

## Design of Two Element Triple Band MIMO DRA with Enhanced Isolation for LTE Applications

Varakumari Samudrala<sup>1\*</sup>; Vinay Kumar Pamula<sup>2</sup>

<sup>1\*</sup>Department of ECE, UCEK, JNTUK, Kakinada, India.

<sup>1\*</sup>varakumari3@gmail.com

<sup>2</sup>Department of ECE, UCEK, JNTUK, Kakinada, India.

<sup>2</sup>pamulavk@ieee.org

### Abstract

*A new two element hybrid MIMO DRA is presented for LTE operation. The presented MIMO having two elements excited with CPW feeding. This is operating under hybrid TM mode. MIMO is intended on partial ground with thickness of 0.035 mm, substrate (FR-4) with dielectric constant ( $\epsilon_r$ ) of 4.6, thickness 1.6 mm and loss tangent 0.019. The DRA is placed on the two elements individually. The dimensions of the presented MIMO are 90 X 107.8 X 13 mm<sup>3</sup>. The antenna gives a multiband to covers 0.8 GHz, 1.5 GHz, and 1.7 GHz for  $|S_{11}| \leq -10$  dB. The proposed MIMO can cover LTE Band 5 and Band 6 at 0.84 GHz with operating band width of 83.2 MHz (0.8106 – 0.8938 GHz), LTE Band 21 at 1.5 GHz with operating band width of 45.4 MHz (1.4825 – 1.5279 GHz) and LTE Band 9 at 1.7 GHz with operating band with is 72.6 MHz (1.7382 – 1.8108 GHz). The simulated isolation of -74.96 dB, -75.53 dB and -81.41 dB are obtained with respect to the mentioned frequencies, respectively. MIMO provides very good radiation efficiency >140 % at band-1, > 81% at band-2 and >82% at band-3. The proposed antenna is discovered to attain good isolation, better impedance matching, low Envelope Correlation Coefficient (ECC) and adequate gain. Hence, This MIMO suitable for LTE applications. The HFSS software is used for the simulation.*

**Key-words:** Isolation, LTE Bands, Multiband, DRA, ECC.

### 1. Introduction

The highlights of antenna like high radiation efficiency, more bandwidths are achieved the focus of the investigators on Dielectric Resonating Antenna (DRA). In the Wireless communication technology, the current trend needs high data rates and more band widths to convey the information. But these parameters are limited. Hence, to meet these requirements we adopted another technique,

i.e., the use of Multiple Input and Multiple Outputs (MIMO) system. This increases the data rates and improves the system response [1]-[2]. The operating frequency for LTE from 400 MHz to 4 GHz. [3]. To improve the data rates MIMO with small size is preferred for 4G applications. Multiband MIMO technology with less mutual coupling to provide high data rates for wireless transmission [4]-[6]. MIMO system innovation is adapted to increase the data rate mean while we have maintained the less separation distance between the ports. If the space between the antennas is less again there is problem with mutual coupling. Hence, while designing the MIMO system, increase the isolation and decrease the envelope correlation coefficient to improve the diversity. Wireless technology wherever several piers are utilized at source and destination [7]. MIMO mainly aimed to improve the information rate and minimizes the errors. To get more information speed or gathering MIMO idea is embraced in little appliances. MIMO antennas provide more data rates and radiation efficiency. The overall performance is more effective [8]-[9]. The single component MIMO reception apparatuses are precisely solid, have insignificant mis mount blunders, and simple to create when contrasted with multi components, however the issue is to achieve high separation between radiating elements and having very low Envelope Correlation Coefficient (ECC). Very recently so many articles given most effective solutions is presented to focus on this problem [10]-[19]. In this research work, we propose a 2-radiating-element MIMO DRA system solution enabling multiband behavior, High isolation and low ECC, and high efficiency. This article presents a two -element multiband DRA for 4G applications.

The antenna is designed using meander line patches, whereas substrate of 1.6 mm height and ground having thickness of 0.035 mm and ground considered as partial ground structure. The CPW feeding with two elements placed symmetrically which provides less mutual coupling among supply elements and verse radiation configuration which minimizes the delay among radiating elements. The presented multiband MIMO is easy to construct. In this presented MIMO, the reference level considered for impedance bandwidth is – 10 dB and for isolation bandwidth is- 15 dB.

