CPW Fed Fractal Based Four-Port Mimo Antenna With A Noval Method For Isolation Improvement

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Abstract :

A compact multiple-input multiple-output whose ports are exited with CPW feeding configuration is proposed here.This configuration having very good isolation properties between the antennas incorporated (>-20 dB).The four antennas are placed symmetrical around the axis gives a band with in UWB range specified by FCC (3.1GHZ-10.6GHZ).Each UWB antenna element in this configuration having a hybrid fractal which composed of Sierpinski Carpet and Koch geometry.Hybrid fractal geometry along with CPW feed gives wider band width. In order to Improve the mutual coupling between the antennas two stubs are attached in the ground plane for each antenna element. The Hybrid MIMO antenna works on frequency band 2.4GHz-11GHz with a mutual coupling lower than -20dB and Envelop Correlation Coefficient lower than 0.01.

Keywords: Multiple-input multiple-output(MIMO), Envelop Correlation Coefficient (ECC), Hybrid Fractal, Mutual Coupling, UWB.

1. Introduction

In this modern wireless world all gadgets have to transmit and receive signals in wireless format.Which needs an efficient antenna which is to be very compact to fit in the miniaturized gadget. Here comes the importance of fractal based antennas which have the inherent property of miniaturization.Fading is the major problem which arises while transmitting and receiving the signals over wireless path.The remedy to get good quality reception at receiver is diversity reception using Multiple-input Multiple-output antenna system.

Multipe-Input Multiple-Output (MIMO) Technology transforms single point to point channel into multiple parallel channels to offer higher channel capacity and reduced Bit Error Rate (BER).As the UWB range specified by FCC which lies between 3.1GHz-10.6GHz may cause interference between the adjacent channels.The inherent short distance limitation of UWB (due to the low transmission power mask by FCC) can be overcome by integrating UWB and MIMO.

Recently many MIMO antennas are proposed by many researchers for UWB and Isolation Improvement [1]-[9]. In order to optimize the antenna parameters [1] uses a bio-inspired mixed algorithm which uses an antenna of size 0.29λ ×0.27λ achieved an isolation 15–20 dB. Orthogonaly placed antennas with Parasitic elements placed between dipole and reflector [2] ensures good performance in terms of matching the impedance. MIMO antennas proposed for 5G application in [3][4][7] where metal strip is printed on the DR to improve the isolation up to 24dB in [3] and the two-port MIMO[4] with chip capacitor is used as the decoupler to get isolation of 24dB.where as a 4 port MIMO with isolation 10dB is proposed in [7]. Two port MIMO with good isolation property is introduced in[7][8][9] where size of antenna proposed in [8] is competitively greater than other structures and uses PIFA placed orthogonal to each other to reduce the isolation. The two port MIMO in [9] proposes changes in ground plane to improve the mutual coupling properties.

Fractal MIMO for 6G is proposed in [10][11][12]. antenna designed in [10] uses polyamide material with isolation over 30dB.the size used here is 130×130× 1.6 mm^3.The MIMO in [11] uses 4 orthogonal circular fractal geometries with the size being 56mm×56mm and achieved an isolation over 15dB .Koch fractal based MIMO[12] is introduced with matamaterial for 6G application. Isolation improvement up to 20–35 dB is achieved with a size of antenna 95 × 95 × 1.6 mm .

This work concentrates on Multi fractal geometry with CPW feed for improving the performance of fractal antenna.Multi-Fractal Geometry Effects on Bandwidth in the following manner

- **Increases self-similarity:** Multi-fractal geometries exhibit increased self-similarity, leading to a more uniform current distribution and wider bandwidth
- **Enhances resonant modes:** Multi-fractal structures can support multiple resonant modes, increasing the antenna's bandwidth and providing more frequency options.
- **Improves radiation efficiency:** Multi-fractal geometries can improve radiation efficiency by reducing energy losses and increasing the antenna's directivity.

