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Isolation Enhancement in UWB MIMO Antenna Using I-Shaped Stub

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Abstract

In UWB MIMO antenna systems, enhanced isolation is needed because reduced coupling leads to greater antenna performance. A MIMO antenna system is proposed that has enhanced isolation in UWB. The suggested MIMO antenna has a size of 33x48 mm^2 that contains two rectangle patches with a bandwidth range of 3-11 GHz. Various antenna performance parameters such as S-parameters, VSWR, Reference Impedance, Efficiency, Far fields and MIMO performance parameters such as Envelope Correlation Coefficient (ECC), and Diversity Gain (DG) are observed. This model is small, has a wide bandwidth, a good gain value, and high isolation. The proposed MIMO has a significantly low envelope correlation coefficient (ECC<0.009), high diversity gain (DG>9.95 dB), isolation is enhanced which is below -13 dB, acquired S-parameters are less than -10 dB resonated at 4.52 GHz and 9.88 GHz within the operating frequency range. It is impressive that the suggested antenna has huge isolation although the radiating elements have low edge to edge gap (3 mm).

Keywords: Enhanced Isolation, ultra-wide band, MIMO antenna system, I-shaped stub.

1. Introduction

The enormous benefits that multiple antenna (MIMO) technology offers over single antenna configurations like SISO, SIMO, MISO have led to the adoption of MIMO technology by many current telecommunications standards. Previously MIMO antennas were designed by using meta-material unit cells and meta-material leaky wave antenna with substrate integrated waveguide which are operated over a narrow band [1-3]. The narrow band deteriorates the MIMO parameters. In order to improve the performance of MIMO antenna system, various techniques are employed like defected ground structures [4], line resonators [5] and electromagnetic band gap structures[6]. Ultra-wide band antennas have better performance compared with narrow band antennas [7]. In [8,9] a novel printed antenna with dual notches having size 66x35 mm^2 and a co-planar waveguide antenna for mobile communications with a size 81x81 mm^2 are presented. They have no edge-to-edge gap and have different ground planes due to which the design gets complicated. These designs also have large dimensions. In [10,11] a novel decoupling UWB MIMO antenna having a compact size (27x47 mm^2) and an UWB-MIMO antenna using F-shaped stub with dimensions 50x30 mm^2 are investigated. Though they have compact size and common ground, there is no edge-to-edge gap which may cause interference among radiating elements. The edge-to-edge gap should be an optimum value. A novel stub structure UWB-MIMO antenna is investigated in [12]. The size of this design is 40x68 mm^2.It has a common ground plane and very large edge-to-edge gap which is not a appreciated one. In [13] a modern semi-circular shaped antenna with an optimum isolation is presented. It contains a small size of 18x36 mm^2 also a common ground plane and edge-to-edge gap. But the edge-to-edge gap mentioned is more i.e; 21.5 mm which leads to poor antenna performance. In [14] an ultra-wide diversity antenna with size 37x45 mm^2 is presented. It has very low edge-to-edge gap and also the radiating elements are designed on a same ground plane but it has very low gain. An advanced isolation in ultra-wide band MIMO antenna with the help of carbon black film is presented in [15]. The mutual coupling effects are decreased by using carbon black film but the system cost raises as a result of this strategy.

An UWB-MIMO antenna system for 3-11 GHz is presented in this paper. Two radiating components make the system's structure. I-shaped stub and slots are used to minimize the mutual coupling in between the antenna elements. During the whole operating range, isolation has improved and is lower than -13 dB. A 3D EM software called CST is used to design and simulate this system. It is evident that the antenna is having huge isolation although the patches have low edge-to-edge gap.

2. Antenna Design

2.1 Antenna Configuration

An enhanced isolation ultra wide-band (UWB) MIMO antenna system is proposed. The dimension of the proposed MIMO Antenna is 33x48 mm^2 consists of two stepped-shaped rectangle radiating elements. The isolation is improved by using I-shaped stub and slots in the ground plane. It is constructed on an affordable, widely accessible FR-4 substrate with a 1.6 mm thickness. It is considered that the substrate has a dielectric constant of 4.4.