## 2. Antenna Geometry

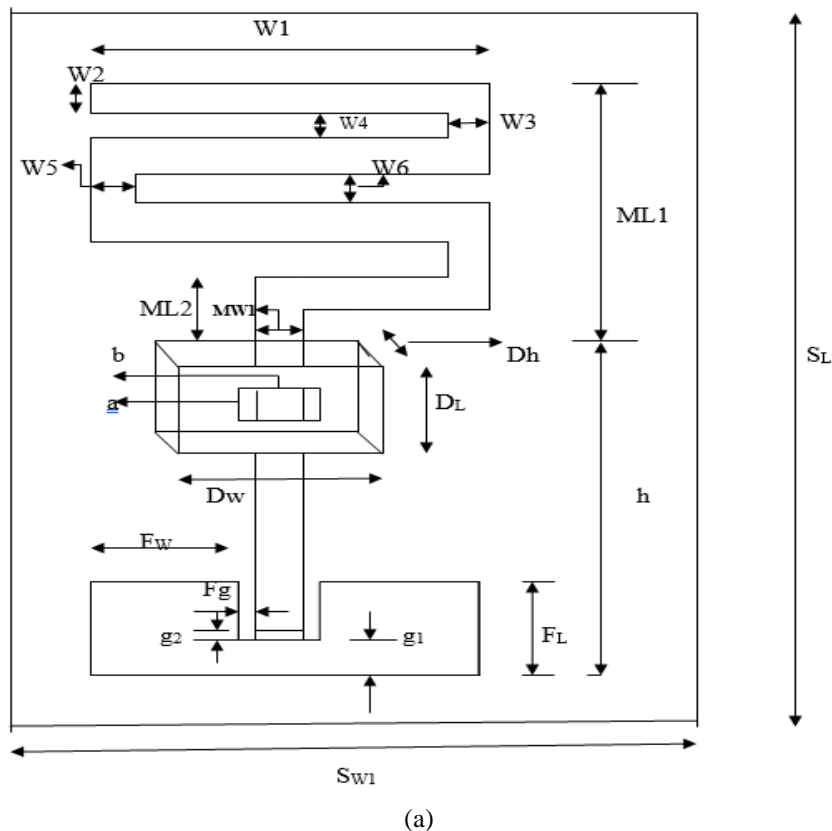
The proposed two-element multiband MIMO Dielectric Resonator Antenna dimensions are shown in [Figure 1]. The antenna system is contained of two meander line radiating elements, whose dimensions of each element as given in the table 1. The elements are placed on substrate with  $\epsilon_r$  of 4.6, dielectric loss ( $\tan \delta$ ) of 0.019 and thickness of 1.6 mm. The length, width, and height of the substrate of single radiating element are designated as  $S_L$ ,  $S_W$ , and  $S_H$  respectively, whose dimensions

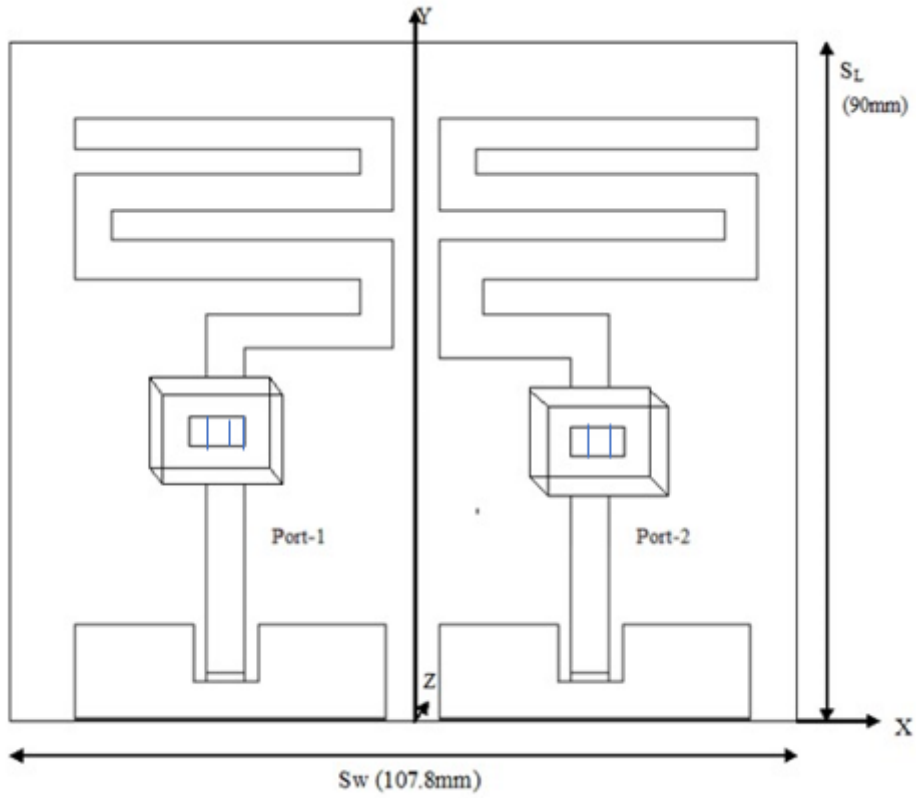
are  $S_L= 90$  mm,  $S_w= 53.9$  mm, and  $S_H= 1.6$  mm. The partial ground plane has the dimensions of  $50 \times 53.9 \times 0.035$  mm<sup>3</sup>. The radiating elements are optimized for better impedance matching and placed symmetrically to attain a bandwidth of  $|S_{11}| \leq -10$  dB with improved isolation and very good ECC. The optimized value of the 2-element antenna parameters is shown in the table 1.

