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DUAL BAND NOTCH MIMO ANTENNA WITH MEANDER SLOT AND DGS FOR ULTRA-WIDEBAND APPLICATIONS

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ABSTRACT

A two-element multiple-input multiple-output antenna is presented in this paper. A pair of rectangular patch elements with staircase truncations at the patch-feed interconnection serves as the planar monopole radiating element for this design. The defected ground structures are realized with T-shaped stub etched with L-shaped and meandered slots form the ground plane of the antenna. These DGS procedures and arc-shaped slot and a split ring slot yields the dual band notch characteristics at 4.21 GHz-5.16 GHz, 7.84 GHz-8.63 GHz in a spectrum of 2.109 GHz-11.05 GHz. The far-field distributions at various frequencies and ECC value below 0.5 across the band confirms the concept of polarization diversity.

Keywords: MIMO, DGS, meander slot, polarization diversity, ECC.

1. INTRODUCTION

The urban civilization nowadays makes a challenge to the wireless engineers to produce the portable mobile communication devices that can be used in a dense infrastructure. Mostly the fading problems are occurred in urban areas due to the variations in the signal characteristics according to the surrounding objects. The multipath fading can be reduced by employing multiple antennas MIMO antennas are used for high data rate and good channel capacity [1-2]. In a general MIMO communication system, multiple antennas are inserted in transmitter and receiver and the radiating elements require low isolation. Channel capacity will be increased by using ultra wideband in MIMO antennas. Due to this they are many advantages like low cost, high data rate etc. By providing MIMO technique with UWB antenna one can avoid multipath fading. MIMO antennas play an important role in future mobile communications.

A planar monopole antenna with UWB characteristics exhibits the notch behaviour in IEEE802.11a application by inserting the inverted-U and inverted-V shaped slots in the swallow-tailed patch [3-4]. In [5-6], several isolation techniques were proposed such as etching the planar ground strips, band-notched ground slits, placement of resistive cards between the radiating elements in order to receive uncorrelated signals. In [7-8], a UWB-MIMO antenna is proposed with a common circular radiating element having orthogonal differential feeding for obtaining high-isolation and dual-polarization characteristics with dual notch bands with the help of $\lambda/2$ stubs and slits. A planar MIMO diversity antenna with low mutual coupling is proposed in [9-10] with the help of a sickle shape metallic strip and cross-shaped slot in the ground plane. A MIMO diversity antenna that covers both WLAN 2.4 GHz band and UWB is proposed in [11-12], with a U-shaped patch, T-shaped monopole path and pentagonal wide slot DGS. In [13-14], a MIMO antenna with two-element is presented which provides the inter-element isolation with using the fork shaped structure. A parasitic T-shaped strip is used between patch elements in a UWB MIMO antenna [15-16] in order to suppress the mutual coupling and a notch band at 5.5 GHz is obtained by a pair of L-shaped slits. In a MIMO UWB antenna presented in [17-18], a t-shaped slot is cut in the ground improves the impedance matching and a slot line minimizes the mutual coupling characteristics [19-21].

In this paper, a compact MIMO antenna design is presented for polarization diversity applications with ultra-wideband characteristics. The design is featured with the dual band notch characteristics at the 4-5 GHz C-band as well as the 8-9 GHz X-band communication modules. The geometrical configuration of the antenna is explained in Section 2. The simulation results are explained in Section 3 with the antenna parameters such as return loss, mutual coupling, radiation patterns and the other MIMO antenna parameters such as ECC. Finally, the conclusion is given in Section 4.

2. ANTENNA DESIGN

The multiple-input multiple-output antenna is structured with two planar radiating elements in a square shape which are separated by 22.5mm each other and layered on 1.6mm FR4 epoxy dielectric material. The microstrip line feed with 50ohm characteristic impedance is used to feed the patch elements and the feed structure is tapered for providing the better impedance matching. The basic antenna geometry features are extracted from [10] are shown in Figure-1(a). The defected ground structure is etched on the substrate bottom with a partial ground of length L_{G1}, and a vertical slotted T-shaped stub is connected to it. Pair of thin rectangular strips are protruded from the edge of the partial ground towards the T-shaped stub. In the next iteration, the stair-case slots are made at the patch-feed interconnection which can be seen in Figure-1(b). The T-shaped stub in the defected ground plane is etched with meandered geometry in Fig. 1(c), Fig. 1(d). Finally, in patch elements the arc-shaped slot and split ring slot is etched. The above mentioned geometrical alterations to the base model are performed to expect the dual notch band performance with considerable isolation characteristics for the MIMO functionality.

