National Journal of Antennas and Propagation, ISSN: 2582-2659 Vol. 6, No. 2, 2024 (pp. 49-68)
RESEARCH ARTICLE
HTTP://ANTENNAJOURNAL.COM

Circularly Polarized Rectangular Dielectric Resonator Antenna (CP-RDRA) Arrays with Fractal Cross-Slot usingT-bend & Miter bend power divider feeding networks

Krishna Rao Pedada[1], M. Satya Anuradha[2], V. Rajya Lakshmi[3]
[1]*Assistant Professor,Department of ECE, Aditya Institute of Technology and Management, Tekkali.*
[2]*Professor, Department of ECE, Andhra University, Visakhapatnam.*
[3]*Professor, Department of ECE, ANITS, Visakhapatnam.*

KEYWORDS:
Ultra-wideband,
Circular polarization,
Rectangular
DRA array,
Fractal cross-slot-Miter bend &
T-power divider feeding,
Return-loss,
Radiation pattern,
VSWR,
Gain and Axial-ratio.

ARTICLE HISTORY:
Submission : 24.08.2024
Revised : 26.10.2024
Accepted : 14.12.2024

DOI:
https://doi.org/10.31838/NJAP/06.02.07

Abstract

In the design of circularly polarized (CP) dielectric resonator antenna (DRA) arrays, the regular-shaped DRAs with simple feeding configurations are mostly used as array elements to make the design procedure more efficient. However, such an array element DRA usually achieves only about 6% axial ratio (AR) bandwidth. In this design, a CP DRA element coupled by a fractal cross-slot which can radiate efficiently and excite the rectangular DRA simultaneously is considered. By adjusting the dimensions of the fractal cross-slot properly, the resonances of the fractal cross-slot and the dielectric resonator can be merged to obtain a wider AR bandwidth. Based on the proposed fractal cross-slot-coupled CP DRA element, three different CP DRA arrays are designed: a 4 coupled DRA array of parallel power divider without T-bend, a 4 coupled DRA array of parallel power divider with Miter bend and a 4 coupled DRA array of 2 set power divider with Miter bend. The designed DRA arrays are fabricated and measured, and structures and performances of the arrays are presented and discussed.

Author's e-mail: krishnapedada.r@gmail.com, satyaanuradham@gmail.com, rajya-lakshmiv87@gmail.com

How to cite this artiicle: Pedada KR, M. Anuradha S, Lakshmi RV . Circularly Polarized Rectangular Dielectric Resonator Antenna (CP-RDRA) Arrays withFractal Cross-Slot usingT-bend&Miter bend power divider feeding networks. National Journal of Antennas and Propagation, Vol. 6, No. 2, 2024 (pp. 49-68).

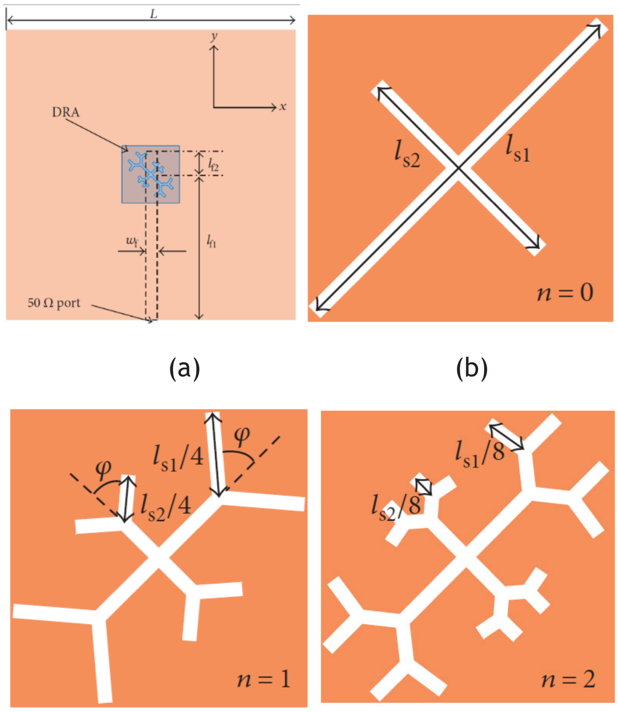
INTRODUCTION

Dielectric resonator antenna (DRA) has indeed garnered significant attention and research over the past four decades due to its various advantageous features and merits associated with DRA such as its small size, wide bandwidth, low cost, high efficiency, and ease of excitation. Dielectric resonator Antenna is a type of radio antenna commonly used at microwave frequency and beyond. DRAs can be fed up by various feeding techniques such as fed by coaxial probe, fed by microstrip line, fed by coplanar waveguide, fed by aperture couple.[1] Traditionally, regular-shaped DRAs with simple feeding configurations are utilized in array designs, but they typically achieve only about 6% axial ratio (AR) bandwidth. To address this limitation, by introduce a CP DRA element coupled by a fractal cross-slot, which efficiently radiates and excites the rectangular DRA simultaneously. In the array of integrated antenna design the element used is DRA, because of its input impedance exhibit proper resistive load at resonance frequency.[3] By adjusting the dimensions of the fractal cross-slot appropriately, the resonances of the fractal cross-slot and the dielectric resonator can be merged, leading to a wider AR bandwidth.[1] This approach enhances the performance of the CP DRA element, enabling it to achieve better AR bandwidth compared to normal feeding configuration type design. Various rectangular DRAs with various fractal slot configurations were simulated using ANSYS HFSS to generate a comprehensive dataset for model training.

This paper presents the simulated and experimental results to demonstrates the four element RDRAs of various cross-slot fractal configurations to achieve circularly polarization along with parallel power divider networks like T-bend and Miter bend which gives the analysis of various antenna parameter like return loss (S11), VSWR, Gain, high axial ratio bandwidth and the side lobe levels also reduced. The antenna is operating with frequency of 4 GHz to 9GHz and it is operated best at 4.3GHz, 7.1GHz, 8.1GHz.these types of antennae are mostly used,including but not limited to mobile communications, satellite communications, radar systems, aerospace applications and IoT devices. As technology advances and new materials and design techniques emerge, the potential of DRA in wireless communications continues to be explored and refined.

There are various shapes can be available that can be designed for various applications. The array of DRA elements is placed on different shapes of power diver network.

Design of CP Rectangular DRA Array



(a) (b) (c) (d)

Fig. 1(a): The geometry of the proposed single element rectangular DRA antenna with fractal slot (b)The geometry of the 0th iteration fractal cross slot for circular polarization (c)The geometry of the 1st iteration fractal cross slot for circular polarization (d)The geometry of the 2nd iteration fractal cross slot for circular polarization

Antenna structure: The design follows the CP DRA design which shows in Figure 1(a) for single element rectangular DRA. Single element rectangular DRA design employs, for substrate it uses Rogers RT/TR 5880 with a permittivity of r=2.2, a loss tangent of 0.0009, and a 0.508mm thickness, sized 50mm x 50mm.For radiating element radiating patch consists of overlapping circles and semi-circle. Adjusting circle diameter(a) and semicircle diameter(b) for optimal ultra-wide band performancethe diaMiters for *a* and *b* are 8.2mm and 12.2mm, respectively.

Fractal slot effect:Fractal indicates the irregular fragment or the broken fragment. The term Fractal initially presented through Mandelbrot[I] for describing a family of complex shapes which have non integer dimension and have self-similarity inherit from self-similarity in their geometrical structure.[7] Fractal is used in antenna design for producing multiband and compact antennas taking advantage of their exceptional features.

The Fractal dimension can be given by (FD) = $\log_{10}(N)/\log_{10}(1/r)$ where N can be defined as the overall number of distinct copies, r can be defined as the reduction factor value that indicates how will be the new side length regarding the original side length.[7]

The original side length.Figure1(b),1(c),1(d) shows Fractal Cross-Slotsessential for impedance matching and bandwidth enhancement, the foundation for fractal slot is the cross slots with lengths l_{s1} and $l_{s2}(=k_s l_{s1})$ and width w_s, the fractal cross-slot is carved on the ground plane beneath a central ceramic cube (9.8mm x 9.8mm x 9.1mm, permittivity εr=8.9). The fractal design arises from iterative processes based on standard cross-slots, with iterations affecting slot dimensions. The structure influence resonance and bandwidth. By adjusting the cross slot through iterative process effects impedance matching. Coplanar waveguide feeding structure supplies power to the antenna. The microstrip line of impedance 50-ohms ensures power transfer with good impedance matching. It is very crucial that the dimensions of feedline are length(l_{f1}+l_{f2}) and width $w_{f2}$and optimized coplanar waveguide distance(s_{o2}) considered as 0.2mm. specifications are listed in Table 1. Introducing a fractal cross slot into the ground plane beneath the resonator achieves an efficient axial-ratio bandwidth for a specific CP rectangular DRA element.

Table 1: specifications table of Figure 1.

W_2	L_2	W_{f2}	l_{12}	a	b
28	26	1.5	3	8.2	12.2
N	L_{o2}	S_{o2}	h	m	
0.2	10.3	0.2	1.6	15	

Table 2: Specifications table of array element

Component	Variables	Value(mm)	Component	Variables	Value(mm)
Substrate	W×L×H	50×50×1.6	Feed Line	l_{f1}	25
	€r	4.4		l_{f2}	4
				w_f	1.52
Fractal Slot	l_{s1}	9.7	DRA	W×L×H	13x10x5
	l_{s2}	5.529			
	k_s	0.57			
	φ	40 deg			
	w_s	0.4			

In addition to above single element DRA extended to array design of four element DRAs connected in linear array manner. All elements are aligned along a straight line. The minimum length linear array is the 2-element array. Here we use 4 element array antennae. The Fractal slot aperture coupled DRA elements are used. The power divider dimensions would change for parallel power divider as at bottom it is 50Ω line so the width w_1 is 3.05mm and length l_1 is 5.87mm. The upper line is 36Ω line with width w_2 of 5.08mm and length l_2 of 5.74mm. The horizontal line above is of 70Ω line of dimensions width w_3 is 1.65mm and length l_3 of 104.88mm. The other dimensions follow the previous DRA dimensions. The Gap between DRA's L_d is 21.428mm.

Simulation Results Using HFS (A)

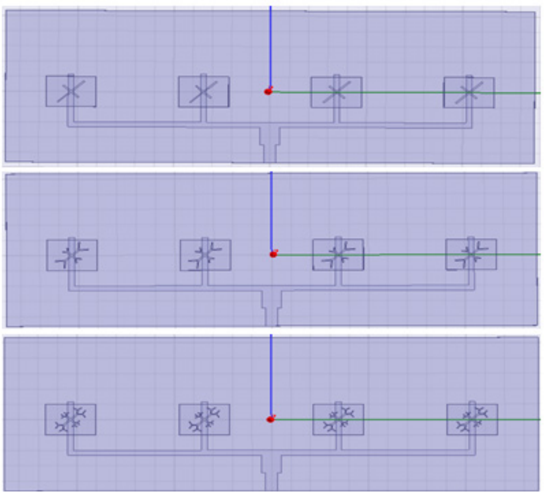


Fig.2(a) : Design of circularly Polarized 4-coupled RDRA array using T bend parallel power divider network with Fractal Cross-Slot- of 0th, 1st and 2nd iterations.

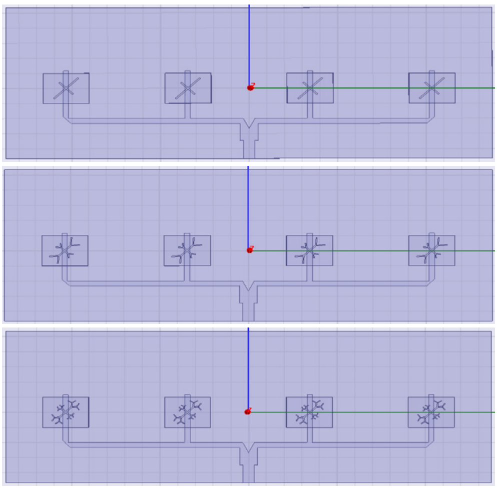


Fig.2(b) : Design of circularly Polarized 4-coupled RDRA array using Miter bend parallel power divider network with Fractal Cross-Slot- of 0th, 1st and 2nd iterations.

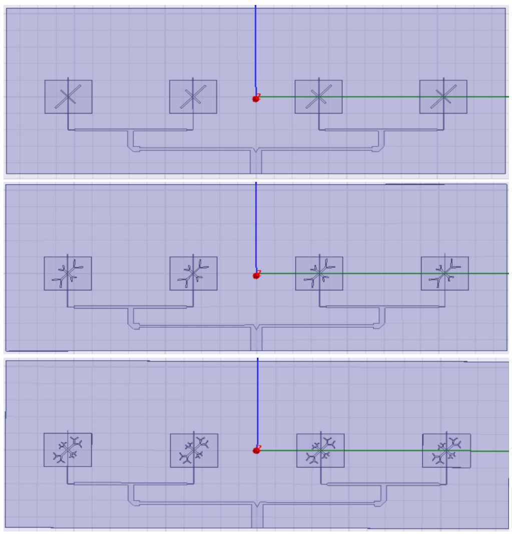


Fig.2(c): Design of circularly Polarized 2set coupled 4 element RDRA array using Miter bend parallel power divider network with Fractal Cross-Slot- of 0th, 1st and 2nd iterations.