CPW Effects on Bandwidth in following manner

- **Lowers Dispersion:** CPW has lower dispersion compared to traditional microstrip lines, which means that the signal propagation velocity remains more constant across different frequencies. This results in a wider impedance bandwidth.
- **Higher Impedance Matching:** CPW's coplanar structure allows for easier impedance matching between the feedline and the antenna. This reduces reflections and increases the antenna's bandwidth.
- **Reduces Losses:** CPW has lower losses compared to traditional microstrip lines, especially at higher frequencies. This is due to the reduced radiation losses and lower dielectric losses.

Table I : MIMO antenna Comparison

Ref	**MethodologyUsed**	**Antenna Size (mm unless λ)**	**Number of Ports**	**Isolation**
[1]	Mixed multiobjective optimization	0.29λ ×0.27λ	**2**	15–20 dB
[2]	Polarization diversity, chokes, grooves	85mm × 85 mm	4	>45 dB
[3]	Metal Strips	91mm×91mm	2	20 dB
[4]	Chip decoupler, shared radiator	150×63mm	2	24 dB
[5]	Rectangular slot carved on the top metal cladding	80mm× 80mm	8	>25 dB
[6]	Cross substrate, CSRR, patch	90mm× 90mm	4	~40 dB
[7]	protruded ground parts are connected by a compact metal strip	30mm×30mm	2	>20 dB
[8]	PIFAs are placed orthogonally	140mm×70mm	2	>10 dB
[9]	Rectangular slits below the feed line	25mm × 32mm	2	>20 dB
Proposed MIMO	Stubs attached with Ground	48mm×48mm	4	>20 dB

Table II: Frcatal MIMO antenna comparison

Ref	**MethodologyUsed**	**Antenna Size in mm**	**Number of Ports**	**Isolation**

[10]	Fractal patch featuring four engraved circles	130mm×130mm	4	>30 dB
[11]	circular patch with the partially chamfered ground.	56mm×56mm	4	15dB
[12]	Koch fractal with Matamaterial	95mm × 95 mm	4	20dB
Proposed MIMO	Stubs attached with Ground	48mm×48mm	4	>20 dB

2. UWB Antenna Design

Sierpinski carpet and Koch fractal are mixed to make the antenna and the semi-circular CPW feed is used to excite the antenna.The upper Carpet structure is 100% of geometry which is added with 50% of Koch geometry to get the Radiator.A Strip line of length 12.42mm is used to feed the radiator.The antenna is fabricated on

FR-4 Glass epoxy material with dielectric constant $\varepsilon_r = 4.4$ and loss tangent

tanδ =0.02, with height 1.6mm The bandwidth has been increased to the range of UWB(3.1GHz-10.6GHz) The UWB antenna has total size of 24mm x 20mm x 1.6mm.