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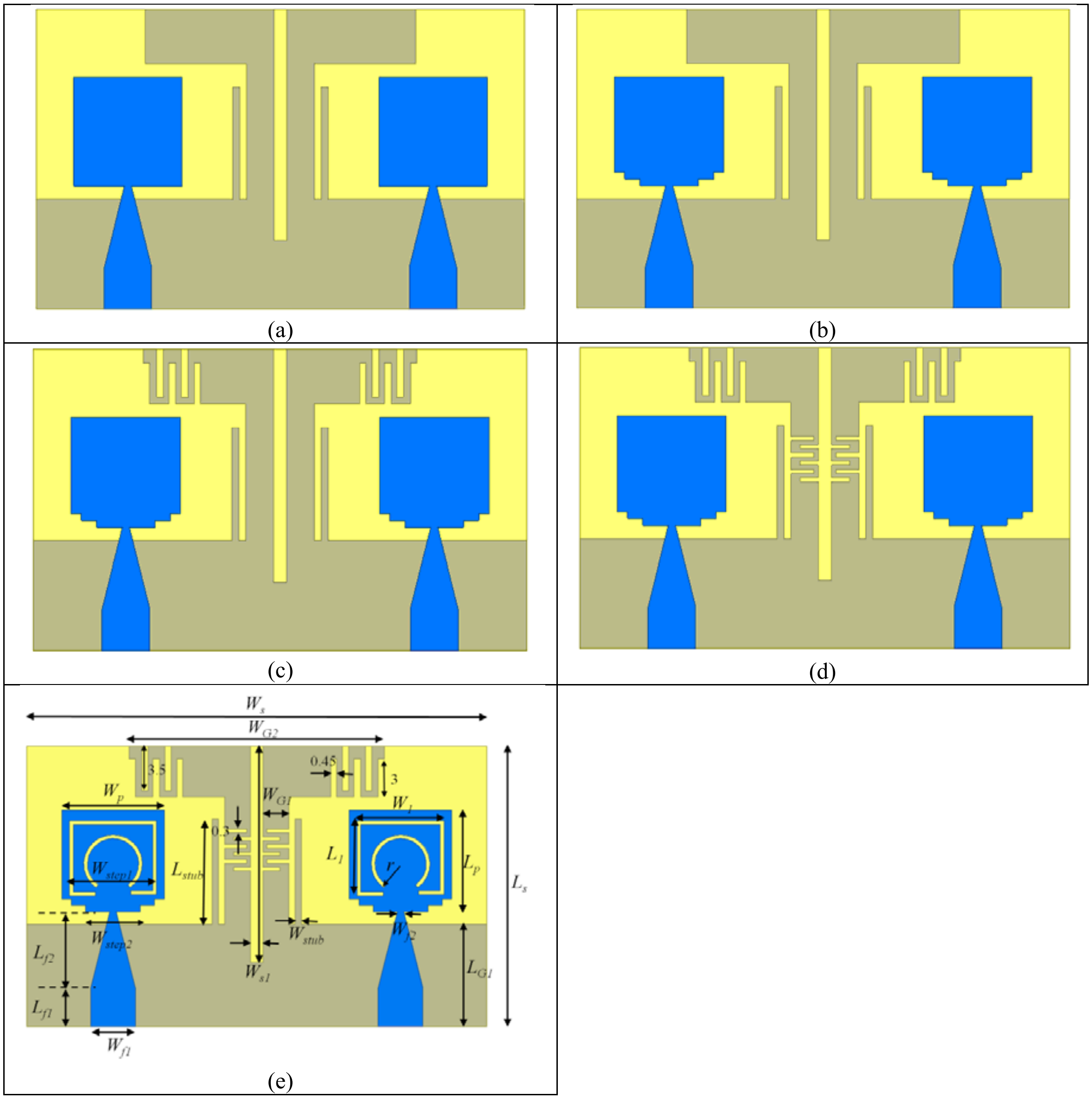

Figure-1. Geometrical evolution of proposed MIMO antenna (a) Base Antenna Geometry (b) with stair-case slotted patch (c) & (d) with meander slotted DGS (e) with slots in the patch elements.