Simulation Results & Discussions

(A) Simulation results for 4-coupled rectangular DRA array using T-bend parallel power divider with Fractal Cross-slot coupled DRA elements by using of 0th iteration

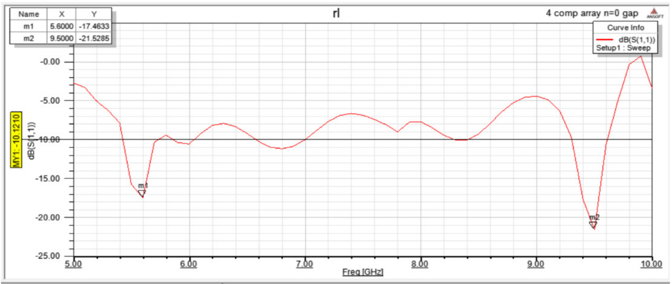


Fig.3: Simulated return loss versus Frequency for proposed antenna

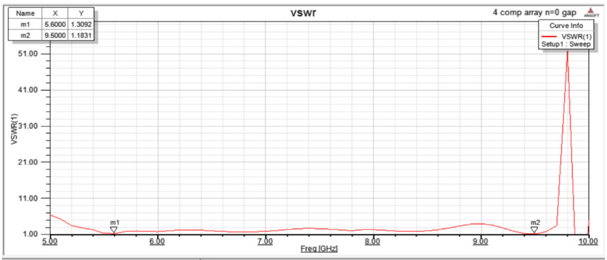


Fig.4: Simulated VSWR for proposed antenna

Return loss indicates how much power is reflected towards source due to mismatch of impedance between antenna and transmission line.it is the key parameter to assess an antenna performance. The typical value for any antenna is lower than -10dB.The Voltage Standing Wave Ratio *(VSWR)* of an antennaindicates the amount of power safely delivered to the antenna that depends on impedance matching and the value liesbetween1andinfinity. Forpracticalapplications,itshouldbebetween1and2. It is evidence from Fig.3 and Fig.4 the Return loss(S11) and VSWR values of proposed antenna is observed that S11 is -17.6633 and -21.5285 at 5.6GHz and 9.6GHz which lower than -10dB andVSWR is 1.3092 and 1.1831 at 5.6GHz and 9.6GHz which lies between 1 and 2 in practical.

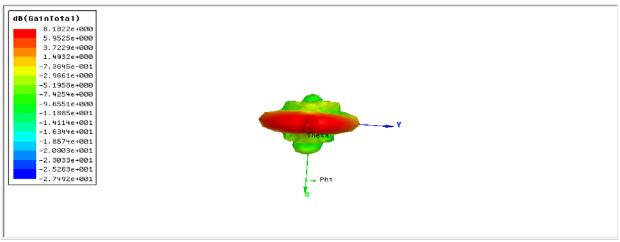


Fig. 5: Simulated Gain at 5.6GHz frequency for proposed antenna

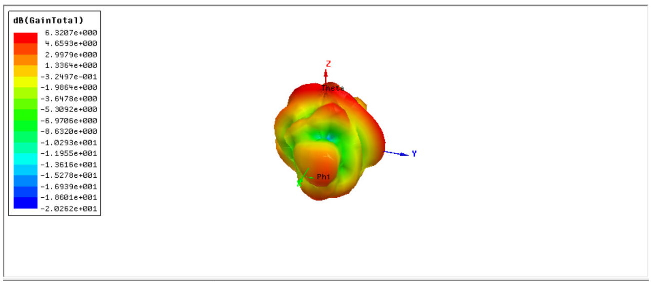


Fig. 6 Simulated Gain at 9.5GHz frequency for proposed antenna

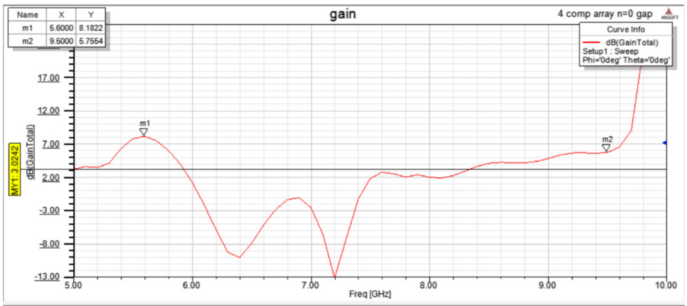
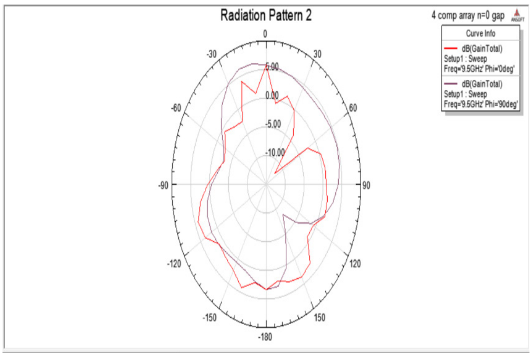
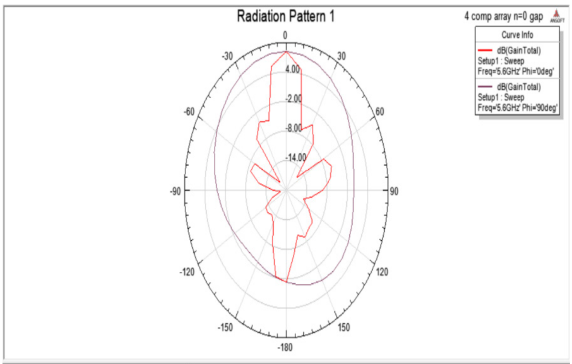


Fig.7: Gain Vs Frequency plot for proposed antenna

The gain versus Frequency of proposed antenna for 0th iteration of Fractal slots which corresponding to Fig.2(a) is observed from Fig.5,Fig.6 and Fig.7 this proto type of antenna produces high gain 8dB at 5.6GHz and 6.3dB at 9.5GHz.



(a)



(b)

Fig.8 (a) and (b) simulated radiation pattern at 5.6GHz and 9.6GHz

Radiation pattern defines,it is the orientation of power variations by the antenna as a function of direction away from the antenna.This power variation as a function of the arrival angle is observed at the antenna's far-field.

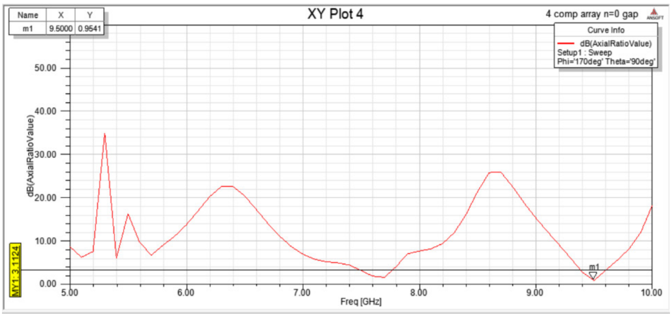


Fig. 9: Simulated Axial Ratio for proposed antenna

The Axial Ratio (AR) is defined as the ratio of minor and major axis of the polarization. For a circularly polarized antenna, the closer the axial ratio is 0dB.but practically the Axial Ratio can be considered as below 3 dB line in dB plot. It is observed that from the he Axial Ratio of propose antenna which shown in Fig.9. is 0.9541 which is below 3dB.

(B) Simulation results for 4-coupled rectangular DRA array using T-bend parallel power divider with Fractal Cross-slot coupled DRA elementsof 1stiteration.

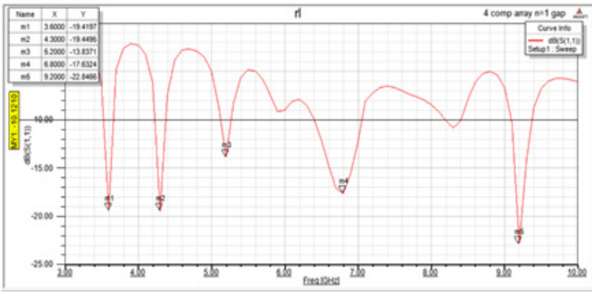


Fig. 10: Simulated return loss versus Frequency for proposed antenna

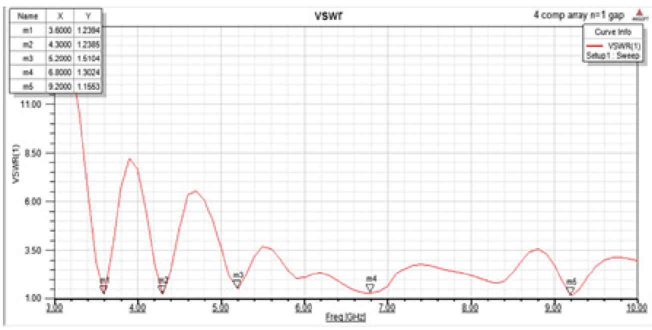


Fig. 11: Simulated VSWR for proposed antenna

It has been observed from Fig.10 and Fig.11 the Return loss(S11) and VSWR values of proposed antenna is observed that S11 is -19.4495, -14.8371 and -22.8466 at 4.3GHz,5.2GHz and 9.2GHz which lower than -10dB and VSWR is 1.2385,1.5104 and 1.1556 at 4.3GHz, 5.2GHz and 9.2GHz which lies between 1 and 2 in practical.

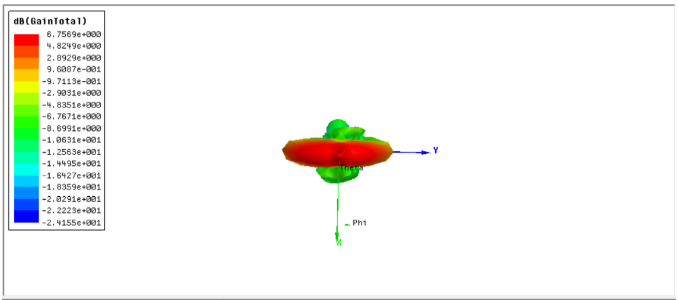


Fig.12: Gain plot of proposed antenna at 5.2GHz

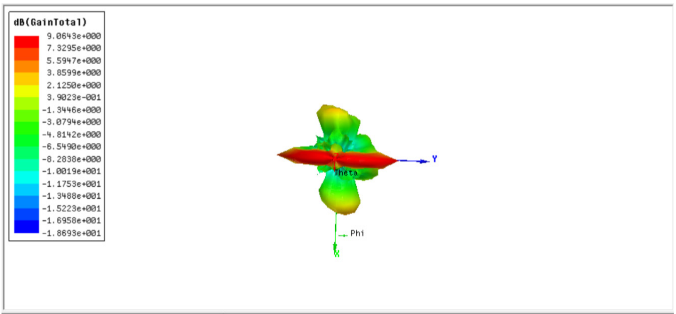


Fig. 13: Gain plot of proposed antenna at 9.2GHz

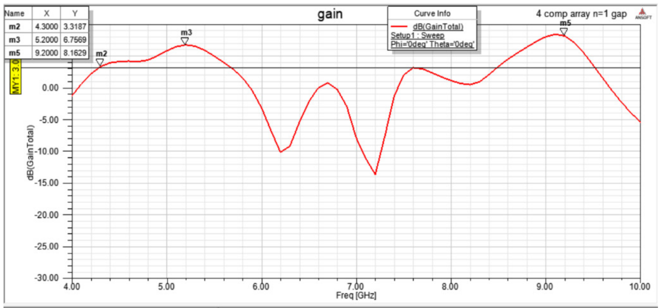
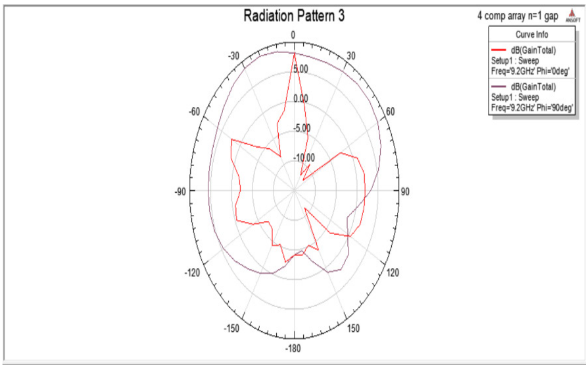


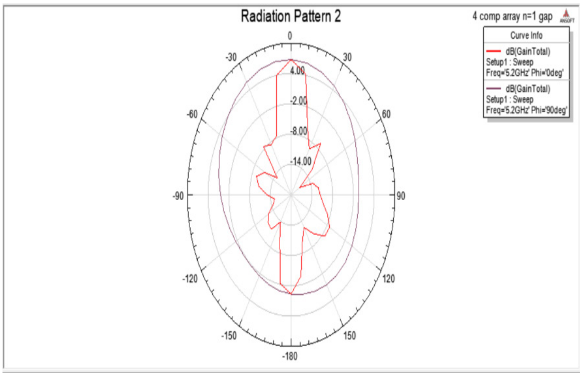
Fig.14: Gain Vs frequency plot of proposed antenna

The gain Vs frequency plot for proposed 1st iterated fractal slot RDRA array antenna which is corresponding to Fig.2(a) is observed from Fig.12, Fig.13 and Fig.14 the proposed antenna gives more gain than previous 0th iterated fractal cross slot antenna which shows in Fig.2(a) i.e 6.75dB at 5.2GHz and 9.06dB at 9.2GHz.