2.2 Substrate

Many different substrates have been the subject of work. The substrates used in microstrip patch antennas ranges from

$2.2 \leq \epsilon_r \leq 12$. Although the antenna is larger because of the lower permittivity of the dielectric material, it has a greater bandwidth and better efficiency. Radio frequency or microwave circuits connected to antennas limit the ϵ_r. It is considered that the substrate has a dielectric constant of 4.4. The substrate utilised here is FR4 Lossy with dimensions of 33x48 mm^2 and a thickness of 1.6 mm. Using the CST (Computer Simulation Technology) design suite the proposed antenna is designed and simulated.

2.3 Ground

Particularly when it comes to reducing mutual coupling between broadband and ultra-wideband MIMO antenna elements, defected ground structures are the most widely used techniques. Basically, DGS is a defected ground plane that severely disrupts the distribution of surface current.

The back of the substrate is built with a rectangular ground plane and a I-shaped stub. A common ground plane connects the antenna components. To improve isolation between the antenna elements, the ground plane is etched with slots and integrated with the I-shaped stub. Here we used the PEC material as the ground with a thickness of 0.05 mm. First a rectangular plane with dimensions 10x48 mm^2 is designed. The upper edge of ground plane is etched with two slots each of dimensions 1x11 mm^2. Later an I-shaped stub of dimensions 23x8 mm^2 is attached to the upper edge of stepped ground plane as shown in fig 1.

2.4 Patch

A low-profile antenna that can be installed on a surface is called a patch antenna. It is made up of a planar sheet of metal that can be rectangular, circular, triangular, or any other shape, mounted on a larger sheet substrate. Patch antennas are utilized for microwave frequency applications with frequencies larger than 100 MHz.

In this case, the patch was made out of PEC material. The requisite miniaturization, wideband and multiband features can be accomplished by employing fractal structures in antennas. The patch design consists of two radiating elements which are stepped-shaped along with feed line. The path for current flow is broadened by using the fractural structures. Increasing the current's path allows a wider bandwidth.

In the first phase, a single radiating stepped element is designed on a slotted ground plane. The second phase involves designing the second radiating stepped element that share a common ground plane or to create a MIMO antenna system, the first step is essentially repeated along the x-axis. The antenna elements are 3 mm apart from edge to edge as shown in fig 2.

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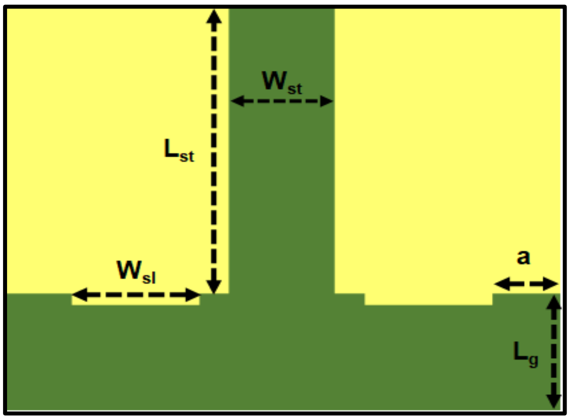

Fig 1: Back view of the proposed antenna

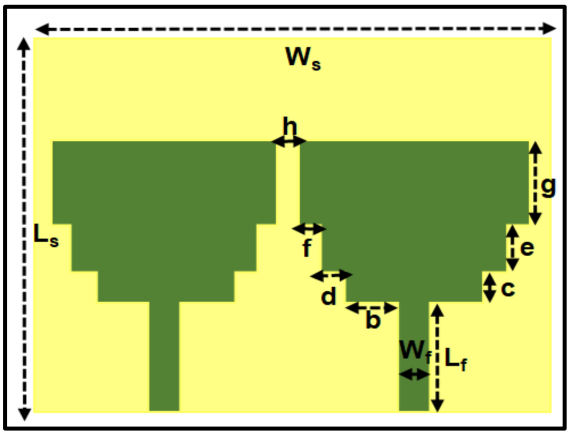

Fig 2: Front view of the proposed antenna

Table 1: Dimensions of the proposed antenna (All dimensions are in mm)

L_s	W_s	L_g	L_{st}	W_{st}	W_{sl}	a	h
33	48	10	22.5	8	11	6	3
L_f	W_f	b	c	d	e	f	g
9.65	3	4.93	2.54	2.28	4.31	1.79	7.35

3. Results and Discussion

A MIMO antenna system is proposed that has enhanced isolation in UWB. The suggested MIMO antenna is having a size of 33x48 mm^2 and is made up of two rectangle patches with a bandwidth range of 3 GHz to 11 GHz. This model is small, has a wide bandwidth, a good gain value, and high isolation. The proposed MIMO has a significantly low envelope correlation coefficient (ECC<0.009), high diversity gain (DG>9.95 dB), improved isolation with a value of -13 dB, and acquired S-parameters are less than -10 dB across the operational range. It is noteworthy that the suggested antenna has huge isolation although the radiating elements have low edge to edge gap (3 mm). For the whole operational bandwidth, the performance characteristics from simulation are in good agreement.