Table-1. Various geometrical parameters of the proposed MIMO antenna.

Parameter	L_s	W_s	L_{G1}	W_{G1}	W_{G2}	L_p	W_p	W_{step1}	W_{step2}	h
Value in mm	22	36	8	2	20	8	8	6.5	4.25	1.56
Parameter	W_{f1}	W_{f2}	L_{f1}	L_{f2}	L_{stub}	W_{stub}	W_{s1}	L_1	W_1	r
Value in mm	3.5	0.5	3	6	8.3	0.5	1	5.9	6.8	2.3

3. RESULTS AND DISCUSSIONS

(a) Return loss & isolation characteristics

The 3D electromagnetic simulation of proposed MIMO antenna iterations using ANSYS Electromagnetic Desktop (HFSS) is yielding the return loss results are presented in Figure-2. To observe the frequency response and the signal reflection characteristics the port 1 and port 2 of various design iterations of MIMO antennas are excited individually. The MIMO antenna with model 1 is having the operating range from 2.15 GHz-4.48 GHz, 5.22 GHz-7.03 GHz, 9.82 GHz-11.08 GHz producing the

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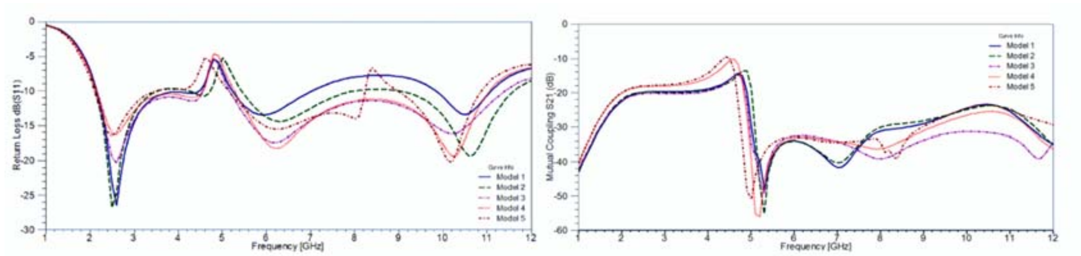
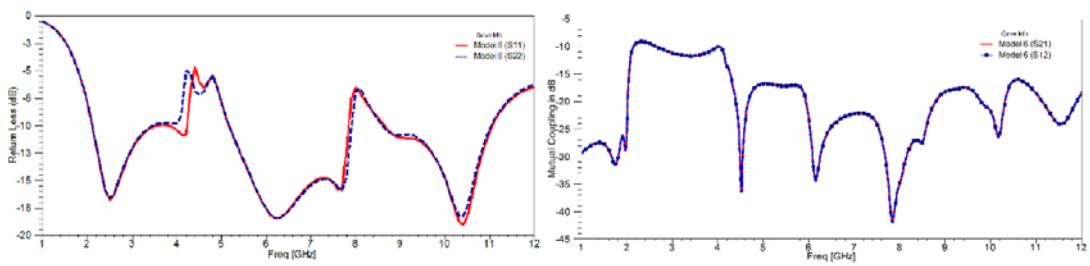
multiband characteristics. The model 2 with stair-cased pattern at the patch-feed junction yields the operating band performance in 2.08 GHz-11.53 GHz with the notching the band at 4.75 GHz -5.37 GHz. The antenna geometry in model 3 with meandered slots in the horizontal arm of the T-shaped stub in the ground is observed to be operate at 2.16 GHz-11.34 GHz UWB band with notch performance at 4.79 GHz-5.34 GHz. In model 4, the meandered slots etched in the vertical arm of the T-shaped ground are leading to reduce the lower and higher cut-off frequency of -10 dB return loss. The split-ring slot and the arc-shaped slot in the patch etched in Model5 are creating the additional notch behaviour at 4.6 GHz, 8.39 GHz notch center frequencies. The desired notch performance can be observed from the proposed model 6, which occurs at 3.46 GHz-5.16 GHz and 7.9 GHz-8.6 GHz with maximum return loss obtained at 4.2 GHz, 4.8 GHz and 8.1 GHz. The return loss plots obtained by exciting the port 2 alone results the similar characteristics that of the port 1. The isolation performance of the MIMO elements can be analysed through the S21, S12 parameters which are plotted in Figure-3. These characteristics show the isolation performance less than -10 dB at notch bands whereas in operating bands it shows below -18 dB isolation performance which indicates the considerable isolation characteristics for proposed MIMO antenna.