Table 1 - Simulated Parameters of Presented MIMO

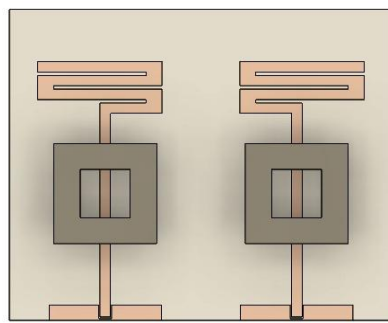
Antenna parameters	Dimensions (mm)	Antenna parameters	Dimensions (mm)
$S_L$	90	$W1$	35
$S_w$	107.8	$W2$	3
$S_H$	1.6	$W3$	4.5
$D_w$	29	$W4$	1
$D_L$	29	$W5$	4.5
$D_h$	11.4	$W6$	1
$a$	14	$F_g$	0.3
$b$	14	$F_w$	14
$d$	11.4	$F_L$	4.5
$MW1$	3	$g1$	0.5
$ML1$	24.7	$g2$	0.5
$ML2$	12.7	$h$	49.2

Figure 1 - Proposed Antenna Geometry: (a) Single Element View with Dimensions, (b) Two Element View with Dimensions (c) Isometric View (d) Front View (e) Back View with Dimensions (f) Back View

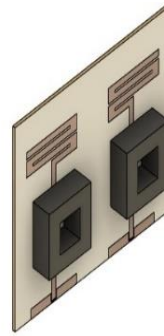




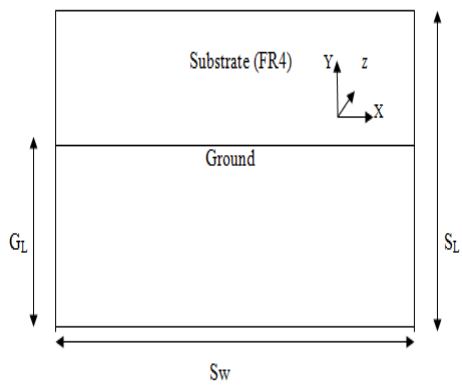
(b)



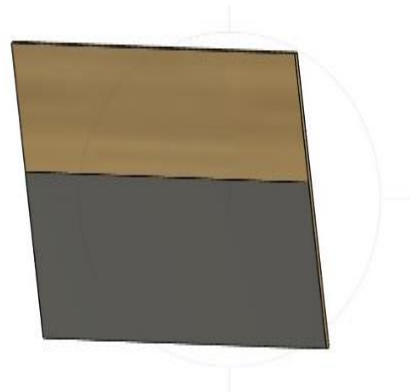
(c)



(d)



(e)



(f)

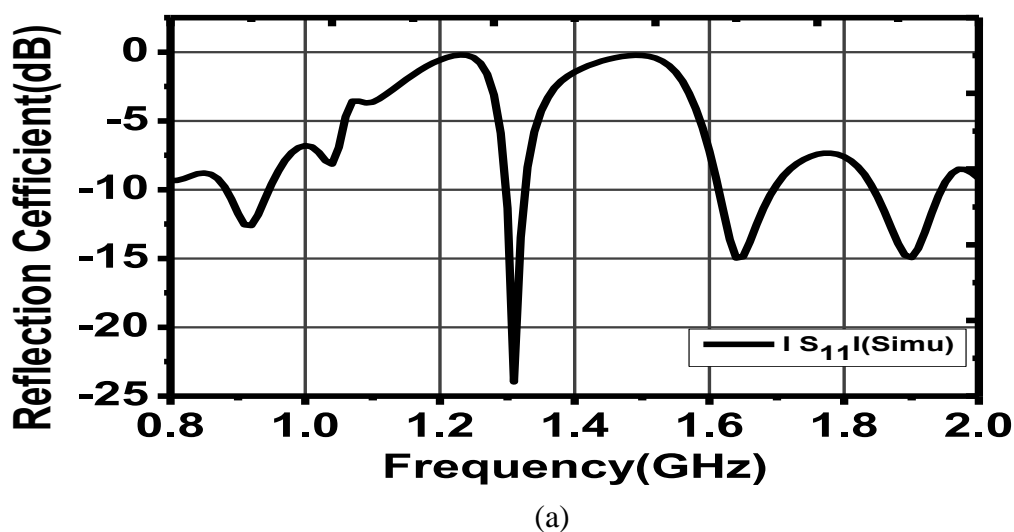
### 3. Design and Analysis

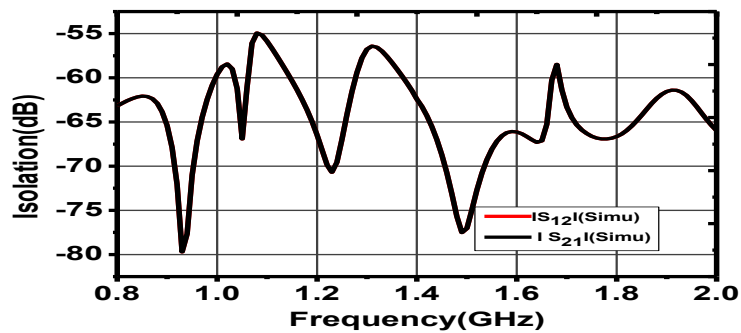
To design an antenna certain steps to be follow, initially single element antenna study has been done and then two element antennas has designed with and without hole inside the DRA. The observations of the responses of two element without hole antenna assisted to get best model, and then simulated.