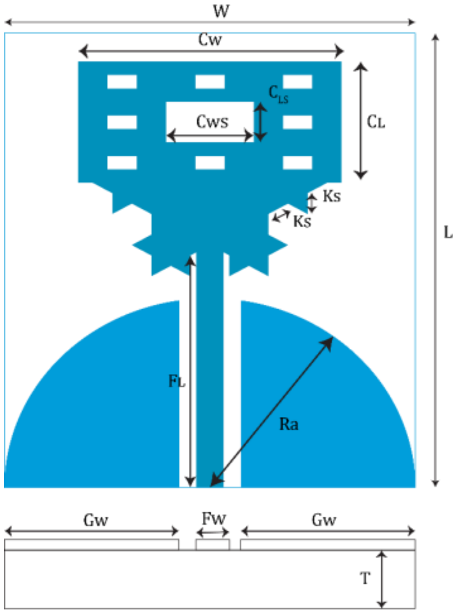


Figure 1: Designed UWB antenna

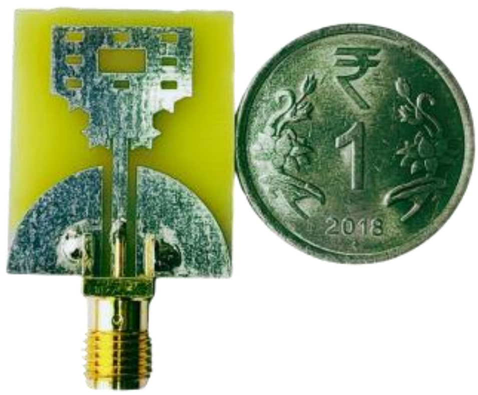


Figure 2: Fabricated UWB Antenna

Figure 1 is the UWB Hybrid fractal antenna designed using HFSS and which is then Micro etched on to the FR4 substrate.The fabricated antenna is given in the figure 2 which is attached with 50Ω SMA connector. Table 2 gives the different length parameters used for the UWB antenna design.

TABLE III : Dimensions of UWB Antenna

Component	Description	Dimension in mm
W	Width of Substrate	20
L	Length of Substrate	24
Cw	Width of Carpet	12.825

C_L	Length of Carpet	6.4125
C_{WS}	Width of slot in Carpet	4.275
C_{LS}	Length of slot in Carpet	2.1375
K_S	Koch side length	1.1
Ra	Ground Radious	10
F_L	Feed length	12.42
FW	Feed Width	1.34
GW	Ground Width	8.5

Figure 2 ,3 and 4 gives the results of the UWB antenna in which figure 2 is the simulated radiation pattern at 6GHz ,which is omni directional pattern where the antenna got good polarization purity in terms of Co and Cross polarization.Figure 3 is the measured radiation pattern which proves its radiation properties are good enough for UWB application. Figure 4 shows the measured and simulated S11 which shows the antenna covers entire UWB range specified by FCC(3.1GHz-10.6GHz).