(a) (b)

Figure-2. (a) Return loss (S11) and (b) Mutual coupling (S21) performance of MIMO antenna iterations.



(a) (b)

Figure-3. (a) Return loss (S11 & S22) and (b) Mutual coupling (S21 & S12) performance of proposed MIMO antenna.

(b) E-field distribution performance

The E-field distribution on the proposed MIMO antenna is shown in Figure-4. The plot on the left indicates the field patterns obtained while Port 1 is excited and the figure on the right depicts the E-field behaviour with the excitation of Port 2 individually.

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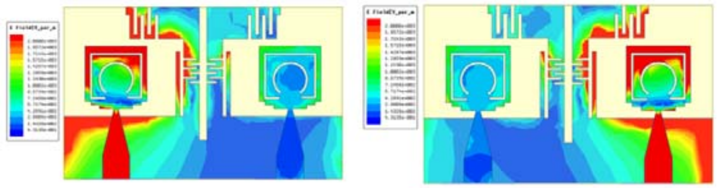
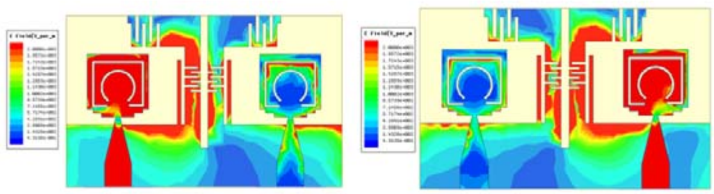


(a)



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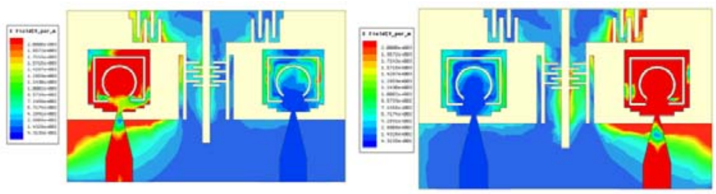
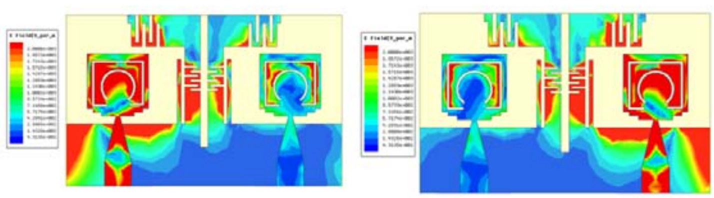


(c)



(d)

Figure-4. Electric field distribution on the elements of proposed MIMO antenna (a) at 2.6 GHz, (b) at 4.7 GHz, (c) at 8 GHz and (d) at 10.2 GHz.

At any frequency point of excitation of one port, the elements connected to the other port are having the low concentration of electric fields which shows the isolation performance is good between the planar monopole elements. The field distribution of the antenna elements and the slotted structures in the defected ground is more concentrated. At 2.6 GHz frequency, the meander slots etched in the horizontal portion of T-shaped stub is having the more field quantities whereas at notch band 4.7 GHz the contour around the meander slots on vertical arms of T-shaped can be considered as the resonant structures. Moreover, the path along the split-ring slot and arc-shaped slot on the patch element are having the more field distribution.