#### 3.1. Effect of with Out Hole Inside the DRA

Initially for single element antenna with  $90 \times 53.9 \times 0.035 \text{ mm}^3$  has been studied, a ground plane having length, width and thickness are  $50 \times 53.9 \times 13 \text{ mm}^3$  and substrate having length and width and Height are  $90 \times 53.9 \times 1.6 \text{ mm}^3$  is adopted. At the same time simulation carried out. Further with the help of single meander element two element with symmetry structure antenna is designed. This antenna is operating under 4 bands, among four bands only one band is perfectly impedance matched remain bands needs to be improved. The reflection coefficient of antenna is -24 dB at 1.3 GHz as given in [Figure. 2 (a)], meanwhile the isolation between the ports is  $> -56 \text{ dB}$  attained under the operating band as given in the [Figure 2 (b)]. While ECC is very less as shown in [Figure. 3]. Hence, it shows the good isolation between the ports for  $|S_{11}| \leq -10 \text{ dB}$  at the resonant frequency of 1.3GHz. Now this band is suitable for modern communication systems such as LTE.

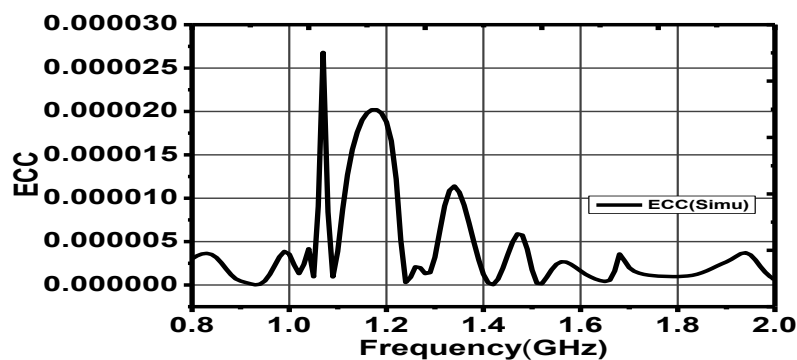
Figure 2 - Antenna S-Parameter without Hole: (a) Reflection Coefficient (b) Isolation





(b)

Figure 3 - Envelope Correlation Coefficient (ECC)



### 3.2. Effect of Hole Inside the Dra

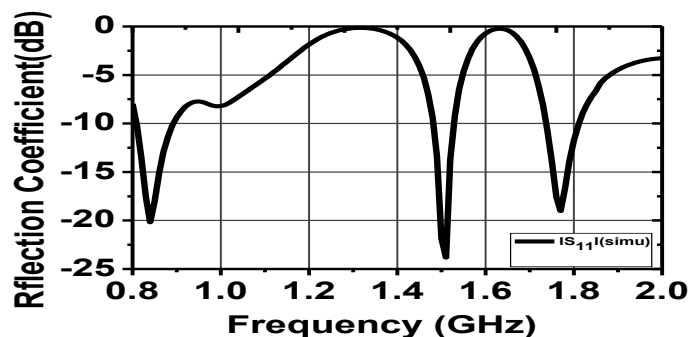
Use In the second step of the design as illustrated in the [Figure 1], a hole is drilled inside the structure of Dielectric Resonator (DR) with dimensions of  $14 \times 14 \times 28 \text{ mm}^3$  to improve the isolation, impedance matching, radiation efficiency and bandwidth. The main observation on antenna with hole is very effective on the improvement of the impedance matching. The dimensions of two-element DRA with hole are  $90 \times 107.8 \times 13 \text{ mm}^3$ . The two meander lines are placed symmetrically on the y- axis as illustrated in the [Figure 1]. Two element antenna system with hole has been studied. Now it is operating under three bands at the resonant frequency of 0.84 GHz, 1.5 GHz and 1.7 GHz with 83.2 MHz, 45.4 MHz, and 72.6 MHz bandwidth, respectively. LTE bands such as LTE band 5 and band 6 at 0.8 GHz and band 21 at 1.5 GHz and band 9 at 1.7 GHz lie within the operating bands, with the help of two elements without hole, it is provided only one band with perfect impedance matching. But with the drilling of hole inside the DR obtained perfect impedance matching under three bands and it is covering 4 LTE band of operations. Hence, these bands are suitable for LTE/4G communication system. Reflection coefficient and isolation as illustrated in [Figure. 4]. It can be realized that bandwidth for  $|S_{11}| \leq -10 \text{ dB}$  enhanced and covering of four LTE

bands such as Band 5, Band 6, Band 21, and Band 9 are operating under operating band of frequency as in [Figure 4 (a)]. There is a good improvement in the isolation from -75 dB to -81 dB in the operating bands [Figure 4 (b)]. This is obtained by considering hole inside the DRA. The 3D radiation pattern of two element antennas at 0.8 GHz, at 1.5 GHz and 1.7 GHz has given in the [Figure 9 (a), (b) and (c)] respectively. It is observed that peak radiating power is concentrated more on the y axis and -y axis only. To attain all the sides, we need to place patches on x axis also. Further it is implemented with four element antennas. The envelope correlation coefficient (ECC) is noticed as 0.000001 at 0.8 GHz, 0.000001 at 1.5 GHz and 1.7 GHz. So, the mutual coupling is very less between the port 1 and port 2. The simulated antenna parameters values at three operating frequencies as shown in the given table 2.