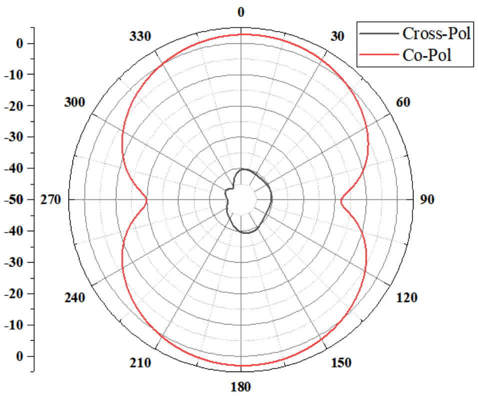


Figure 2 : Simulated Co and Cross Pol of UWB antenna at 6Ghz

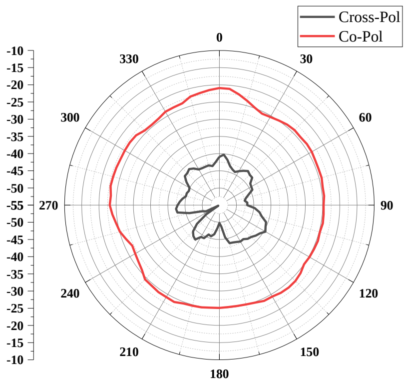


Figure 3: Measured radiation pattern of UWB antenna at XY Plane at GHz

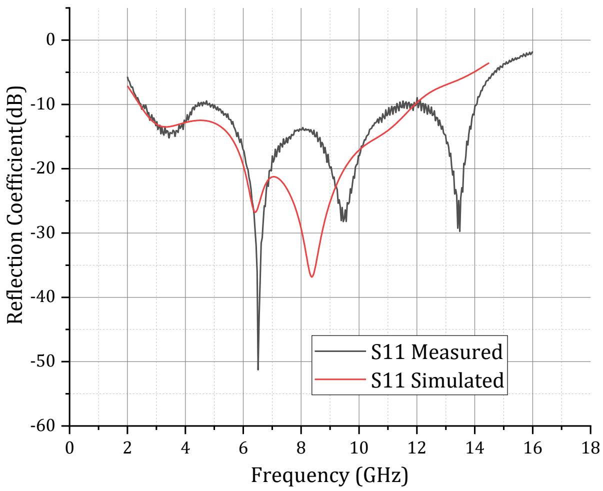


Figure 4: Measured and Simulated S11 of UWB antenna

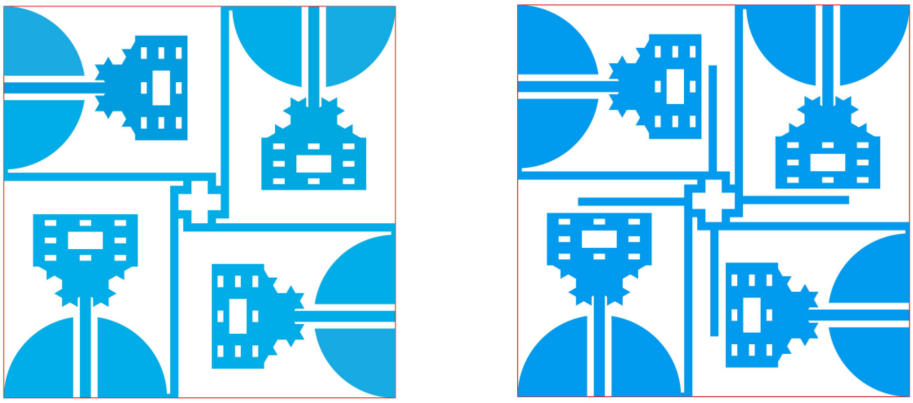
Measured and Simulated S11 of the antenna shows it covers the entire UWB band range of 3.1GHz-10.6GHz.

3. UWB Hybrid Fractal MIMO antenna Design

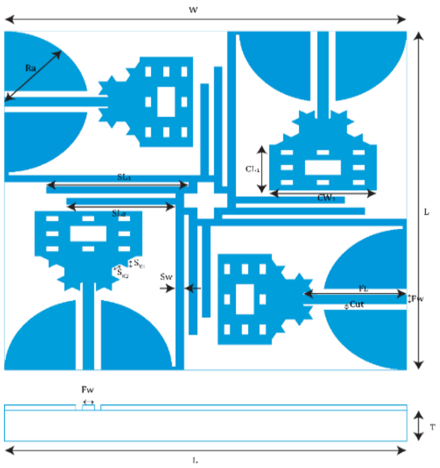
The hybrid UWB fractal is configured as4 port MIMO.The antenna is fabricated on FR-4 Glass epoxy material with $\varepsilon_r = 4.4$ and loss tangent tanδ =0.02, with height 1.6mm .To make it used for diversity reception in MIMO mode, a high degree of isolation is necessary. For decoupling structure here proposes a noval method with stubs attached to the ground structure. The entire structure is fabricated using FR4 substrate with the dimensions 48mmx48mmx1.6mm.

TABLE IV : Dimensions of UWB Hybrid Fractal MIMO Antenna

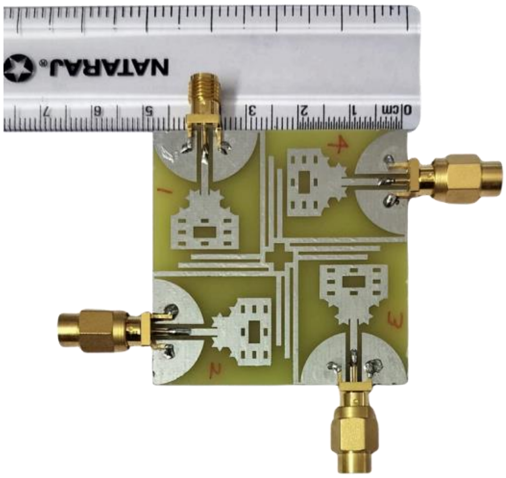
Component	Description	Dimension in mm
W	Width of Substrate	48
L	Length of Substrate	48
C_{W1}	Width of Carpet	12.83
C_{L1}	Length of Carpet	6.41
S_{K1}	Koch side length	1.1
S_{K2}	Koch side length	1.1
Ra	Ground Radious	10
Sw	Width of strip line	1
F_L	Feed length	12.42
F_W	Feed Width	1.34
Cut	Width of cut in feed	0.83
S_{L1}	Length of stub 1	17
S_{L2}	Length of stub 2	13



