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A TRIPLE BAND CIRCULAR PATCH ANTENNA WITH CIRCULAR RINGS AND DEFECTED GROUND STRUCTURE

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Abstract:
In this paper, a triple band Circular patch antenna (CPA) with Circular rings and DGS is presented. It is designed on an FR4 substrate. The overall antenna dimensions are 26 X 27 X 1.6mm^3. The CPA is operating over a frequency range of 12.45GHz to 15.80GHz with a bandwidth of 3.35GHz offering a peak gain of 5.13dBi at 15.14GHz.The proposed antenna with Quadruple Circular ring patch antenna is offering a triple band with a frequency bandwidth of 120 MHz(9.92GHz - 10.04 GHz), 440MHz(12.14GHz-12.58GHz), 440MHz(14.34GHz-14.78GHz), and 560MHz(16.10GHz-16.66GHz) with a peak gain of 5.33dBi at 12.33GHz.The proposed antenna with a rectangular slit DGS(RSD) is operating over a frequency range of 4.78GHz to 6.01GHz, 6.62GHz to 7.21GHz, and 7.95GHz to 14.61GHz with a bandwidth of 1.23GHz, 590MHz, and 6.66GHz respectively. The peak gain offered for RSD is 6.03dBi at 13.80GHz. The proposed antenna is operating in C, X, and Ku bands useful in satellite and radar applications. The simulations are carried out using HFSS software.
Keywords: Circular patch antenna, triple band, Circular rings, Quadruple, Defected Ground Structure (DGS).