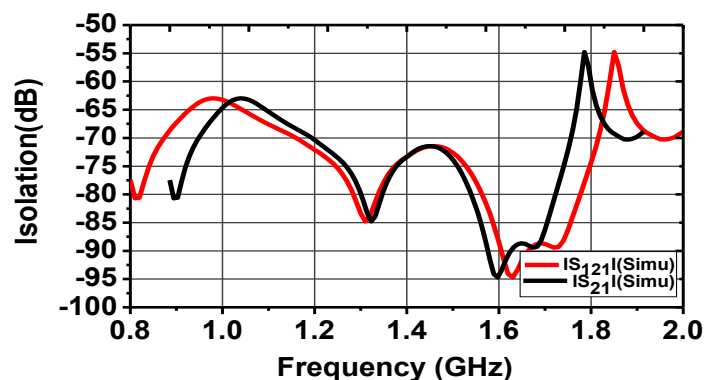
Table 2 - Simulated Antenna Parameter Values at Port1 and Port2

Antenna Parameters	Frequency (1.3GHz)
Covered bandwidth (GHZ)	1.2976 – 1.3279 (30.3MHz)
Isolation (dB)	>-56dB
Return loss (dB)	-24dB
Diversity Gain (dB)	9.99999
ECC	>0.000001

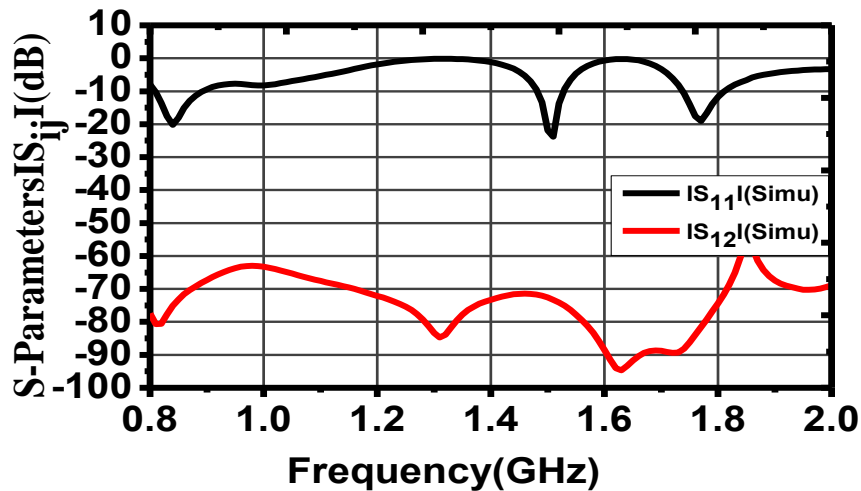
Figure 4 - S-Parameters :(a) Reflection Coefficient (b) Isolation (c) Both Return loss and Isolation



(a)



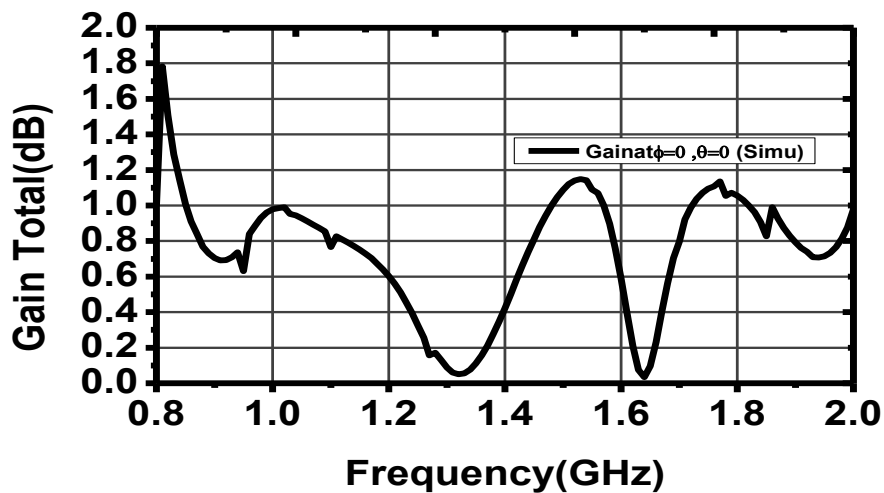
(b)



(c)

As given 3D radiation pattern at port1 and port 2 in the [Figure 9], the antenna is radiating uniformly in all the directions. If it is operating at both the ports, the peak power observed on y axis only. More isolation attained with good radiation efficiency compared to [13] with the use of hole inside DRA only attained triple bands with good isolation and improved ECC with in the operating band as shown in the [Figure 7]. The envelope correlation coefficient is observed at port 1 and 2 which less than 0.000001.

Figure 5 - Analysis of Gain



The antenna gain is adequate at three operating bands as illustrated in the [Figure 5]. This is poor it needs to be improved. The simulated parameters are illustrated in the Table 3. It is noticed that there is good impedance matching, improved isolation with good efficiency in the operating bands.