The applications of RDRA array antenna are enhanced if it generates the radiation pattern of lower SLL (Side Lobe Level), that is greatly occurred at 5.2GHz.



(a)



(b)

Fig.15: (a) and (b) simulated radiation pattern at 5.2GHz and 9.2GHz

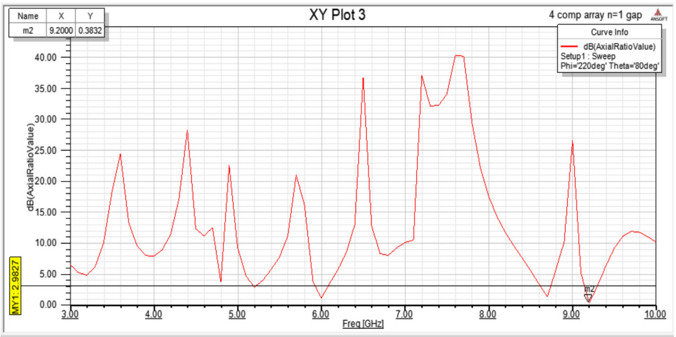


Fig.16: simulated Axial ratio Vs Frequency plot for proposed antenna

It is observed from the Axial Ratio Vs Frequency plot, the ratio of major and minor axis of the polarization Vs Frequency should be minimum and for ideal it is 0dB, practically it is preferable below 3dB.For the proposed antenna it is 0.3832dB at 9.2GHz which is below 3dB.

(C) Simulation results for 4-coupled rectangular DRA array using T-bend parallel power divider with Fractal Cross-slot coupled DRA elementsof 2nd iteration.

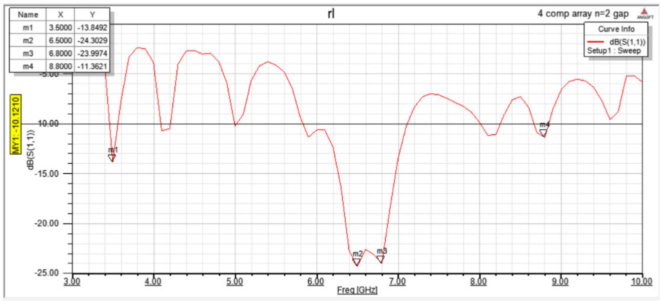


Fig.17: Simulated return loss plot for propsed antenna

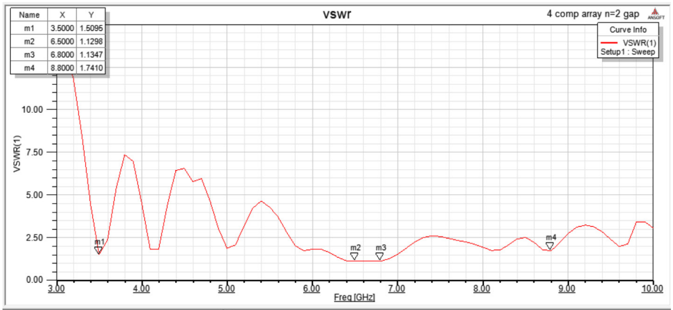
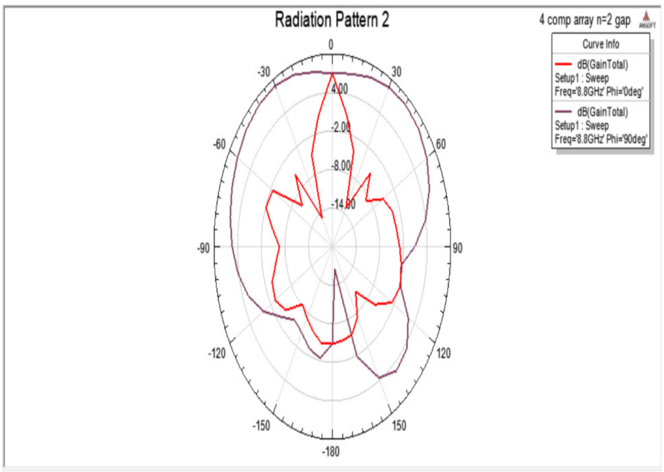


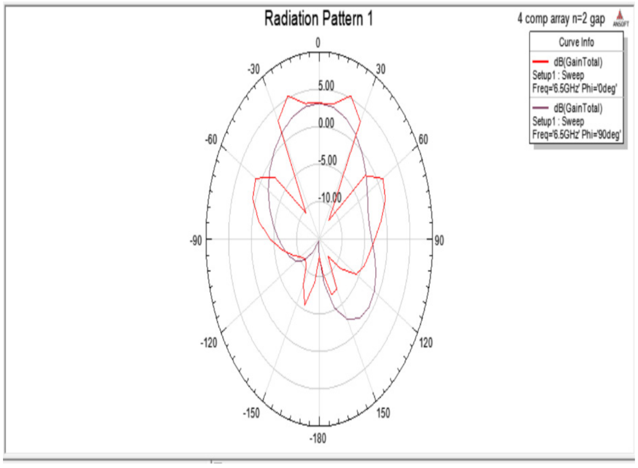
Fig.18: Simulated VSWR for propose d antenna

For the above proposed antenna which is considering in Fig .2(a) the return loss and VSWR are observed from the above Fig.17 and Fig.18 as S11 is -24.3029 at 6.5GHz,-23.9974 at 6.8GHz and -11.3621dB at 8.8GHz.and VSWR is 1.1298,1.1347 and 1.7410 at 6.6GHZ, 6.8GHz and 8.8GHz respectively.

The simulated high gain broad side radiation patterns as shown in Fig.19



(a)



(b)

Fig.19 (a) and (b) simulated radiation patterns at 6,5GHz and 6,8GHz

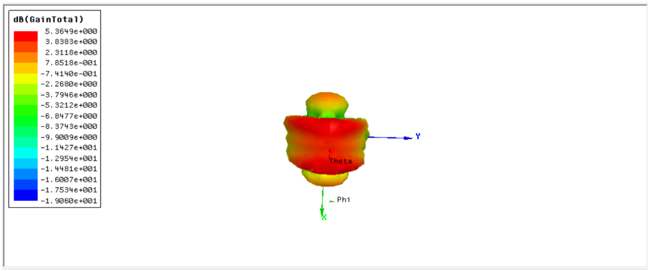


Fig.20simulated Gain for proposed antenna at 6.5GHz

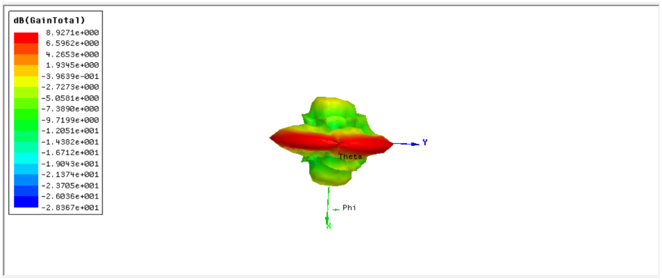


Fig.21simulated Gain for proposed antenna at 8.8GHz

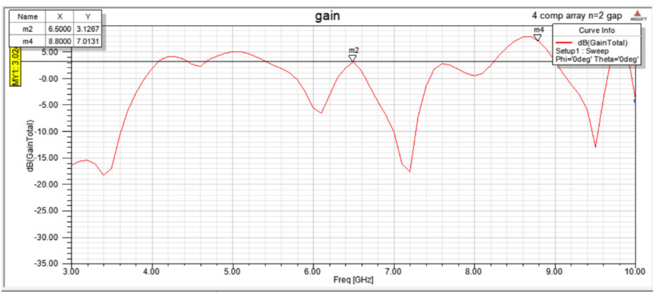


Fig.22: Simulated Gain Vs Frequency plot for proposed antenna

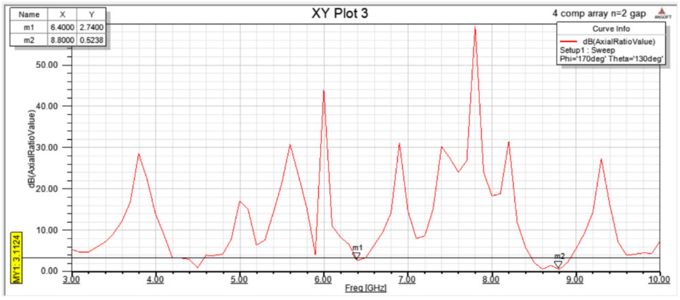


Fig. 23: Simulated Axial ratio plot for proposed antenna

From the above simulated results of Gain and Gain Vs Frequency plots for proposed RDRA linear array antenna, it is observed that the target value of gain achieved by increase the number of iterations in the fractals as shown in Fig.2(a). From theFig.20, Fig.21, Fig.22 it is observed that the gain is 5.36dB at 6.5GHz and 8.92dB at 8.8GHz.The above Fig.23 is indicating the simulated plot for Axial ratio for the proposed rectangular DRA of having 2nd iteration fractal slot and it is observed as 0.5238 which is below 3dB at 8.8GHz.

(D) Simulation results for 4-coupled rectangular DRA array using Miter-bend parallel power divider with Fractal Cross-slot coupled DRA elementsof 0th iteration.

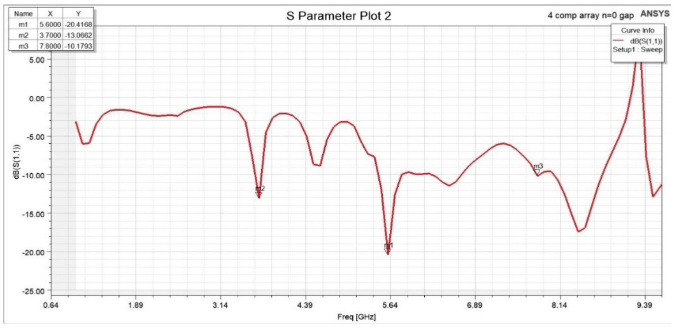


Fig. 24: Simulated S11 for proposed antenna

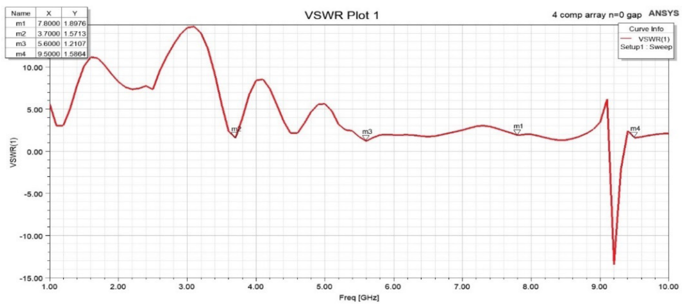


Fig. 25: Simulated VSWR for proposed antenna

From the Fig.24 and Fig.25 it is observed that the return loss(S11) for proposed antenna which is corresponding to Fig.2(b) is -20.4168dB at 5.6GHz and -10.1793dB at 7. 8GHz.which is preferred value of -10dB and VSWR is lies between 1 to 2 i.e 1.2107 at 5.6GHz, 1.8976 at 7.8GHz and 1.5864 at 9.6GHz.

The 3D gain and radiation patterns are as shown in Fig 26-Fig.29

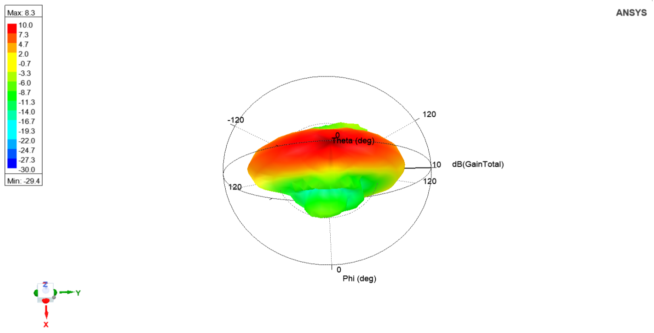


Fig. 26: Simulated Gain for proposed antenna at 5.6GHz

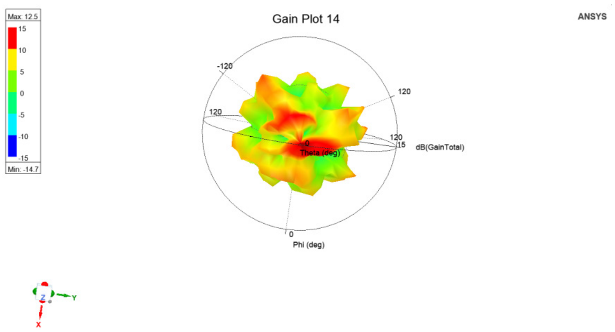


Fig. 27: Simulated Gain for proposed antenna at 9.5GHz

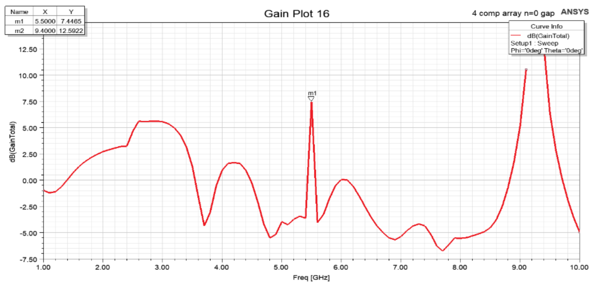
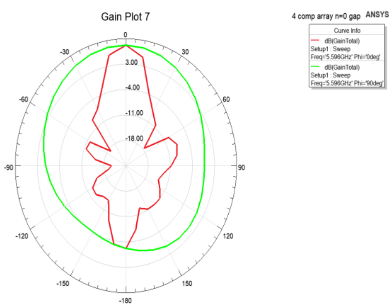
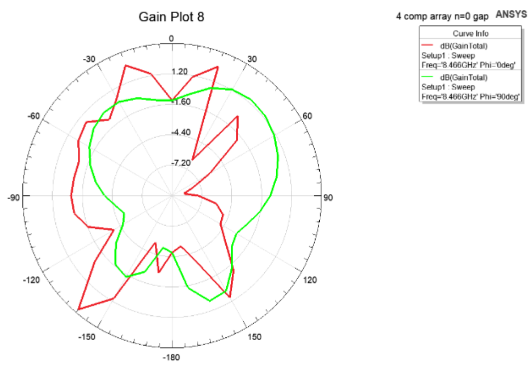


Fig. 28: Simulated Gain Vs Frequency plot for proposed antenna



(a)



(b)

Fig.29 (a) and (b): Simulated radiation patterns at 5.6GHz and 8.4GHz

From above Fig 27-Fig.29 it is observed that the proposed antenna achieved the target peak gain of 12.5dB at 9.5GHz and 8.3dB at 5.6GHz and reduced side lobe level power.by the above observation the proposed RDRA array antenna can be used for wide band application like satellite & Radar applications and IOT applications.