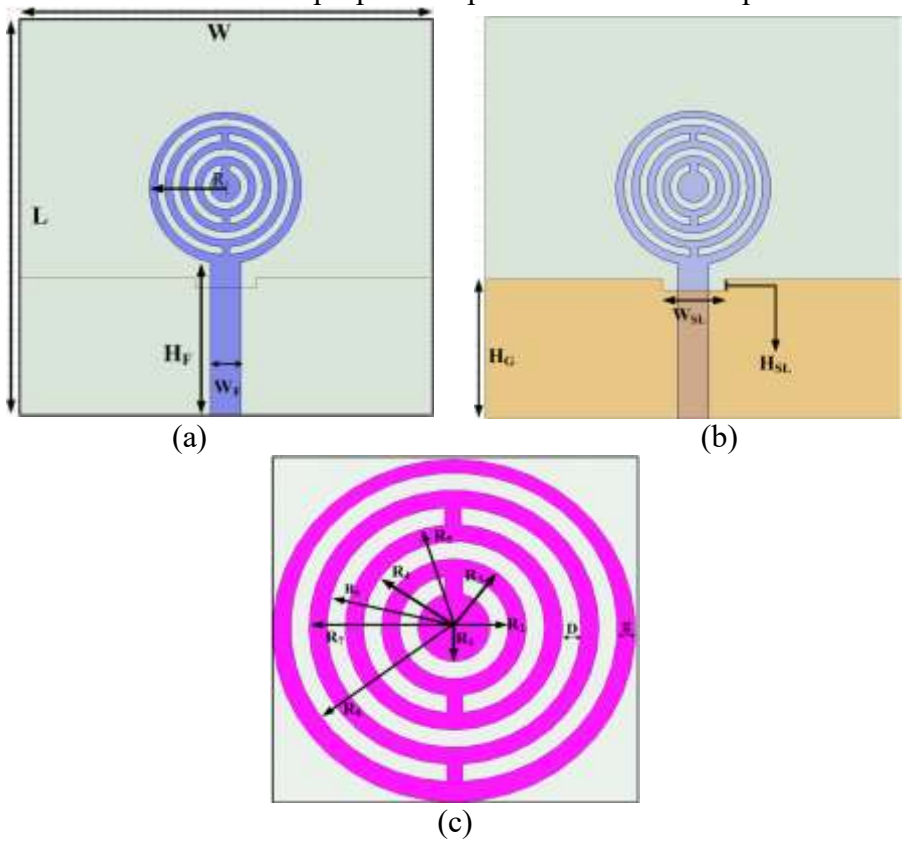
I. INTRODUCTION

Antennas are vital elements in wireless systems. Microstrip patch antenna have significant characteristics such as low profile, inexpensive, light in weight, easy to fabricate, and can be easily integrated with mobile devices is presented [1]. Various techniques are proposed by researchers to design miniaturization and multiband antennas that are widely used in satellite and wireless communication. An annular-ring microstrip patch antenna operates at a frequency range of 4.5GHz to 9.2GHz with a peak gain of 3.6dBi at 5.72GHz is presented [2]. Dual-band Rectangular Ring Printed Antenna operates over a frequency range of 2.4GHz to 2.483GHz and 5.15GHz to 5.875GHz with a peak gain of 5.1dBi at 5.5GHz presented [3].
A circular patch-ring antenna with a bandwidth of 800MHz (5.6GHz -6.4GHz) with a peak gain of 5.7dBi at 5.8 GHz is reported[4].quad-band ring-shaped antenna offering a bandwidth of 476MHz(3.255GHz-3.731GHz), 310MHz(4.51 GHz-4.82 GHz), 570MHz(7.2GHz-7.77 GHz) and 5.1GHz(8.4 GHz-13.5 GHz) with a peak gain of 2.26dBi at 3.5GHz is presented[5].Decagon ring fractal antenna is operating over a frequency range of 2.075GHz to 2.3 GHz,3.3GHz to 3.675 GHz, and 4.375GHz to 6.55GHz with a bandwidth of 285MHz, 564MHz, and 2329MHz and offered a peak gain of 4.1dBi is presented[6].
The defects on the ground plane in a printed microstrip board are considered DGS. It is used to improve antenna performance. Circular Rings Antenna Design with DGS exhibiting a return loss of −24.48 dB at 8.3GHz, −35.50 dB at 11.8GHz, and −21.90dB at 14.5GHz with a peak gain of 7.42dBi at 8.3GHz is presented [7]. The L-shaped patch is operating over a frequency range of 2.38GHz to 2.48GHz, 3.5GHz to 3.62GHz, and 5.66GHz to 5.81GHz with a corresponding bandwidth of 100MHz,120MHz, and 150MHz reported.[8].A patch antenna with six rectangular rings is operating with a frequency bandwidth of 160MHz(7.67GHz-7.83GHz),1.13GHz(9.14GHz-10.27GHz),1.3GHz(11.65GHz-13.01 GHz), and 1480MHz (13.31GHz-14.79GHz) with a peak gain of 9.2dBi at 7.7GHz is presented[9].Triple-band antenna with DGS offering a bandwidth of 197MHz (2.35GHz-2.54GHz),118MHz(3.45GHz-3.57GHz),and90MHz (5.74GHz-5.83GHz) with a peak gain of 3.6dBi

at 5.4GHz is presented[10].A strip-fed patch antenna operates over a frequency range of 2GHz to 6GHz with a peak gain of 4.6dBi is presented [11].
The fractal patch antenna offers a triple band with a frequency bandwidth of 60MHz(3.2GHz-3.8GHz),110MHz(4GHz-5.1GHz), and 300MHz(5.9GHz-6.2GHz) offering a peak gain of 4.22dBi at 6.1 GHz is presented [12]. A microstrip patch antenna offering a bandwidth of 1.1GHz (6 GHz-7.1 GHz), 200MHz(8.2GHz-8.4GHz), and 750MHz (9GHz-9.745GHz) are reported [13]. A rectangular patch antenna is operating over a frequency range of 4.6GHz to 5.07GHz,7.95GHz to 8.50GHz,9.04GHz to 9.37GHz, 9.8GHz to 11.14GHz, and 11.81GHz to 12.27GHz with a peak gain of 5.8dBi at 9.8GHz is presented [14]. asymmetrical TSE Triangular Semi-Elliptic slots with square patch edges are operating with a frequency bandwidth of 590MHz (4900MHz - 5490MHz) and delivering a gain of 3.95dBi is reported [15].
A Triple-band circular patch antenna (CPA) with circular rings and DGS is proposed in this paper. It offers a bandwidth of 1.23GHz (4.78GHz-6.01GHz), 590MHz (6.62GHz- 7.21GHz), 6.66GHz (7.95GHz-14.61GHz) and exhibits return loss of -18.83dB at 5.3GHz, -22.33dB at 6.7GHz, and -18.48dB at 13.84GHz and offering a peak gain of 6.03dBi at 13.84GHz .Section II discusses Antenna Geometry and its dimensions, Section III tells about the Evolution of the proposed antenna and its parametric analysis, Section IV discusses Results and analysis, and Section V discusses the Conclusion.