Table 3 - Simulated Antenna Parameter Values at Port 1, 2

Antenna Parameters	Frequency		
	0.8 GHz	1.5 GHz	1.7 GHz
Covered bandwidth (GHZ)	(0.8106 - 0.8938) 0.0832	(1.4825 -1.5279) 0.0454	(1.7382-1.8108) 0.0726
Isolation (dB)	-75.03	-75.53	-21.92
Return loss (dB)	-20.29	-24.02	-19.03
Diversity Gain(dB)	9.99999	9.99999	9.99999
ECC	<0.000001	<0.000001	<0.000001

The simulated values of proposed multiband antenna as given in Table 3. The ECC is very important characteristic. To enhance the diversity functioning of the system, the correlation between the ports of the MIMO should be minimum because the diversity gain ( $G_{app}$ ) and ECC/  $\rho$  both are inversely proportional to each other. Numerically, envelope correlation coefficient can be represented by utilizing S-parameters such as given in equation (1).

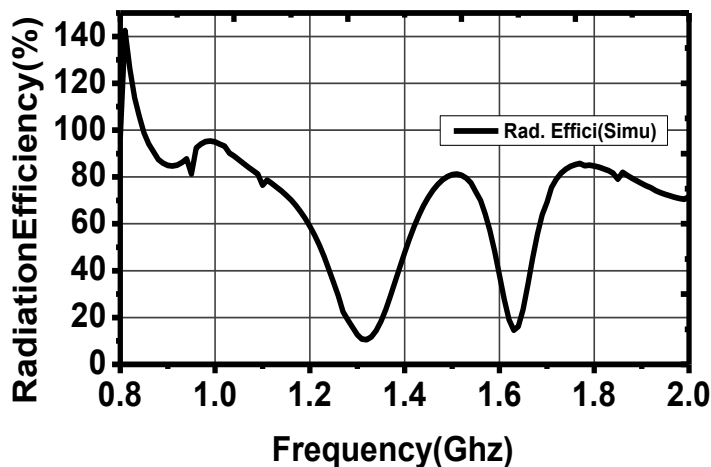
$$\rho = \frac{|S_{11} \cdot S_{12} + S_{21} \cdot S_{22}|^2}{(1 - (|S_{11}|^2 + |S_{22}|^2))(1 - (|S_{22}|^2 + |S_{12}|^2))} \quad (1)$$

The numerical relationship between correlation coefficient and the diversity gain can be represented as given in the equation (2). As for the relation between diversity gain and correlation, if the correlation value is very low then the diversity performance is more. So, to get better diversity gain, correlation value should be less.

$$G_{app} = 10 * \sqrt{1 - |\rho|^2} \quad (2)$$

The presented multiband projection gets very decent co-relation coefficient ( $\rho$ ) of MIMO as illustrated in the [Figure 7]. and diversity gain ( $G_{app}$ ) calculated by above mentioned. The presented  $\rho$  lies between 0 and 0.000001 whereas  $G_{app}$  lies under 9.99999 within the obtained bands.

Figure 6 - Radiation Efficiency of MIMO DRA



The simulated 2D and 3D radiation patterns comparison is illustrated in [Figure 8] and [Figure 9], for the resonant frequency of 0.84 GHz, 1.5 GHz, and 1.7 GHz, respectively. As per the pattern the Most energy is focused on y- axis at 0.8 GHz and all the sides at the remain frequencies. In this Both E plane (at Phi =0 deg) and H plane (Phi = 90 deg) are noticed as illustrated in [Figure 8]. The power is attained in all the directions.