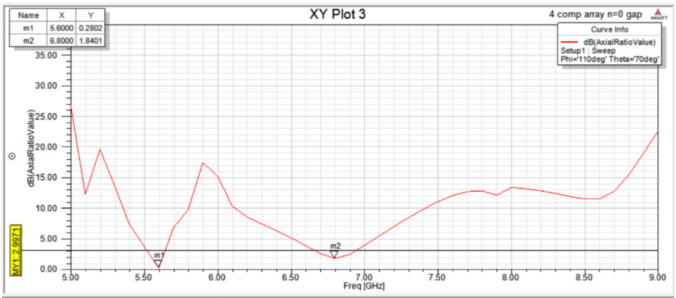


Fig. 30: Simulated Axial ratio plot for proposed antenna

From the Fig.30 it is indicating that Axial Ratio of proposed antenna is 0.2802 at 5.6GHz and 1.8401 at 6.8GHz which is below 3dB.

(E) Simulation results for 4-coupled rectangular DRA array using Miter-bend parallel power divider with Fractal Cross-slot coupled DRA elementsof 1st iteration.

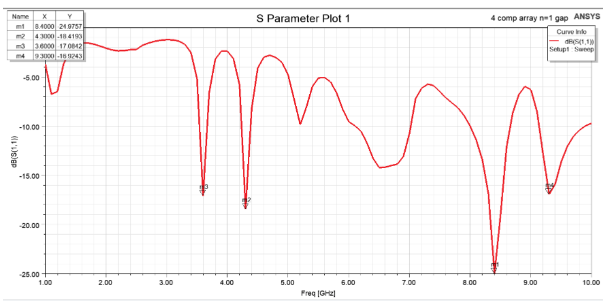


Fig.31 Simulated Return Loss(S11) for proposed antenna

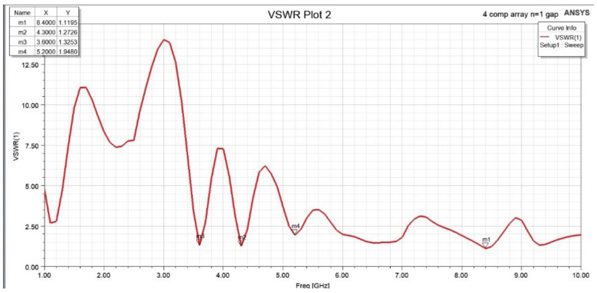


Fig. 32: Simulated VSWR for proposed antenna

From the Fig.31 and Fig.32 it is observed that the return loss(S11) for proposed antenna which is corresponding to Fig.2(b) is -17.0842dB at 3.6GHz, -18.4193dB at 4.3GHz, -24.9757dB at 8.4GHz and -16.9243dB at 9.3GHz.which is below preferred value of -10dB for any antenna and VSWR is lies between 1 to 2 i.e1.3253 at 3.6GHz, 1.2726 at 4.3GHz, 1.9480 at 5.2GHz and 1.1195 at 8.4GHz..

Fig.33-Fig.35 is shown the HFSS simulated 3D-gain plotsand Gain Vs frequency plots for proposed antenna at different frequencies

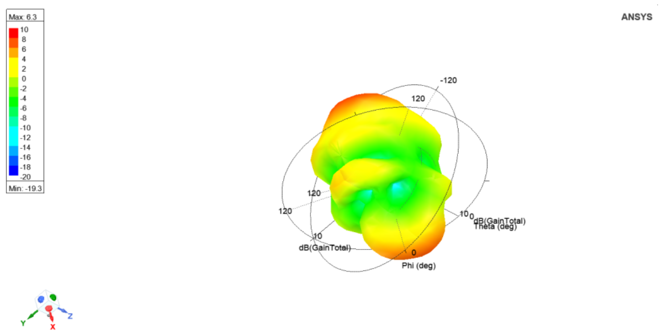


Fig. 33: Simulated Gain for proposed antenna at 4.4GHz

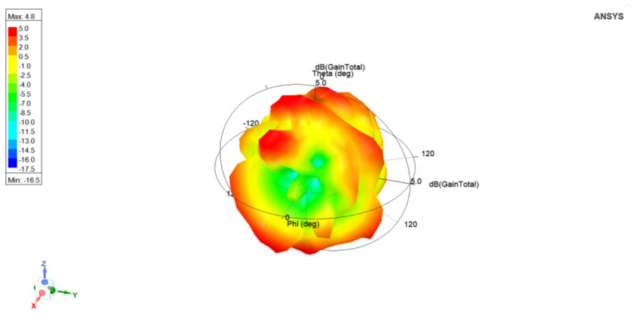


Fig. 34: Simulated Gain for proposed antenna at 8.4GHz

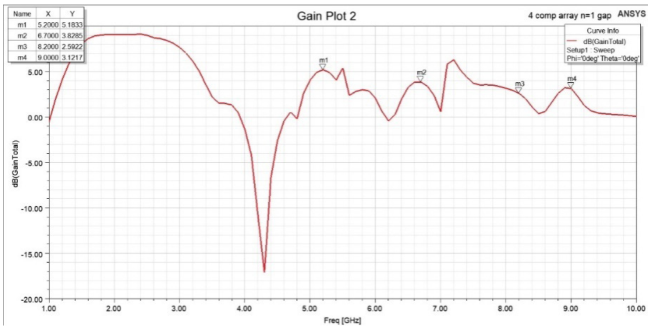
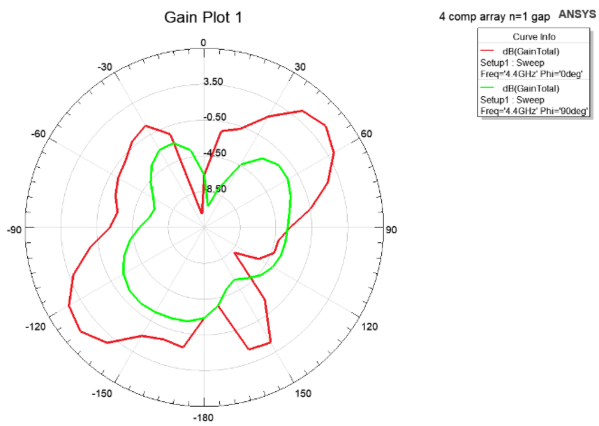
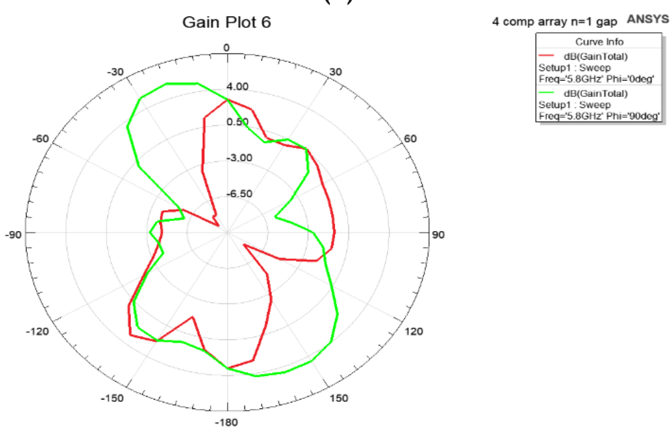


Fig. 35: Simulated Gain Vs Frequency plot for proposed antenna

The gain versus Frequency of proposed antenna for 1st iteration of Fractal slots which corresponding to Fig.2(b) is observed from Fig.33, Fig.34 and Fig.35 this proto type of antenna produces high gain 8.3dB at 4.4GHz and 4.8dB at 8.4GHz.



(a)



(b)

Fig. 36: (a) and (b) simulated radiation patterns at 4.4GHz and 5.8GHz

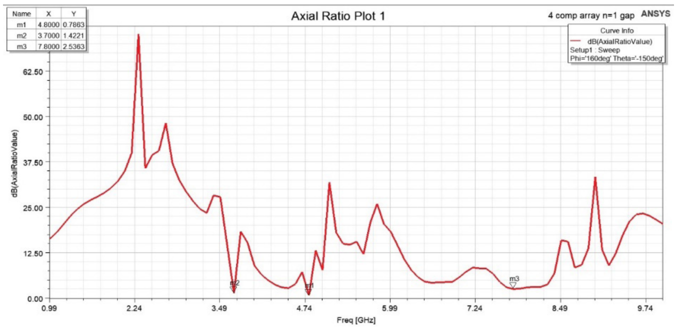


Fig. 37 Simulated Axial ratio of proposed antenna

From the above Fig.37, it is observed that the Axial Ratio of the designed antenna is i.e 0.7863 at 4.8GHz, 1.4221 at 3.7GHz and 2.5383 at 7.8GHz which isbelow 3dB.

(F) Simulation results for 4-coupled rectangular DRA array using Miter-bend parallel power divider with Fractal Cross-slot coupled DRAelements of 2nd iteration.

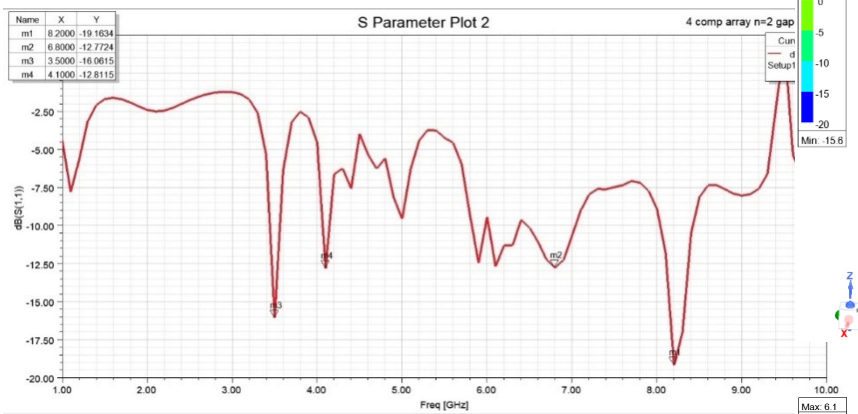


Fig. 38: Simulated Return loss(S11) for proposed antenna for 2nd iteration fractal slot-Mitre bend power divider

From the Fig.38 it is observed that the return loss as -16.0615dB at 3.5GHz, -12.8115dB at 4.1GHz, -12.7724dB at 6.8GHz and -19.1634dB at 8.2GHz

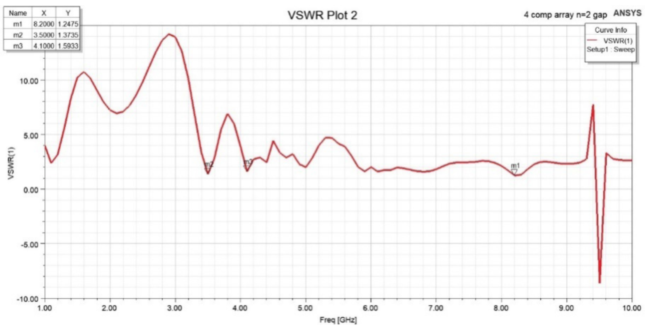
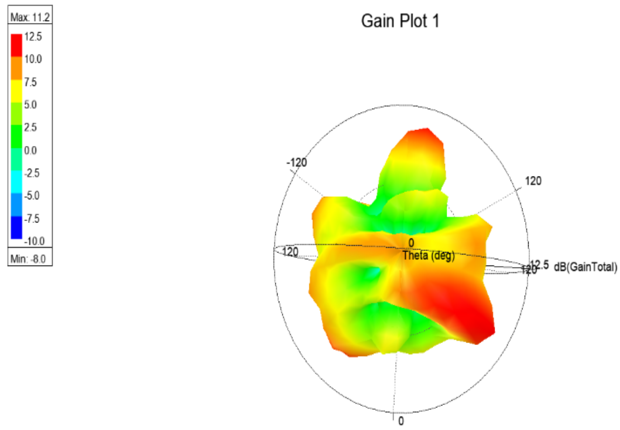
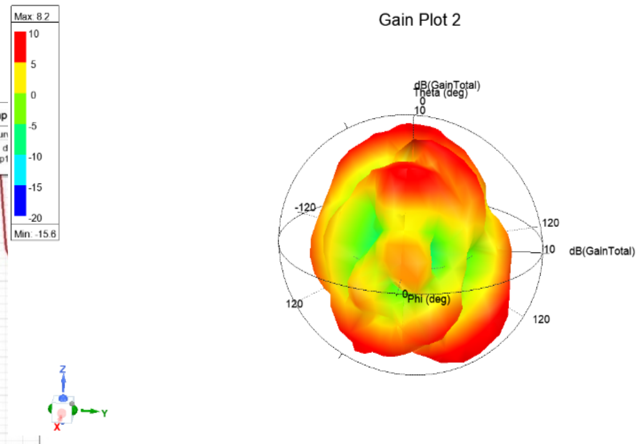


Fig. 39: SimulatedVSWR for proposed antenna for 2nd iteration fractal slot-Mitre bend power divider

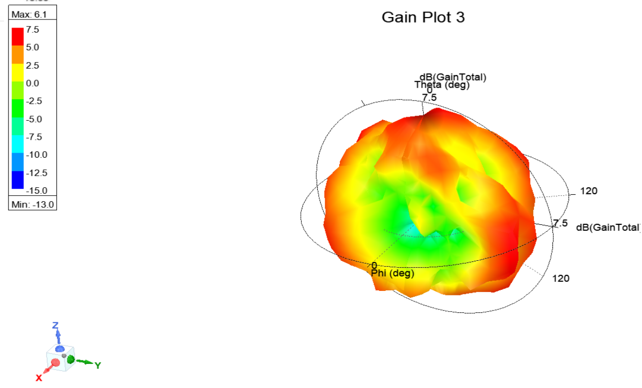
From the above figure it is observed that the VSWR for above shown design in Figure 2(b) is 1.3735dB, 1.5933dB, 1.2475dB at 3.5GHz, 4.1GHz, 8.2GHz respectively.