3.1 S-Parameters

The input-output relationship between ports in an electrical system is described by S-parameters. In the operating frequency range (3-11GHz) the S-parameters obtained are below -10 dB and got resonated at 4.52GHz and 9.88 GHz

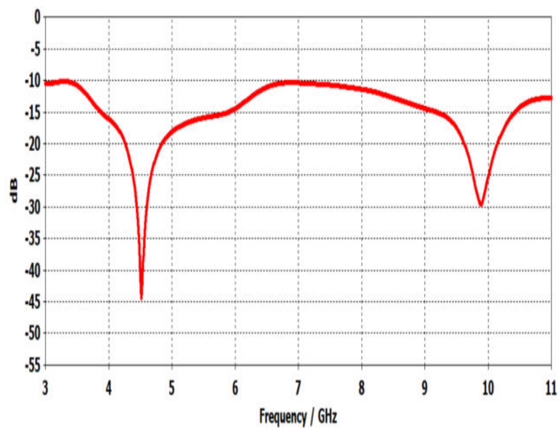

Fig 4: S_{11} and S_{22}

Isolation is enhanced, which is lower than -13 dB across the whole operating frequency range. At 4.52 GHz attained isolation is -23 dB and at 9.88 GHz the acquired isolation is -21 dB.

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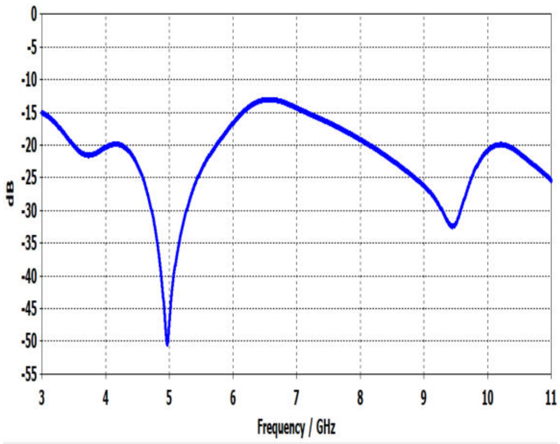

Fig 5: S_{12} and S_{21}

3.2 VSWR

For antennas, the VSWR is always a positive value and ranges from 1 to infinity. The lower the VSWR, the better the antenna matches the transmission line and the more power sent to the antenna. In the operating frequency range, the VSWR is less than 1.9. At resonate frequencies the VSWR is nearer to 1.

$$VSWR = \frac{1+|S_{11}|}{1-|S_{11}|} \quad \text{------- (1)}$$

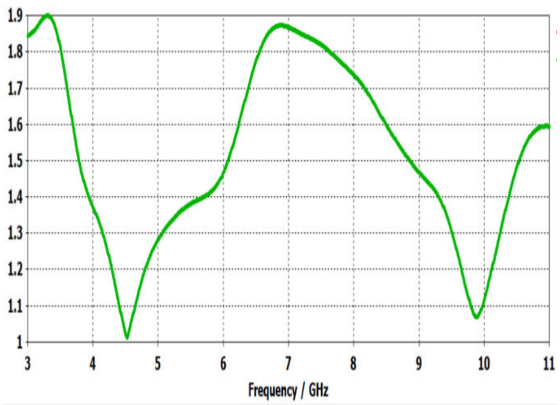

Fig 6: VSWR

3.3 Reference Impedance

It is used for calculating S-parameters of an electric network. In general scenario, the reference impedance is 50 Ω .The obtained reference impedance is 49.3 Ω.