Figure 7 - ECC of Proposed MIMO DRA with a Hole

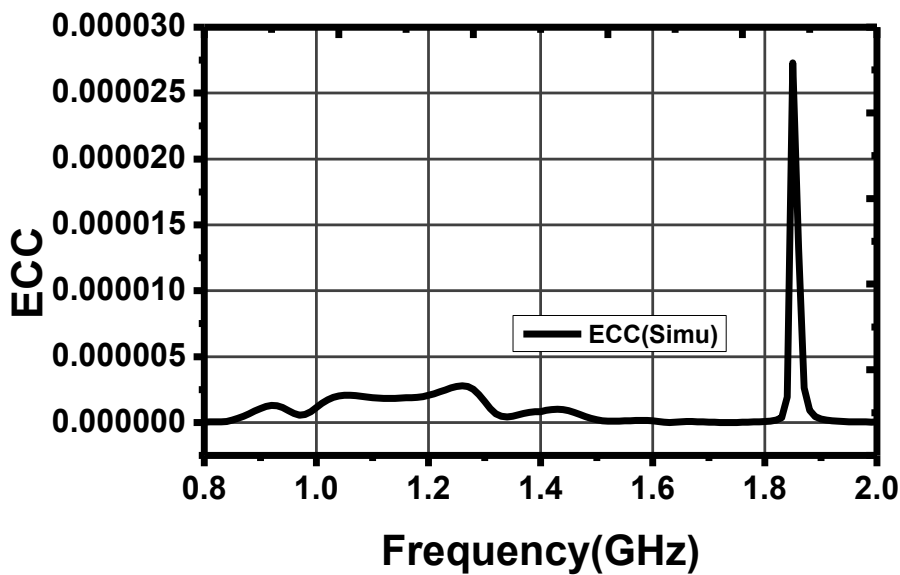
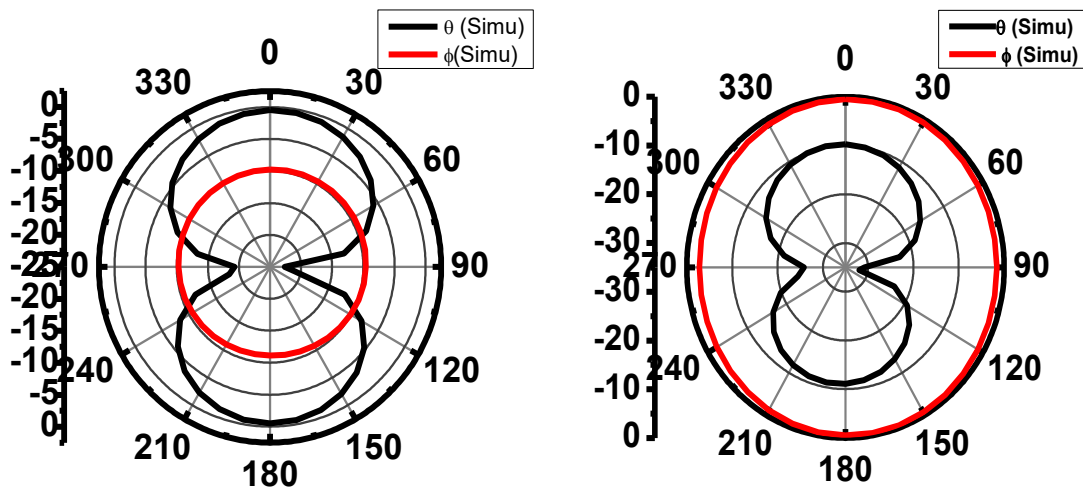


Figure 8 - Radiation Pattern at (a) 0.8 GHz, (b) 1.5 GHz (c) 1.7 GHz



E- plane

H- Plane

(a)

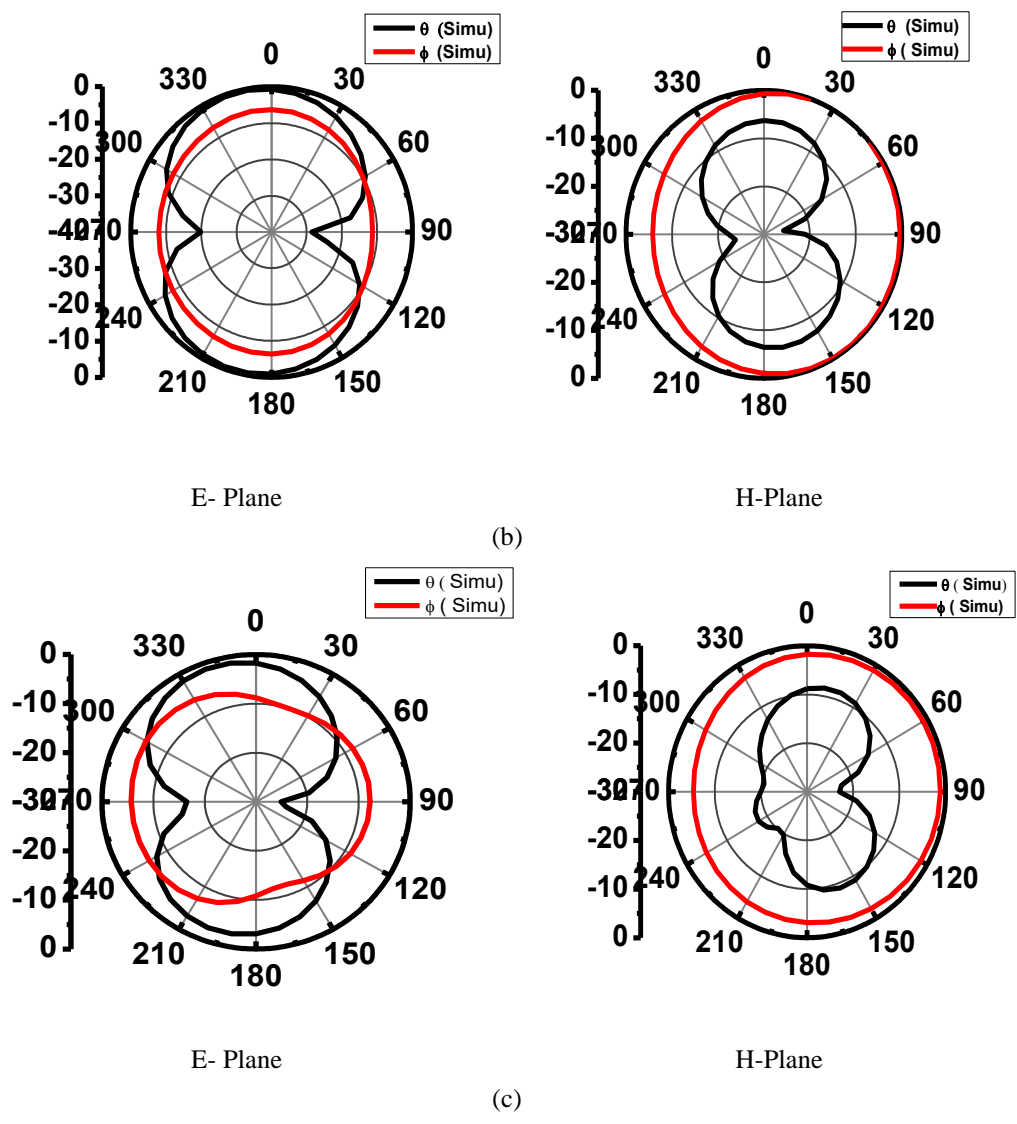
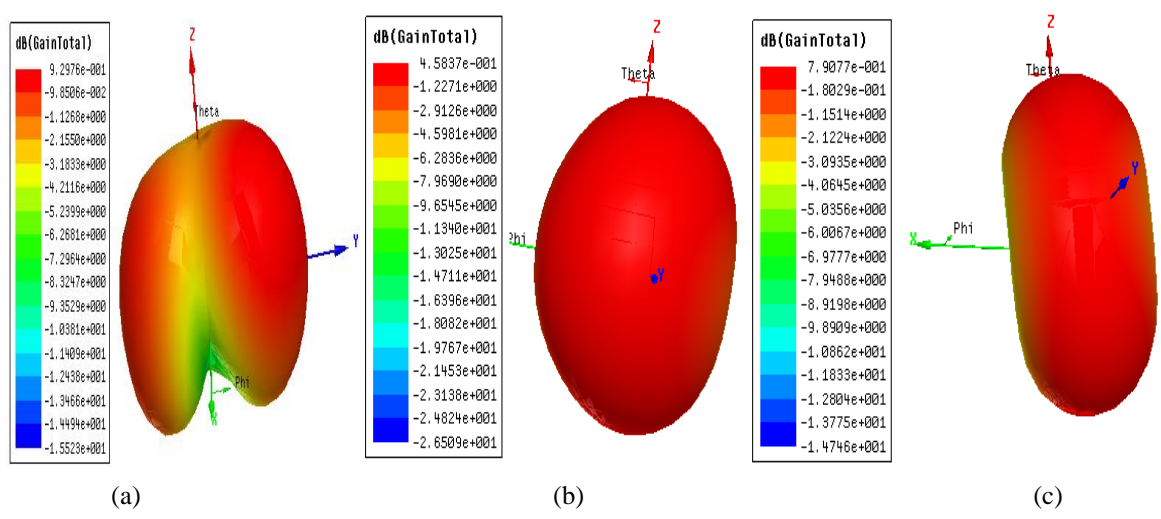