(a)



(b)



(c)

Fig. 40: (a),(b), (c) 3D gain plots at 4.2GHz, 6.8GHz and 8.2GHz

The gain versus Frequency of proposed antenna for 2nd iteration of Fractal slots which corresponding to Fig.2(b) is observed from Fig.40(a), (b), (c) this proto type of antenna produces high gain 11.2dB at 4.2GHz, 8.2dB at 6.8GHz and 6.1dB at 8.2GHz.

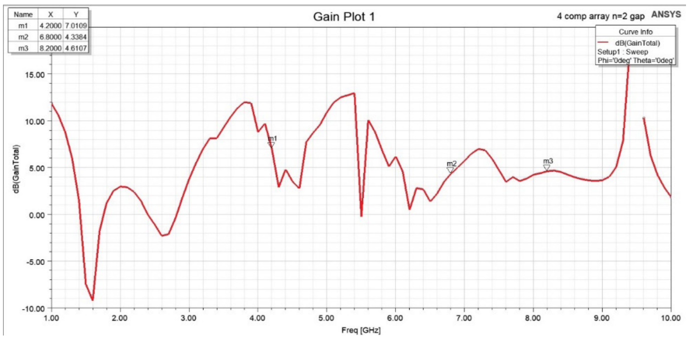
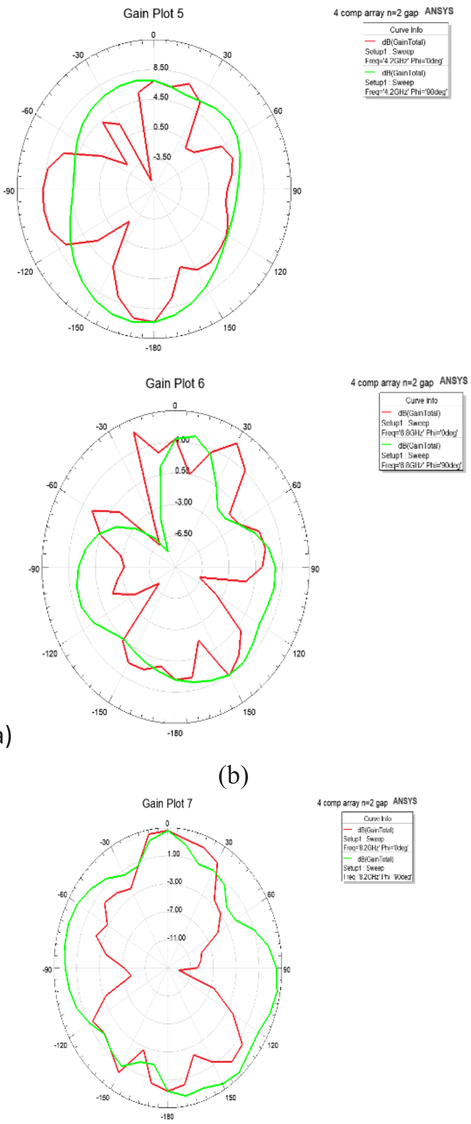


Fig. 41: Simulated Gain Vs Frequency plot for proposed antenna with 2nd iteration fractal slot-Miter bend power divider



(a)

(b)

(c)

Fig. 42: (a),(b), (c) Simulated radiation patterns for proposed antenna

From above Fig.42 (a), (b), (c) represents radiation patterns which includes both E field and H field patterns for proposed 2nd iterated 4 element miter bend power divider RDRA linear array antenna. These patterns indicate that having low side lobe levels at 4.2GHz, 6.8GHz and 8.2GHz which the design is suitable for more wide band applications.

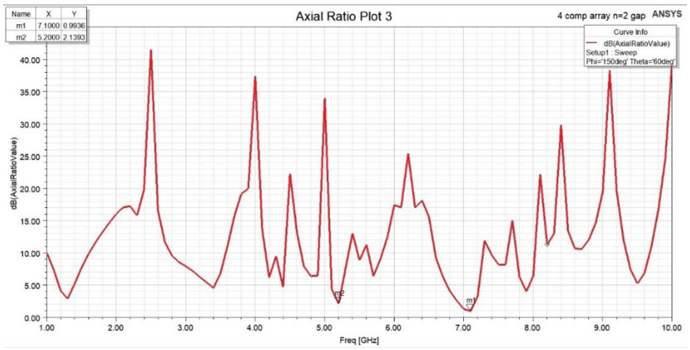


Fig. 43:0 Simulated Axial ratio plot for proposed antennawith 2nd iteration fractal slot-Miter bend power divider

From the above Fig.43, it is observed that the Axial Ratio of the designed antenna is i.e 0.9936 at 7.1GHz and 2.1393 at 5.2GHzwhich is below 3dB.

(G). Simulation results for 0th iteration Fractal Cross-slot coupled 4-RDRA array of 2-set coupledusing2 set of Miter bend parallel power divider network using HFSS.

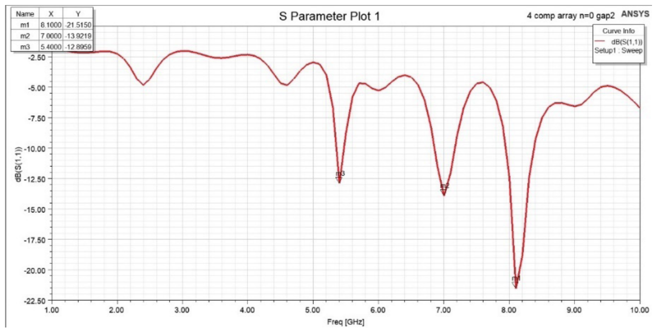


Fig. 44: Simulated return loss plot for propsed antenna for 0th iterated 2 set miter bend power divider

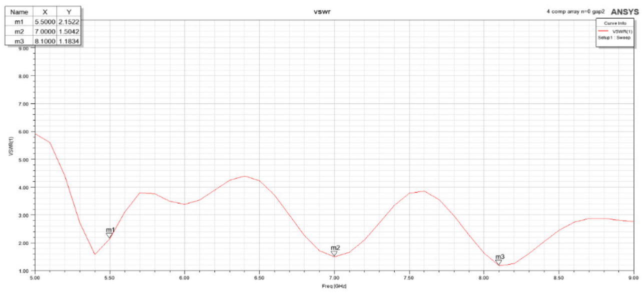
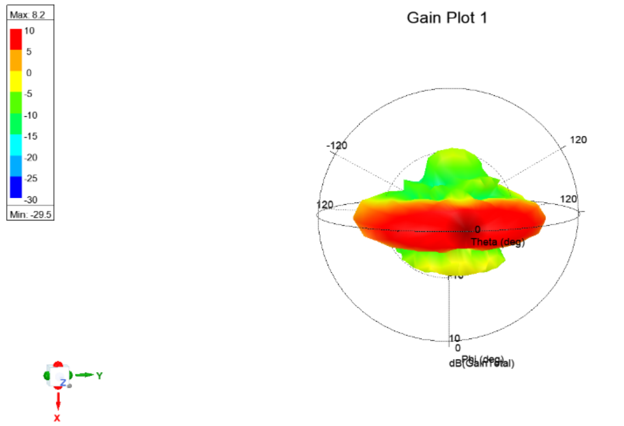
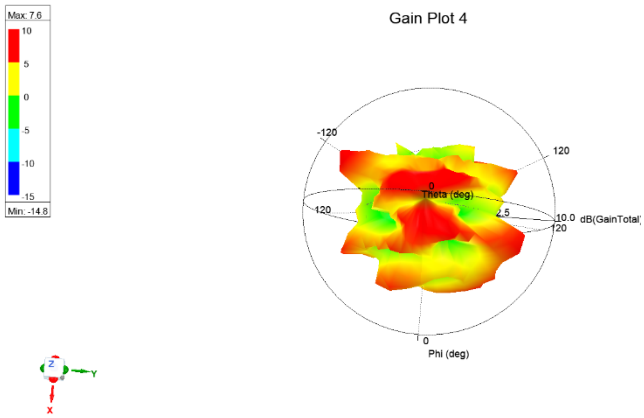


Fig. 45: Simulated VSWR plot for propsed antenna with 2 set mitre bend power divider.

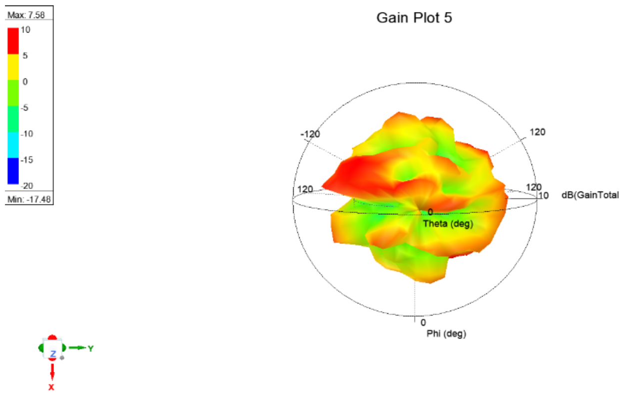
The simulated Return loss and VSWR plots for the proposed 2 set mitre bend power divider with 0th iterated fractal slot RDRA array antenna. These indicates the return loss lies below the -10dB and VSWR lies between 1 and 2 which are preferable for any antenna. The return loss for proposed antenna from the simulated plot is -12.8959, -13.9219, -21.5150 at 5.4GHZ, 7GHz and 8.1GHz respectively and VSWR is 1.5042 and 1.1834 at 7GHZ and 8.1GHz.



(a)



(b)



(c)

Fig. 46: (a),(b), (c) simulated 3D gain plots for proposed antenna at 5.5GHz, 7GHz and 8.1GHz

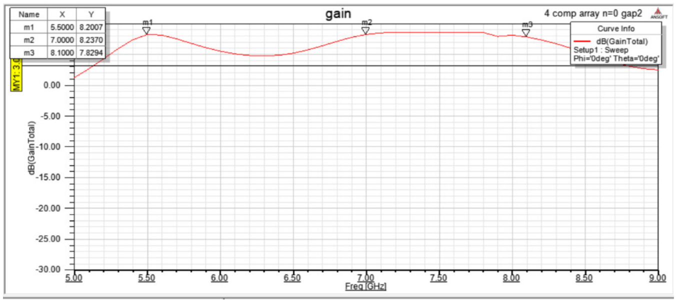
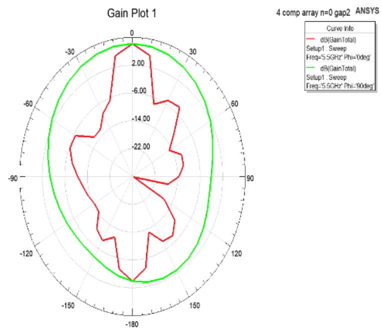
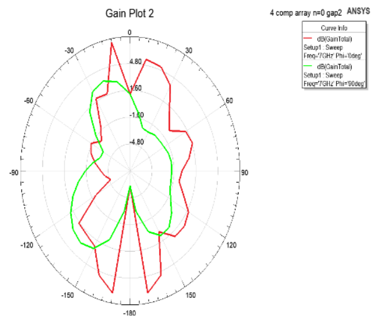


Fig. 47: Simulated Gain Vs Frequency plot for proposed antenna

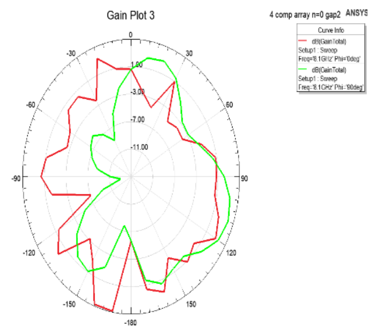
From the above simulated 3D gain and Gain Vs Frequency plots for the proposed antenna with 2 set mitre bend power divider and 0th iterated fractal slot it is observed that proposed antenna design achieves target gain i.e 8.2dB, 7.6dB and 7.58dB at resonated frequencies i.e at 5.5GHz, 7GHz and 8.1GHz respectively which the designed antenna is suitable for enhanced wide band applications.