(a) Configuration A (b) Configuration B



(c) Configuration C



(d) Fabricated Antenna

Figure 5:(a)Simulated Antenna Configuration-A (b) Simulated Antenna Configuration-B (c) Simulated Antenna Configuration-C (d) Fabricated MIMO antenna with stubs attached in ground plane

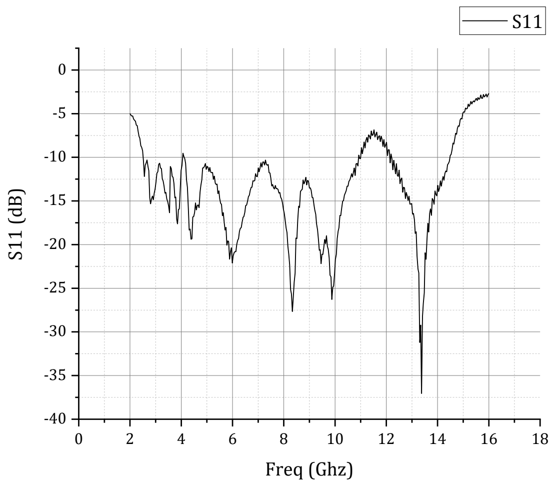


Figure 6: Measured S11 of UWB MIMO antenna

Figure 6 gives the Measured S11 for the UWB-MIMO antenna .It is having a wider impedance bandwidth (2.4GHZ- 11GHz). That is the antenna covers the entire range of UWB specified by Federal Communication commission (FCC).

4. Diversity analysis of UWB MIMO Antenna

The diversity analysis of MIMO can be done by analyzing Envelope correlation coefficient, Diversity gain and Isolation

The correlation between the antenna elements is measured by the correlation coefficient.for calculating ECC we can use the equation which is specified in [2].

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

Diversity gain can be calculated by using [5]

DG can be measured in terms of envelope correlation coefficient (ECC) is given by equation

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

Isolation

Isolation measures the coupling between antennas which placed closely within the MIMO antenna in terms of electromagnetic energy. The isolation's value should be more than 15 dB

