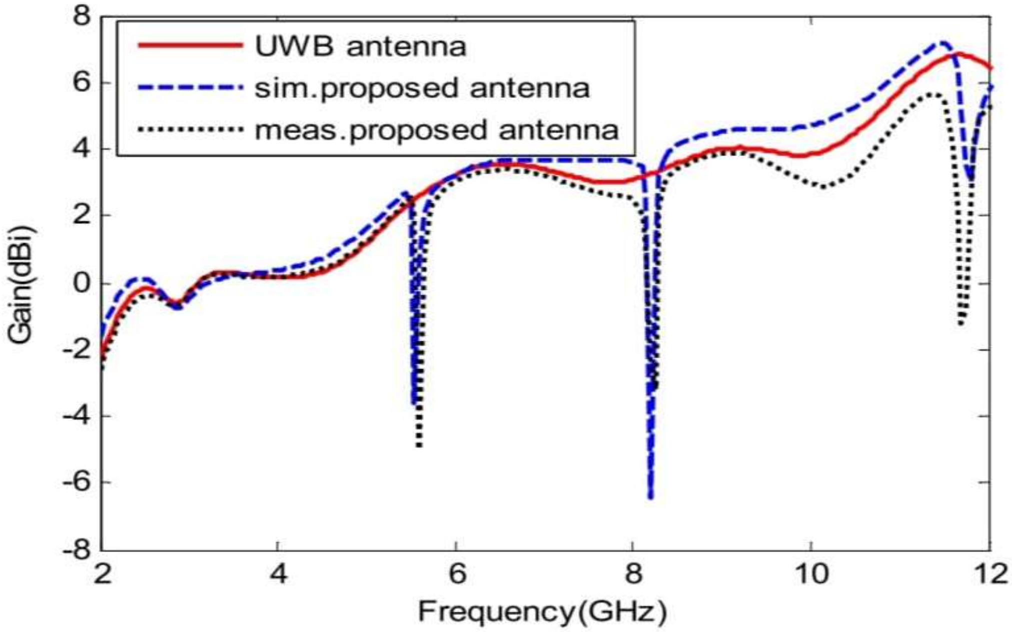

Fig 1.7: Measured gain of the MIMO Vivaldi antenna

C. DIVERSITY ANALYSIS

Diversity Characteristics of the MIMO antenna are assessed through the valuable feature known as the envelope correlation coefficient (ECC). A small ECC is typically indicative of enhanced antenna performance. The ECC, calculated from the S-Parameters using the formula [27]:

$$ECC = \frac{\left|S_{11}^{*}S_{12} + S_{21}^{*}S_{22}\right|^2}{(1 - |S_{11}|^2 - |S_{21}|^2)(1 - |S_{22}|^2 - |S_{12}|^2)}$$

Presentation of experimental ECC , revealing consistently small values, all below 0.02, across the entire impedance bandwidth. This observation underscores the MIMO antenna's capacity for effective diversity, confirming its ability to maintain a high level of independence between its multiple input/output channels.

VII. CONCLUSION

In conclusion, we have introduced a novel UWB MIMO Vivaldi antenna with dual band-notched characteristics, successfully fabricated in a compact size of 26 × 26 mm². Evolutionary design process of the antenna was meticulously detailed, encompassing an exploration variaton of notched characteristics with SRR parameters.The notched ss mechanism was clarified through the analysis of surface current distributions, establishing a comprehensive understanding of its behavior.

Crucially, a strong agreement was observed between simulated and experimental results, confirming the antenna's reliable performance. The MIMO Vivaldi antenna showcased an experimental impedance bandwidth spanning 2.9-11.6 GHz, along with two notched bands covering 5.3-5.8 GHz and 7.85-8.55 GHz. Noteworthy was the consistently low mutual coupling, measuring below -16dB across the entire operating band. Additionally, the antenna exhibited commendable radiating characteristics, stable gain, and an impressively low envelope correlation coefficient (ECC).

In light of these features, the MIMO Vivaldi antenna emerges as a promising candidate for UWB communication and MIMO system applications, offering a compact design with robust performance characteristics.

VIII. REFERENCE

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