(a)



(b)



(c)

Fig.48(a), (b), (c) simulated radiation patterns for proposed antenna

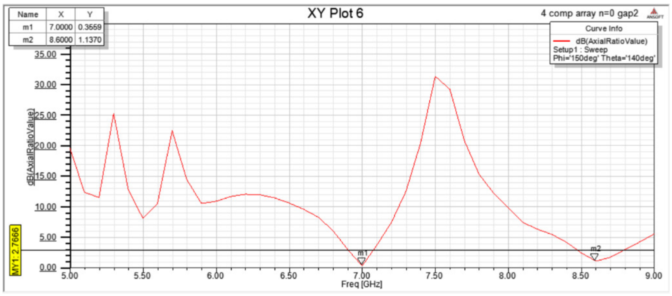


Fig. 49: Simulated Axial Ratio for proposed antenna

From the above Figure.49 it is observed that the Axial Ratio of the designed antenna by HFSS is i.e 0.3559dB at 7GHz and 1.1370dB at 8.6GHz which is below 3dB.

(H). Simulation results for 1st iteration Fractal Cross-slot coupled 4-RDRA array of 2-set coupledusing2 set of Miter bend parallel power divider network using HFSS.

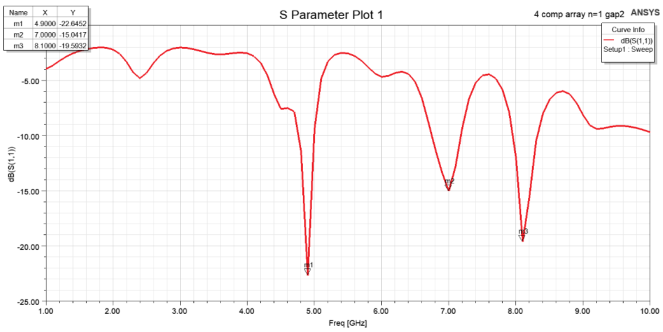


Fig. 50: Return loss plot for the proposed antenna with 1stiterated Fractal Cross-slot

2-set Miter bend parallel power divider

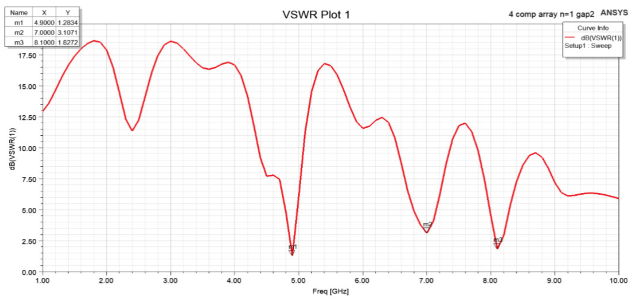
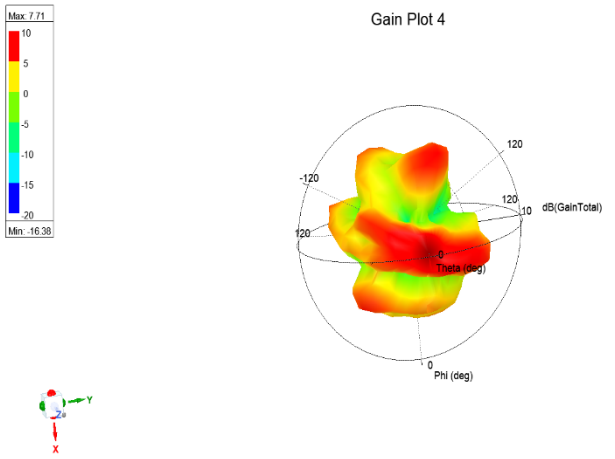


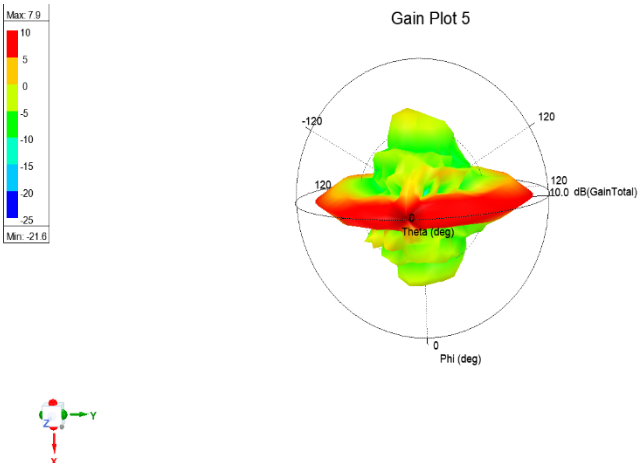
Fig.50: VSWR plot for the proposed antenna with 1st iterated Fractal Cross-slot

2-set Miter bend parallel power divider

From the Fig.50 it is observed that the simulated return loss for proposed antenna as -22.6452 at 4.9GHz, -15.0417 at 7.0GHz, -19.5932dB at 8. 1GHz.which is below -10dB and the VSWR lies between 1 and 2 at resonated frequency range i.e1.2834 at 4.9GHz and 1.8272 at 8.1GHz.



(a)



(a)

Fig.51: (a),(b) Simulated 3D gain plots for proposed antenna at 7GHz and 8.1GHz

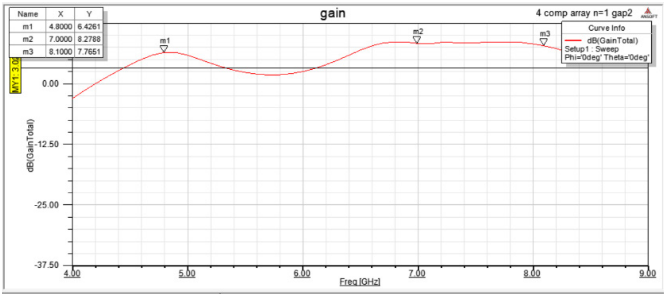
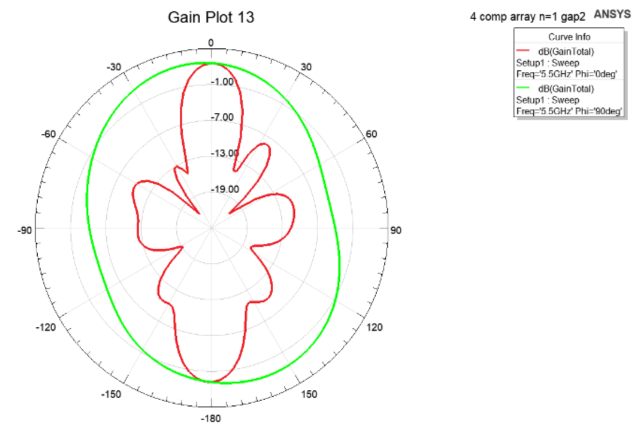
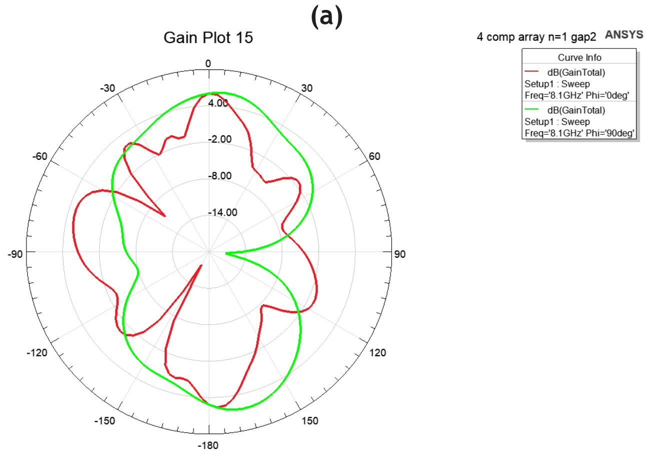


Fig.52 Simulated Gain Vs Frequency plot for proposed antenna

The above Fig.51 and Fig.52 represents that the simulated plots of 3D gain and Gain Vs frequency for the proposed design antenna and these indicate that the designed antenna exhibits the enhanced gain at resonated frequency i.e 7,71dB at 7GHz and 7.9dB at 8.1GHz which are more suitable for large extent of satellite and radar applications as well as IOT applications



(a)



(b)

Fig. 53: (a), (b) simulated radiation patterns of proposed antenna at 5.5GHz and 8.1GHz

From the Fig.53(a),(b) represents the radiation patterns of proposed RDRA antenna and it has been observed that the designed antenna or the applications of proposed antenna will be enhanced greatly and generates linear and circular polarized waves simultaneously and it has omnidirectional radiation pattern at 5.5GHz and 8.1 GHz.

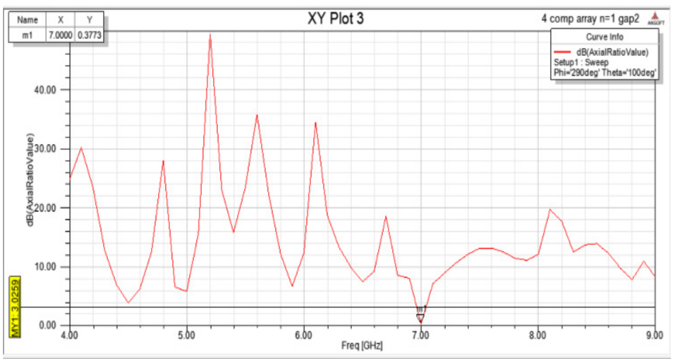


Fig. 54 Simulated Axial Ratio for proposed antenna

From the above simulated plot for Axial ratio it is observed that the proposed antenna give mor Axial ratio band width and the Axial Ratio value is 0.3773 which is lies below the3db.

From the above Figure.46 it is observed that the Axial Ratio of the designed antenna is i.e 0.3773 at 7GHz which is below 3dB.

(I). Simulation results for 2nd iteration Fractal Cross-slot coupled 4-RDRA array of 2-set coupledusing2 set of Miter bend parallel power divider network using HFSS.

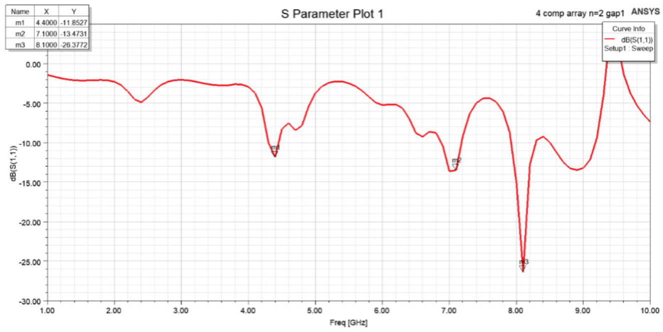


Fig. 55: Simulated Return loss plot for proposed antenna

From the fig. it is observed that the return loss as -11.8527 at 4.4GHz, -13.4731 at 7.1GHz, -26.3772dB at 8. 1GHz.which is below -10dB and the VSWR which shown in Fig.56 for proposed antenna is 1.6863dB, 1.5381dB, 1.1008dB at 4.4GHz, 7.1GHz, 8.1GHz respectively which lies between practical range 1 to 2.