Figure 9 - Radiation Pattern 3D at (a) 0.8 GHz (b) 1.5 GHz (c) 1.7 GHz



The comparison of simulated parameters of the proposed MIMO DRA as illustrated in the Table 4. The correlation between the ports is very less compared to existing MIMO and high isolation with good impedance matching. 3D radiation patterns show the peak power is concentrating more on the -y axis and y axis. Table 4 shows the performance estimation of proposed MIMO DRA with other existing MIMO antennas based on MIMO characteristics and antenna parameters.

Table 4 - Performance Estimation of Proposed MIMO DRA

Ref.No	Feeding type	B.W. (GHz)	Iso. (dB)	Ref.(dB)	Radiation efficiency (%)	$\rho$	$G_{app}$ (dB)
[11]	Line feeding	(0.89-0.93) at 0.90	-17.5	-21	74.0	0.0005	9.9999
		(1.83- 2.05) at 1.80	-16.9	-22	69.0	0.0003	9.9999
		(2.29- 2.40) at 2.30	-28.5	-24	60.0	0.0064	9.9999
P.D.	CPW feeding	(0.8106 – 0.8938) 83.2MHz at 0.8GHz	< -75	-20	140	0.000001	9.99999
		(1.4825- 1.5279) 45.4MHZ at 1.5GHz	< -75	-24	80	0.000001	9.99999
		(1.7382- 1.8108) 72.7MHz at 1.7GHz	< -81	-19	80	0.000001	9.99999

B.W. – Bandwidth, Iso. – Isolation, Ref.- Reflection coefficient

#### 4. Conclusion

Symmetric MIMO DRA with two element aerials for LTE uses is designed and examined in the research article. Proposed MIMO DRA was simulated by CPW feeding. The obtained bandwidth is 83.2 MHz, 45.4 MHz and 72.6 MHz at 0.8 GHz, 1.5 GHz, and 1.7 GHz respectively, according to the simulated results with isolation > -75dB overall operating bands with 140% of radiation efficiency at band1 and > 80% at remain two operating bands. Hence, the simulated values are having good MIMO characteristics. The radiation efficiency is good, and more isolation is attained. The  $\rho$  of the proposed MIMO DRA system is < 0.000001 and  $G_{app}$  is almost 9.99999 dB under the obtained radio ranges. The simulated results indicate, this system is highly suitable for LTE functions.

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