$$\text{Isolation} = 10\log_{10}|S_{21}|^2$$

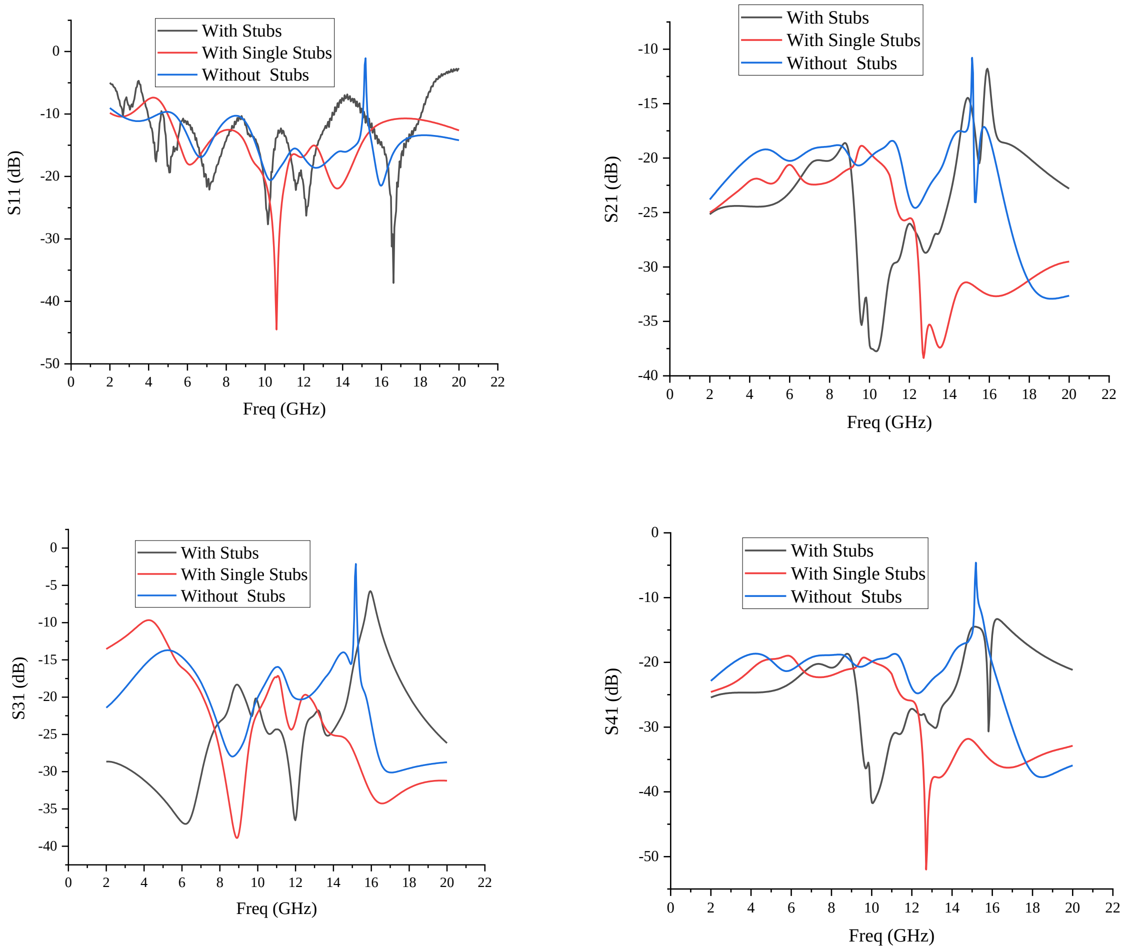


Figure 7: S parameters of different configuration A, B, C (a) S11 (b) S21, (c) S31, (d) S41

Figure 7 depicts the comparison between the different reflection coefficients for the configuration A,B, and C.Which proves the addition of Stubs in the ground plane improves the Isolation up to >20dB for the UWB range.Figure 8 is the Measured reflection coefficients ie. S21,S31 and S41 which shows the antenna gives good Isolation property.Figure 9 is the measured Envelop Correlation coefficient and Directive gain which are very good and ECC very low >0.01 and DG is almost 10.

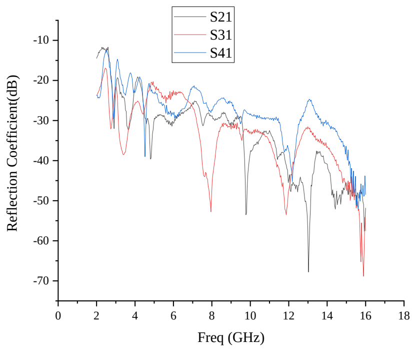


Figure 8: Measured Reflection coefficients of UWB-MIMO antennawith stubs attached at ground plane

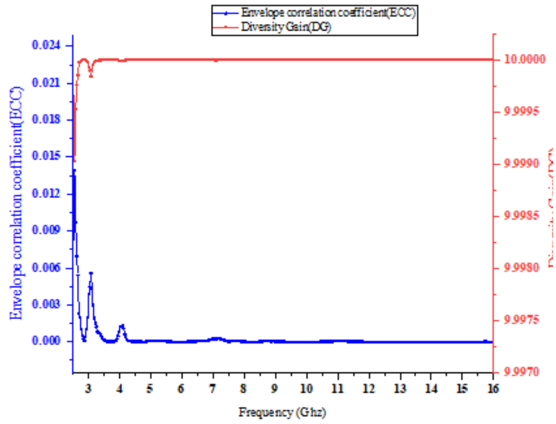


Figure 9: ECC and DC of UWB-MIMO antenna with stubs attached at ground plane

The Hybrid MIMO antenna works on frequency band 2.4-11GHz with a mutual coupling lower than -20dB and Envelop Correlation Coefficient lower than 0.01.