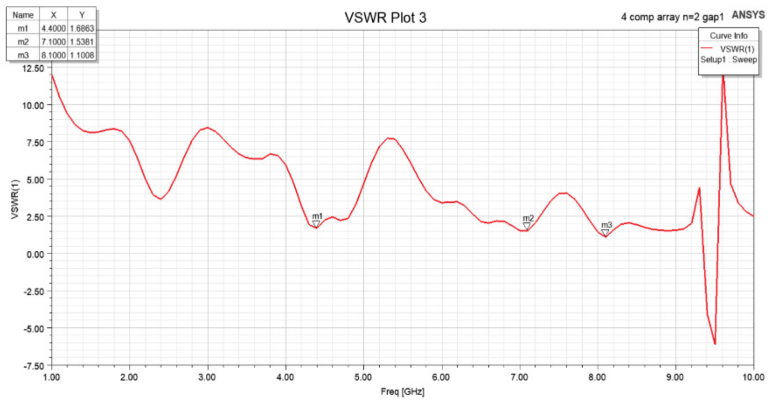
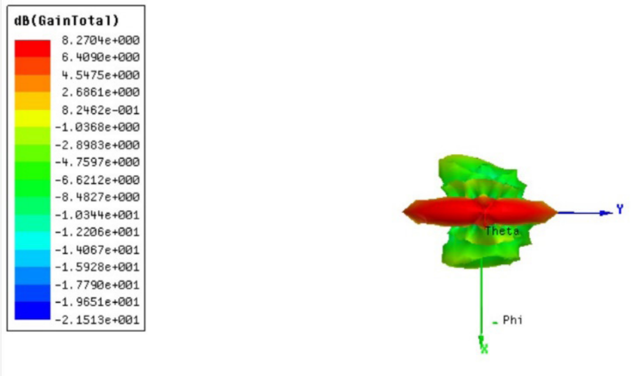
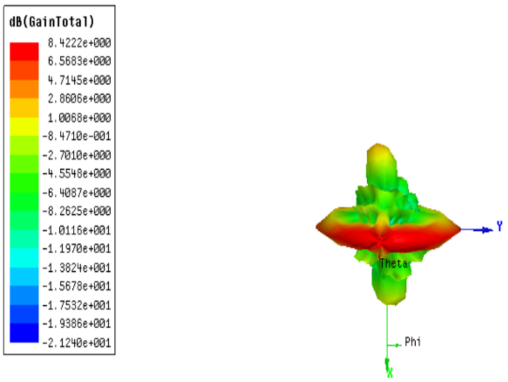


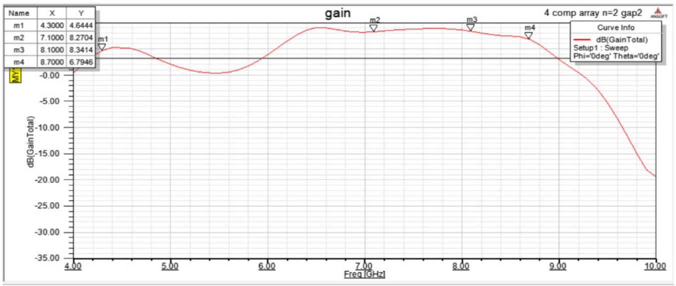
Fig. 56: Simulated VSWR plot for proposed antenna



(a)



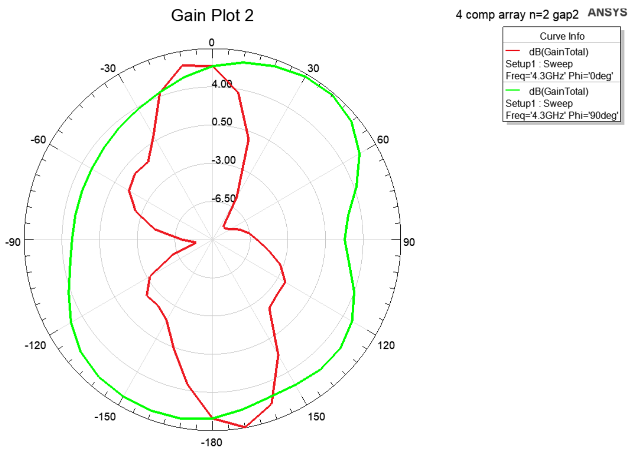
(b)



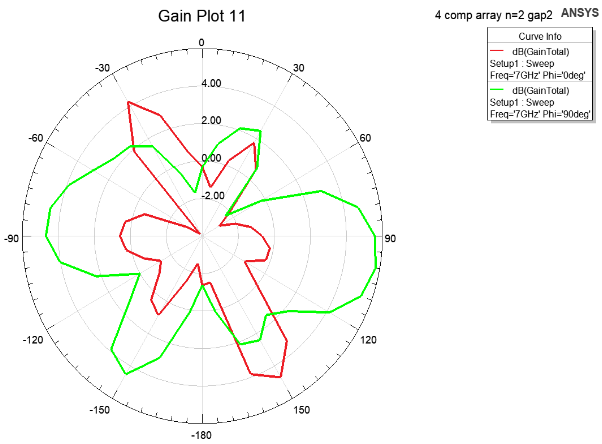
(c)

Fig. 57: (a),(b), (c) simulated 3D gain plot and Gain Vs Frequency plot for the proposed antenna

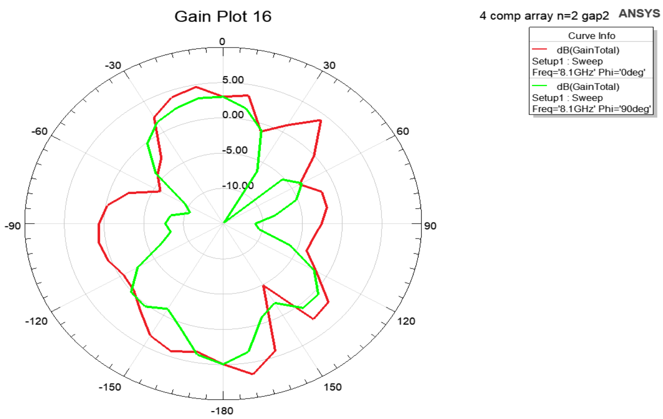
From the above Fig.57(a)(b) (c) it is observed that the gain of proposed antenna is enhanced to 8.27dB at 7.1GHz and 8.4222 at 8.1GHz which is useful for wide range of radar and IOT applications



(a)



(b)



(c)

Fig. 58: (a), (b), (c) simulated radiation patterns for the proposed antenna

The above Fig.58(a),(b),(c) represents the directions of departure of EM wave called radiation patterns plotted at frequencies 4.3GHz, 7GHz and 8.1GHz for proposed antenna. From the above Figure it is observed that at resonated frequency the proposed antenna distributes its high energy in a particular direction at the same time it reduces the side lobe level energy.

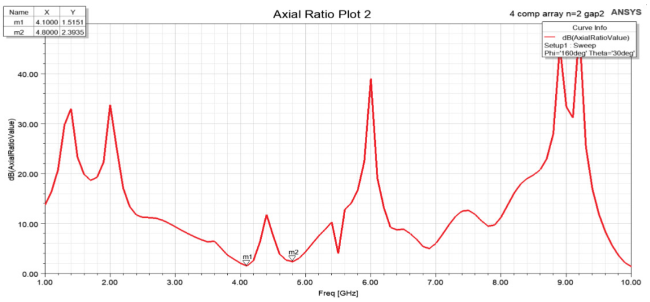
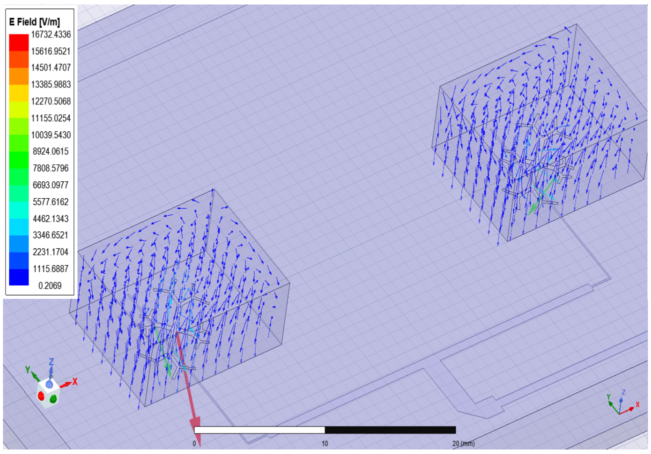


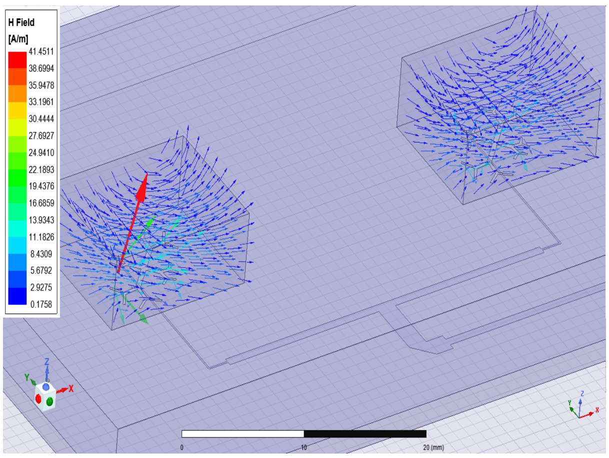
Fig.59: Axial Ratio for the proposed antenna

From the above Axial Ratio plot for proposed RDRA with 2nd iterated fractal couple 2 set Mitre bend power divider, it has been observed that Axial ratio is 1.5151dB at 4.1GHz and 2.3935dB at 4.8GHz which is also below 3dB.

Filed Patterns:

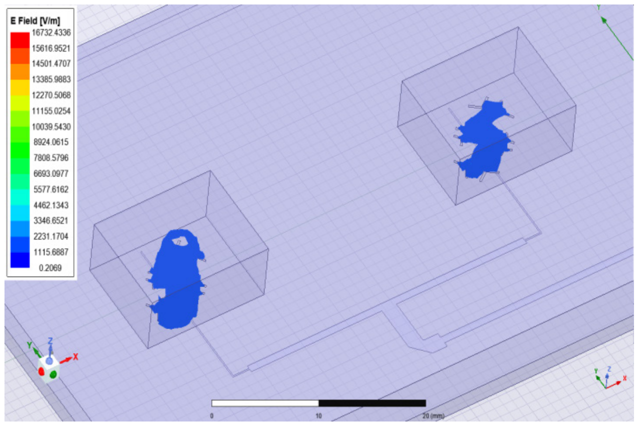


(a) **E field pattern**

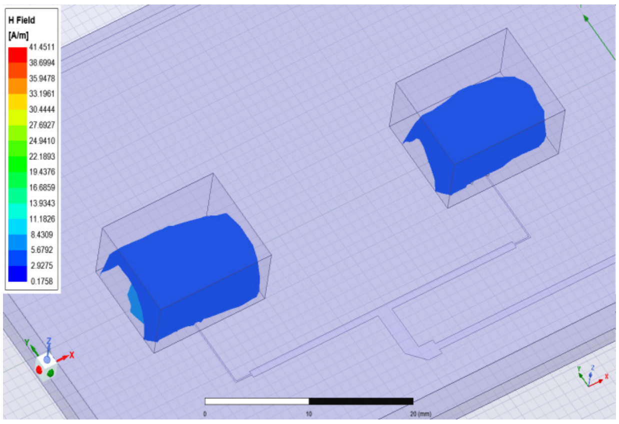


(b) H field pattern

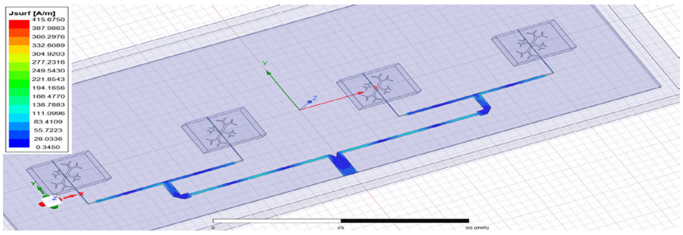
Figure 60(a), (b).Field patterns and current distribution for 4-coupled rectangular DRA array using Miter bend parallel power divider with Fractal cross slot coupled DRA elements of 2nd iteration



(c) E magnitude



(d) H magnitude



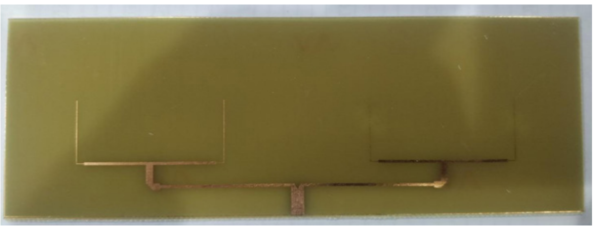
(e) current distributin

Figure 61(c), (d).Field magnitude and current distribution for 4-coupled rectangular DRA array using Miter bend parallel power divider with Fractal cross slot coupled DRA elements of 2nd iteration.

Fabrication Model:

(a)

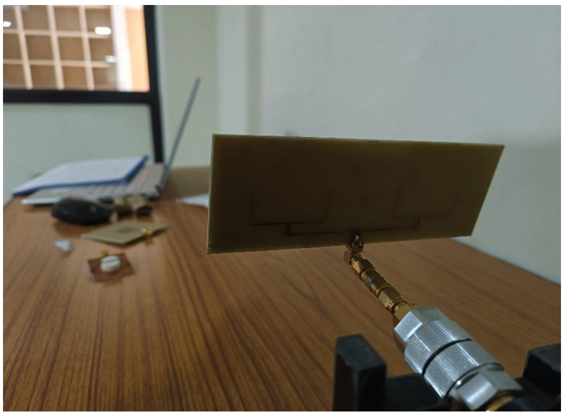
(b)



(c)

Figure.52: Fabricated antenna for second iteration 4 Element RDRA of 2 coupled Miter bend parallel power divider network. (a) Front view of fractal slots without DRAs (b) front view with DRAs (c) Back view of fabricated antenna

(a)



(b)

Figure.53: Experimental setup for fabricated antenna

V. MEASURED RESULTS

Return loss with DRA

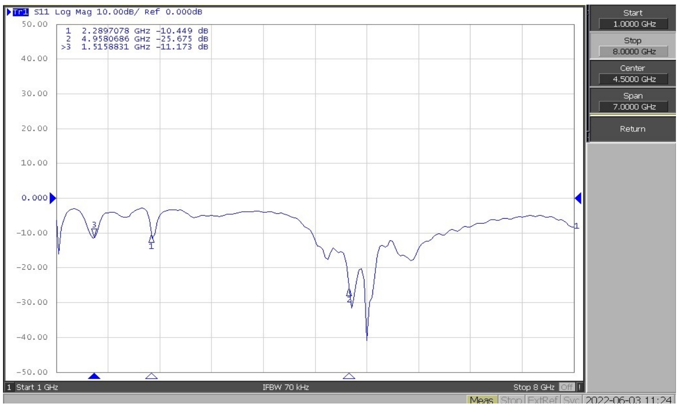


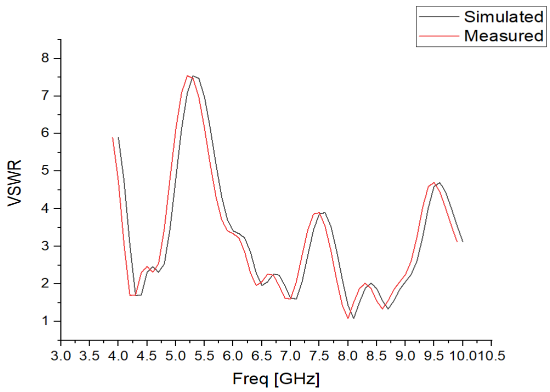
Fig. 54: Measured return loss plot for proposed RDRA