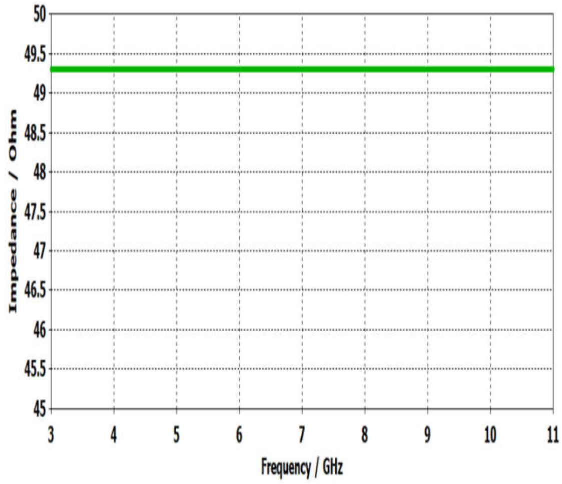

Fig 7: Reference Impedance

3.4 Efficiency

An ideal antenna transmits all of the power applied to it, or has a 100% antenna efficiency. In real world a good antenna radiates only 50 to 60% of the power given to it. It is seen that the proposed antenna had achieved efficiency in range 60-75% within the band of interest and an efficiency of 75% at 4.52 GHz.

$$Antenna\ Efficiency = \frac{P_{rad}}{P_s}\% \quad \text{------ (2)}$$

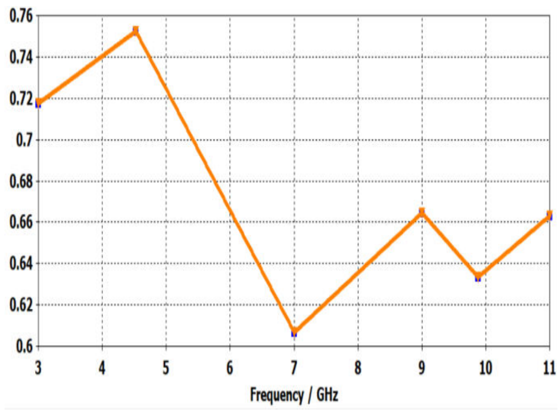

Fig 8: Efficiency

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3.5 Far Fields

The far fields represent the antenna's radiation characteristics as a function of electric field or E-Field (E (θ, Ø)) and magnetic field or H-Field (H (θ, Ø)). Far fields at resonate frequencies are observed.