(c) Far-field radiation characteristics

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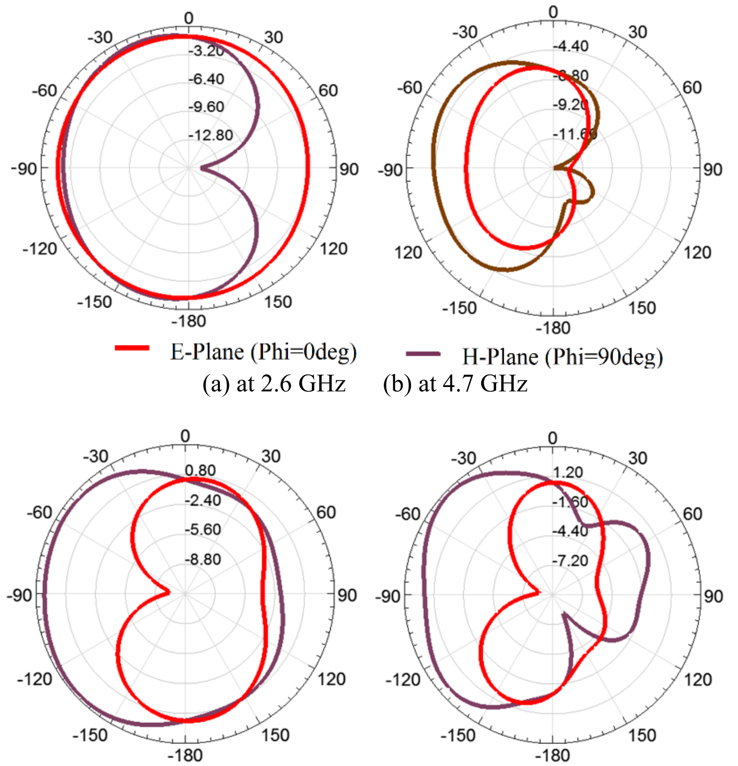
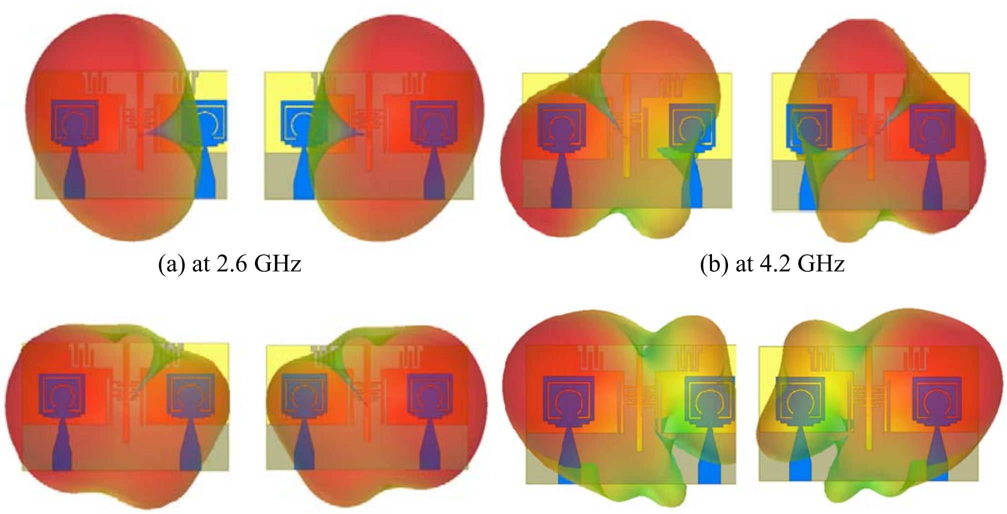


(a) at 2.6 GHz (b) at 4.7 GHz

(c) at 6.2 GHz (d) at 10.2 GHz

Figure-5. E-plane and H-plane radiation patterns of proposed MIMO antenna.

The two-dimensional radiation characteristic of the proposed MIMO antenna is shown in Figure-5. In the azimuth 0deg plane the elevation plane radiation patterns are omni-directional at 2.6 GHz, unidirectional at 4.7 GHz notch band, and a bi-directional nature can be seen at 6.2 GHz and 10.2 GHz bands. The null radiation can be seen in the direction at which the feedline exists in the geometry.



(a) at 2.6 GHz (b) at 4.2 GHz

(c) at 8 GHz (d) at 10.2 GHz

Figure-6. Three dimensional far-field behaviour of proposed MIMO antenna.