VSWR with DRA

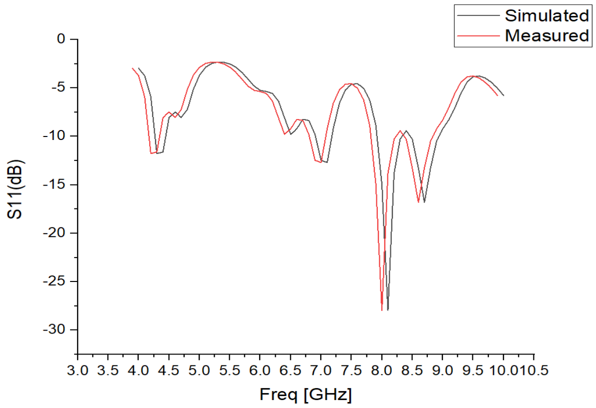
Fig. 55: Measured VSWR plot for proposed RDRA

Results comparison: Simulated Vs Practical:

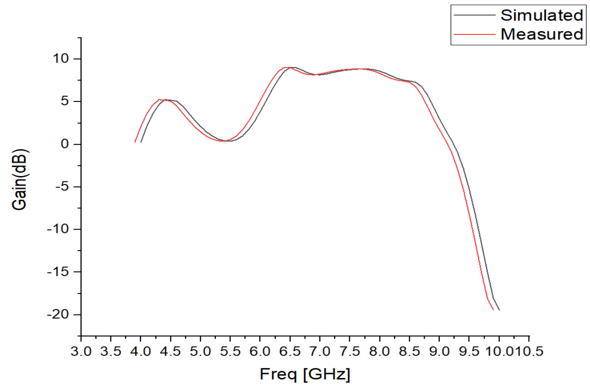
Results comparison between simulated and measured for 4 element and 2 set of DRAelements with Parallel power divider network for 2^{nd} Iteration fractal slot circular polarization



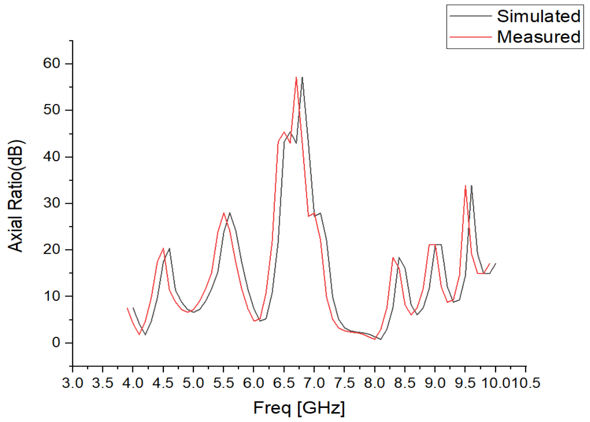
(a) Return loss



(c)Gain



(b) VSWR



(d) Axial Ratio

Fig.56 (a) Comparison of simulated and measured return loss for proposed RDRA (b) Comparison of simulated and measured VSWR for proposed RDRARDRA (c) Comparison of simulated and measured Gain for proposed RDRARDRA (d) Comparison of simulated and measured Axial Ratio for proposed RDRA

Comparison of DRA antennas for different iterations:

Iteration Value(n)	Frequency (GHz)	Return Loss(dB)	Gain (dB)	VSWR	Axial Ratio (AR)(dB)
0(4 Elements with parallel power divider)	5.6	-17.4633	8.1822	1.3092	--
	9.5	-21.5285	6.3200	1.1831	0.9541
1(4 Elements with parallel power divider)	3.6	-19.4197	--	1.2394	--
	4.3	-19.4495	3.3187	1.2385	--
	5.2	-14.8371	6.7569	1.5104	--
	6.8	-17.6324	--	1.3024	--
	9.2	-22.8466	9.0643	1.1556	0.3832
2(4 Elements with parallel power divider)	3.5	-13.8492	--	1.5095	--
	6.5	-24.3029	3.1267	1.1298	--
	6.8	-23.9974	--	1.1347	--
	8.8	-11.3621	7.0131	1.7410	0.5238
0(4 Elements with Miter bend and parallel power divider)	3.7	-13.0662	5.355	1.5713	
	5.6	-20.4168	8.3604	1.2107	0.2802
	7.8	-10.1793	8.6960	1.8976	
	9.5	--	--	1.5864	
1(4 Elements with Miter bend and parallel power divider)	3.6	-17.0842	---	1.3253	1.4221
	4.8	-18.4193	3.9663	1.2726	0.7863
	5.2	--	5.1833	1.9480	
	7.8	-16.9243	3.8164	1.2528	2.5383
	8.2	-24.9757-	2.5922	1.1195	

Iteration Value(n)	Frequency (GHz)	Return Loss(dB)	Gain (dB)	VSWR	Axial Ratio (AR)(dB)
2(4 Elements with Miter bend and parallel power divider)	3.5	-16.0615	--	1.3735	
	4.1	-12.8115	7.0109	1.5933	
	6.8	-12.7724	4.3384	--	
	8.2	-19.1634	4.6107	1.2475	
	5.2	--	--	--	2.1393
	7.1	--	--	--	0.9936
0(4 Elements with Miter bend and 2 set power divider)	5.5	-12.8959	8.2007	2.1522	2.1393
	7.0	-13.9219	8.2370	1.5042	0.9936
	8.1	-21.5150	7.8294	1.1834	--
1(4 Elements with Miter bend and 2 set power divider)	4.9	-22.6452	6.4261	1.2834	--
	7.0	-15.0417	8.2708	3.1071	0.3773
	8.1	-19.5932	7.7651	1.8272	--
2(4 Elements with Miter bend and 2 set power divider)	4.4	-11.8527	4.6567	1.6863	
	7.1	-13.4731	8.2704	1.5381	
	8.1	-26.3772	8.4222	1.1008	
	4.1	--	--	--	1.5151
	4.8	--	--	--	2.3935

Comparison of DRA antennas for second iteration:

Antenna	Beam width(deg)	Side lobe level(dB)
4 Elements with parallel power divider	60	-5.4355
4 Elements with Miter bend and parallel power divider	60	-9.7448
4 Elements with Miter bend and 2 set power dividers	60	-7.3107

CONCLUSION

In this article, a quasi-modified rectangular patch antenna is designed and simulated over HFSS article can be concluded that the various antenna designs which have shown above. The simulated values are compared with the simulated values. The above said all antenna designs like 4 coupled and 2 coupled DRA arrays using various power divider networks like T bend and Miter bend are operating in the range between 4GHz to 9GHz. The values of all parameters like return loss, VSWR, Gain, radiation pattern are well reached to the best mark, In all these frequency ranges the return loss is below-10dB ,VSWR value is less than 2, gain is the best value is around 8dB and Axial Ratio is below 3dB. With these values and frequency ranges the proposed DRA is attractive and can be preferable for many wireless applications like satellite applications, Radar application and IOT applications.

REFERENCES

1. Abdou, T. S., Saad, R., & Khamas, S. K. (2023). A circularly polarized mm-wave dielectric-resonator-antenna array for off-body communications. *Applied Sciences, 13*(3), 2002. https://doi.org/10.3390/app13032002
2. Nor, N. M., Jamaluddin, M. H., Kamarudin, M. R., & Khalily, M. (2016). Rectangular dielectric resonator antenna array for 28 GHz applications. *Progress in Electromagnetics Research C, 63*, 53-61.
3. Muralidharan, J. (2024). Advancements in 5G technology: Challenges and opportunities in communication networks.

Progress in Electronics and Communication Engineering, 1(1), 1-6.

4. Khalily, M., Rahim, M. K. A., Khalajmehrabadi, A., & Kamarudin, M. R. (2011). A compact circularly polarized and wideband rectangular dielectric resonator antenna. In *2011 IEEE International RF and Microwave Conference (RFM)* (pp. 1–4). IEEE.
5. Sharma, A., & Gupta, R. (2023). Energy-efficient routing protocols in wireless sensor networks: A comprehensive survey. *Journal of Wireless Sensor Networks and IoT, 5*(2), 45–58.
6. Roy, S. (2013). Design of rectangular dielectric resonator antenna for artificial neural network. *International Journal of Engineering Research and Applications, 3*(3), 424–430.
7. Patel, S., & Kumar, V. (2022). Recent advancements in nanomaterials for energy storage applications: A review. *Innovative Reviews in Engineering and Science, 4*(1), 12-27.
8. Ramesh, S., & Priya, D. (2021). A study on blockchain technology: Applications and challenges. *International Journal of Communication and Computer Technologies, 9*(1), 15–22.
9. Chaudhuri, S., Mishra, M., Kshetrimayum, R. S., & Sonkar, R. K. (2020, June). Wideband rectangular dielectric resonator antenna array for ISM band applications. In *2020 IEEE Region 10 Symposium (TENSYMP)* (pp. 622–625). IEEE.
10. Xiao, Y., Leung, K. W., Lu, K., & Leung, C.-S. (2022). Mode recognition of rectangular dielectric resonator antenna using artificial neural network. *IEEE Transactions on Antennas and Propagation, 70*(7), 5054–5065. https://doi.org/10.1109/TAP.2022.3146860
11. Kavitha, M. (2024). Embedded system architectures for autonomous vehicle navigation and control. *SCCTS Journal of Embedded Systems Design and Applications, 1*(1), 25–28.
12. Verma, A., & Kaur, J. (2021). Performance analysis of MANET routing protocols under varying network conditions. *International Journal of Communication and Computer Technologies, 9*(2), 33–40.
13. Lin, J.-H., Shen, W.-H., Shi, Z.-D., & Zhong, S.-S. (2017). Circularly polarized dielectric resonator antenna arrays with fractal cross-slot-coupled DRA elements. *International Journal of Antennas and Propagation, 2017*, 1–9. https://doi.org/10.1155/2017/8160768
14. Guo, Q., & Zhang, J. (2019). A dual-band rectangular dielectric resonator antenna array for 5G applications. In *2019 IEEE International Conference on Communications Workshops (ICC Workshops)* (pp. 1–6). IEEE.
15. Abdullah, D. (2024). Leveraging FPGA-based design for high-performance embedded computing. *SCCTS Journal of Embedded Systems Design and Applications, 1*(1), 29–32.
16. Abushakra, F. Z., Al-Zoubi, A. S., & Hawatmeh, D. F. (2018). Design and measurements of rectangular dielectric resonator antenna linear arrays. *ACES Journal, 33*(4), 422–429.
17. Li, X., & Wang, Y. (2023). IoT-based smart home automation systems: Security challenges and solutions. *Journal of Wireless Sensor Networks and IoT, 5*(3), 102–115.
18. Uvarajan, K. P. (2024). Integration of artificial intelligence in electronics: Enhancing smart devices and systems. *Progress in Electronics and Communication Engineering, 1*(1), 7–12.
19. Abdulkareem, S. F., & Mezaal, Y. S. (2019). Applications of fractal and quasi-fractal geometries in slot antenna design: A review. *Journal of Mechanics of Continua and Mathematical Sciences, 14*(4), 216–238.
20. Ravikumar, G., Venkatareddy, D., & Asharani, M. (2024). Development of synthesizable filter-centric loop filter design for ADPLL architecture in SoC. *Journal of VLSI Circuits and Systems, 6*(2), 1–13.
21. Al-Khaled, K., Ajeel, M. S., Darweesh, A., & Al-Khalid, H. (2024). A reliable algorithm for solving Blasius boundary value problem. *Results in Nonlinear Analysis, 7*(4), 1-8.
22. Ahmed, N., & Singh, P. (2022). Machine learning approaches in predictive maintenance: Techniques and applications. *Innovative Reviews in Engineering and Science, 4*(2), 78–91.
23. Nikkhah, M. R., Rashed-Mohassel, J., & Kishk, A. A. (n.d.). High-gain aperture coupled rectangular dielectric resonator antenna array using parasitic elements. *IEEE Transactions on Antennas and Propagation*.
24. Al-Zoubi, A. S., Kishk, A. A., & Glisson, A. W. (2010). A linear rectangular dielectric resonator antenna array fed by dielectric image guide with low cross polarization. *IEEE Transactions on Antennas and Propagation, 58*(3), 996–1003.
25. Zaidi, Z. (2024). Solution techniques for time-dependent availability in complex and repairable systems: A comparative study. *Results in Nonlinear Analysis, 7*(4), 9–20.
26. Arunalatha, B., Kanaka Durga, G., & Chandrasekhar, P. (2024). Development of low power GNSS correlator in Zynq SoC for GPS and GLONASS. *Journal of VLSI Circuits and Systems, 6*(2), 14–22.