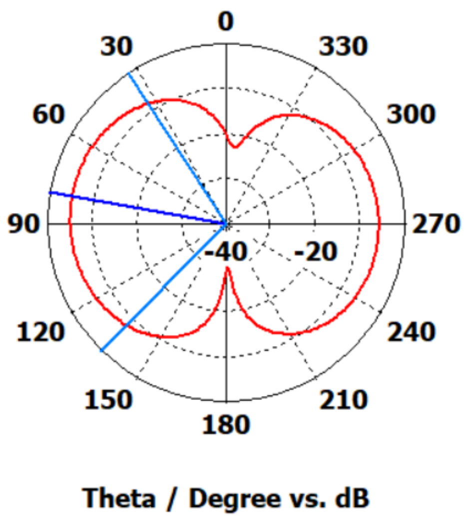

Fig 9: H-Field at 4.52 GHz

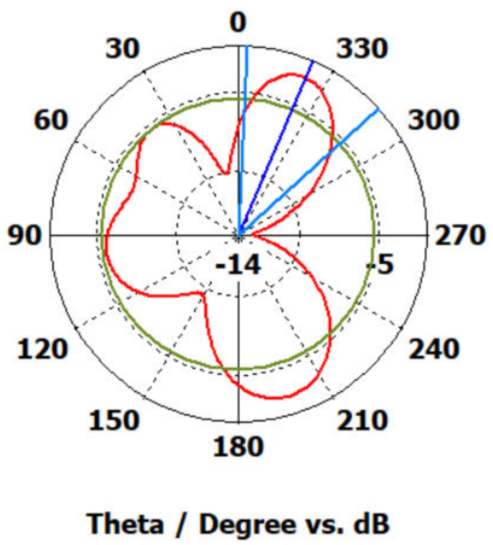

Fig 10: H-Field at 9.88 GHz

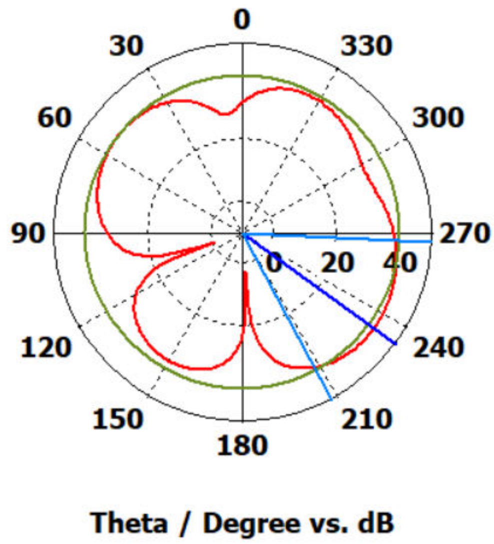

Fig 11: E-Field at 4.52 GHz

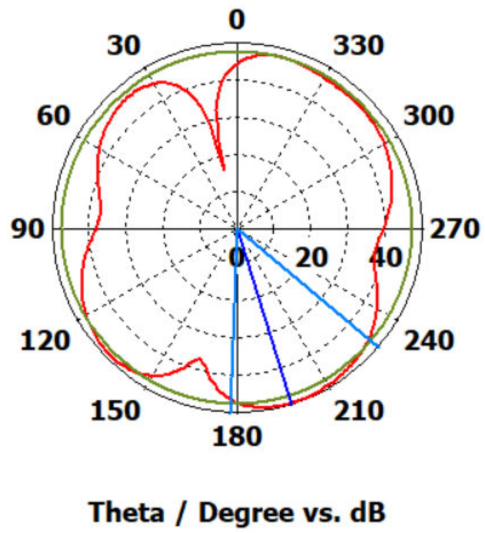

Fig 12: E-Field at 9.88 GHz

3.6 Envelope Correlation Coefficient

Two antennas can have an ECC as 0 if one is totally horizontally polarized and the other is completely vertically polarized. The ECC obtained is less than 0.009. ECC can be calculated as

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

------ (3)

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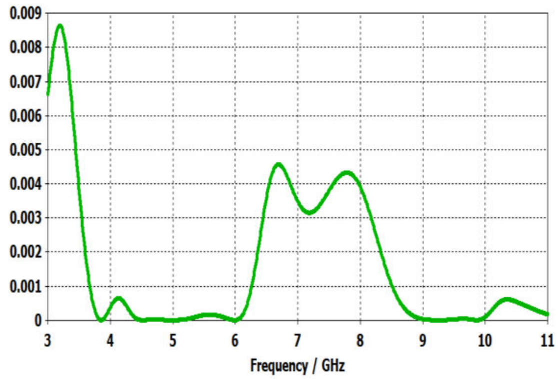

Fig 13: Envelope Correlation Coefficient

3.7 Diversity Gain

Diversity gain measure how much the signal-to-interference ratio will increase as a result of the diversity scheme. The simulated DG for the proposed system is greater than 9.95 dB. Diversity gain (DG) can be calculated using ECC as

$$DG = 10\sqrt{1-(ECC)^2} \quad \text{------ (4)}$$

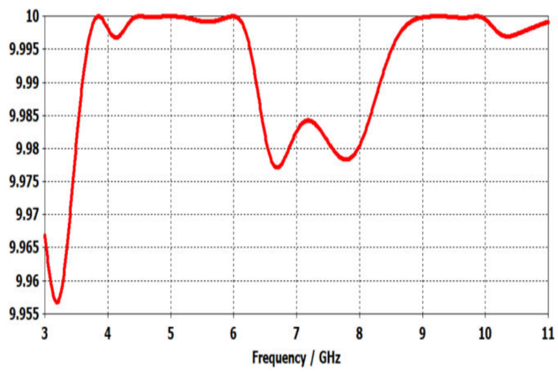

Fig 14: Diversity Gain

4. Conclusion

An UWB MIMO Antenna system having dimensions 48x33 mm^2 has been presented which is designed on FR-4 lossy substrate and simulated. The two stepped-shaped rectangle patches are used to design this antenna, which covers the UWB operations while the isolation is improved by using I-shaped stub and slots in the ground plane. Isolation is enhanced which is lower than -13 dB across the entire UWB. Resonate frequencies obtained are 4.52 GHz (C-Band) which is used for long distance radio communications and 9.88 GHz (X-Band) which is used for satellite communications, radar and space communications. Notable features of the suggested antenna include its small size, wide bandwidth, acceptable gain, and huge isolation although the radiating elements have low edge to edge gap which is 3 mm. Throughout the UWB, the simulated performance characteristics are in good agreement. The proposed antenna miniature nature and omni-directional patterns make it appropriate for mobile electronics.

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