5. Radiation Characteristics of UWB MIMO antenna

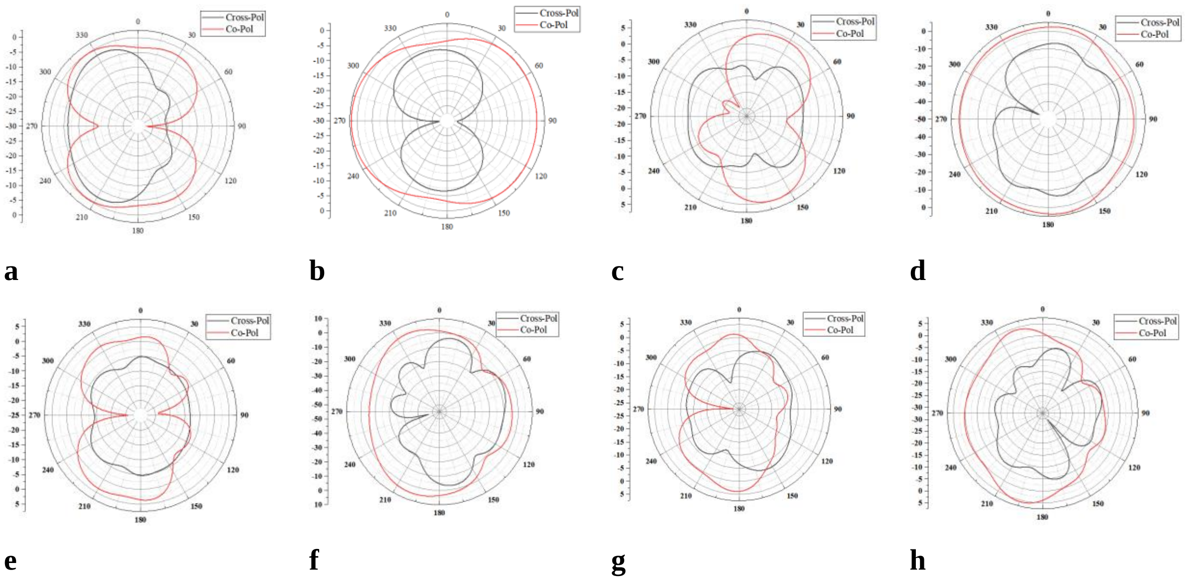


Figure 10: (a)Radiation Pattern at XY Plane at 6GHZ (b) Radiation Pattern at XZ Plane at 6GHZ

(c). Radiation Pattern at XY Plane at 8.4 GHZ(d). Radiation Pattern at XZ Plane at 8.4 GHZ

(e). Radiation Pattern at XY Plane at 9.8 GHZ(f). Radiation Pattern at XZ Plane at 9.8 GHZ

(g). Radiation Pattern at XY Plane at 13.5 GHZ(h). Radiation Pattern at XZ Plane at 13.5 GHZ

In Figure 10 the radiation pattern for 4 different resonant frequencies in XY and XZ plane are depicted. Omni and Quasi-Omni radiation pattern are obtained for 6GHz,8.4GHz, 9.8GHz and 13.5GHz.

6. Conclusion

CPW Fed Fractal Based Four-Port MIMO antenna with a Noval Method for Isolation Improvement is presented here .Initially a UWB fractal antenna designed by mixing Koch and Sierspinski carpet geometries. From the measured results, it is found that he antenna can be used for UWB application. The Antenna shows good impedance band width (2.4GHz-12GHz).The UWB antenna then configured as 4 port MIMO in which all 4 antenna elements are placed orthogonally and got Good isolation, Envelop correlation coefficient along with coverage of full UWB range .The mutual coupling lower than -20dB and Envelop Correlation Coefficient lower than 0.01 are measured for the proposed MIMO.The measured results proves its candidature for UWB application .

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