In Figure-6, the three-dimensional far-field characteristics are presented for the dual band notch MIMO antenna. The patterns are obtained for each individual port excitations to know the performance of the antenna in a multipath environment. The orientation of directions of maximum radiated fields are seems to be like mirror images for each case of individually excited ports. It follows a nearly orthogonal behaviour which can be useful for receiving/transmitting two perpendicular polarized multipath signals in such environment. The concept of polarization diversity can be observed clearly.

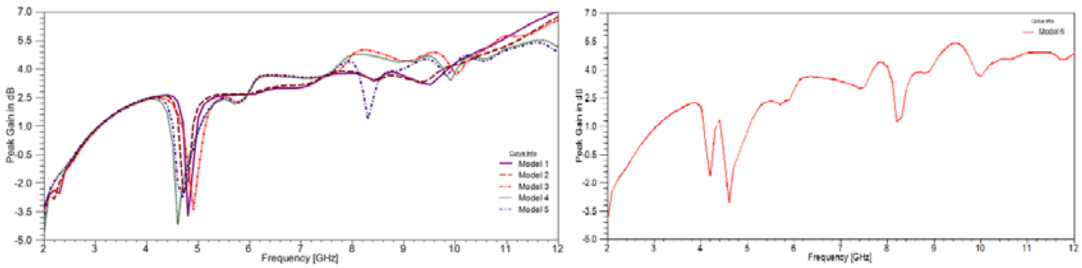


Figure-7. Peak Gain Vs Frequency performance of (a) MIMO antenna iterations and (b) proposed antenna.

Peak gain of the various MIMO antenna designs are presented in Figure-7, the increasing nature of the antenna gain can be observed w.r.t increase in frequency. But a sudden degradation in antenna gain can be experienced at the notch band spectrum in each geometrical case. The maximum antenna gain for the proposed antenna is found to be 5.39 dB at 9.4 GHz within the operating band and a minimum gain is obtained -3.04 dB at 4.1 GHz and 1.01 dB at the 8.1 GHz frequency.

(d) Envelope correlation coefficient characteristics

The behaviour of MIMO antenna can be analysed using envelope correlation coefficient parameter and its characteristics w.r.t frequency proposed MIMO antenna is plotted in Figure-8. The ECC parameter can be computed using the following expression.

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

The value of envelope correlation coefficient is below 0.14 across the frequency sweep. In the operating spectrum of proposed MIMO antenna, its value is under 0.04 which shows a low correlation between the antenna elements and at notch bands the value has a rise and fall nature and thereby proving the good isolation performance among the MIMO elements. The acceptable limit for ECC is 0.5 to have a good MIMO performance [11] according to which the proposed design is satisfactorily meeting this criterion.

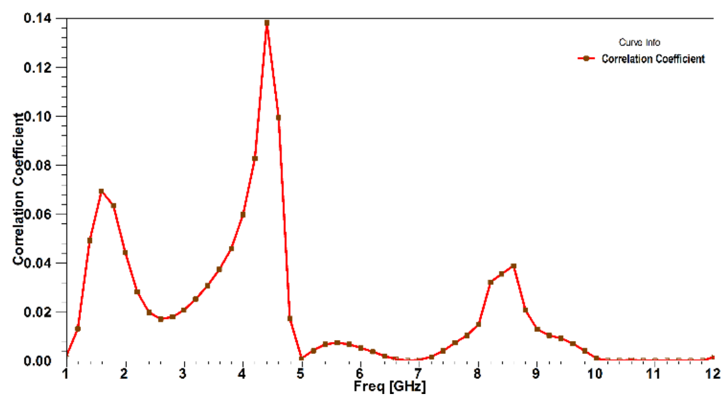


Figure-8. Envelope correlation coefficient vs frequency characteristics of proposed antenna.

4. CONCLUSIONS

In this article, the MIMO diversity antenna is presented to mitigate the problems in the multipath environment. The proposed antenna operates in the ultra wide operating bandwidth ranging 2.109 GHz-11.05 GHz creating the band notch performance at .21 GHz-5.16 GHz, 7.84 GHz-8.63 GHz for reducing the interference level from the C-band and X-band communication modules. The isolation characteristics are proved with the E-field distribution on the antenna elements and moreover the characteristics obtained from the S21 plots and envelope correlation coefficient behaviour. The proposed antenna can be better suitable to be used in new smart phones and PDAs for having high capacity, high data-rate trans-receiving applications.

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