II. ANTENNA GEOMETRY

Antenna Modelling:
The geometrical configuration of the proposed Quadruple circular rings patch antenna (QCRPA) with rectangular slit DGS(RSD) is presented in Figure 1. The substrate of L=26mm, W=27mm, and h=1.6mm. The CPA is fed with a microstrip line of H_F=10mm and W_F=2mm, and the radius of the CPA is R=5mm. The dimensions of the proposed triple-band antenna are presented in Table 1.



(a) (b)
(c)

Figure 1. Proposed QCRPA with RSD (a) Front view, (b) Back view, and (c) Circular Rings

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Table 1. Dimensions of the proposed Quadruple circular ring patch antenna.

Parameter	Dimension (mm)	Parameter	Dimension (mm)
L	26	**R_2**	1.6
W	27	**R_3**	2
H_F	10	**R_4**	2.6
W_F	2	**R_5**	3
H_G	9	**R_6**	3.6
H_{SL}	1.2	**R_7**	4
W_{SL}	3	**R_8**	4.6
R	5	**D**	0.5
R_1	1	**g**	0.5

III. EVOLUTION OF PROPOSED ANTENNA DESIGN

1. CIRCULAR PATCH ANTENNA(CPA)

A CPA with a 50 Ω microstrip feed line is presented in Figure 2. The parametric analysis of the CPA is done by varying the radius and feed width respectively.

Figure 2. Circular patch antenna

1.1 EFFECT OF RADIUS ON CPA:

A CPA of varying Radius(R) is 4 mm, 5 mm, and 6 mm are done in Figure 2. For R=5mm obtained better results, offering a dual-band with a bandwidth of 620 MHz (12.28 GHz to 12.90 GHz), 1.96 GHz (13.75 GHz to 15.71 GHz), exhibiting a return loss of -22.95dB at 12.53GHz, -30.05dB at 15.24GHz. The return loss plot for a different radius of the CPA is presented below in Figure 3.

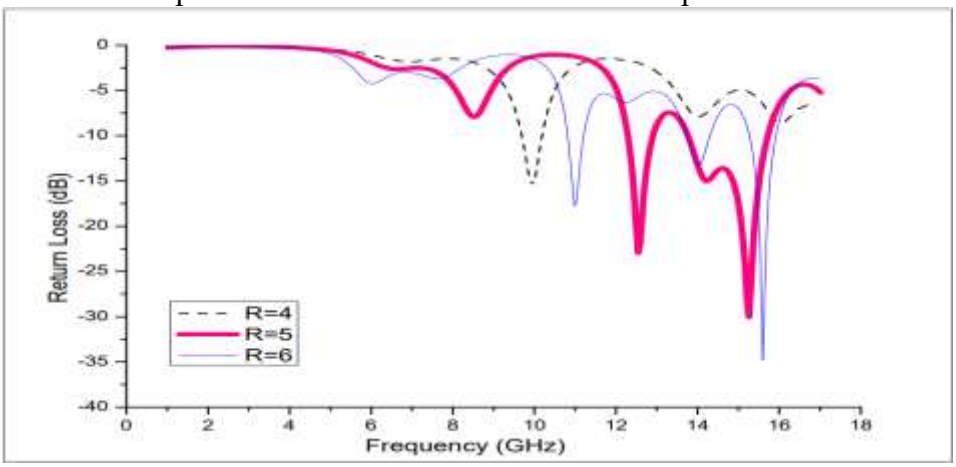

Figure 3. Return loss for the different radius of CPA

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1.2 EFFECT OF FEED WIDTH W_F:

The parametric analysis of varying the width of the feed line is 1mm,1.5mm, and 2mm is done in Figure 2. Different feedline is considered for bandwidth improvement of CPA. The W_F= 2mm offers a better bandwidth compared to other values. The proposed feedline width provides a bandwidth of 3.35 GHz (12.45GHz – 15.80 GHz) exhibiting a return loss of -23.06dB at 13.89GHz and -28.89dB at 15.14GHz. The return loss plot for different feed widths of the CPA is presented below in Figure 4.

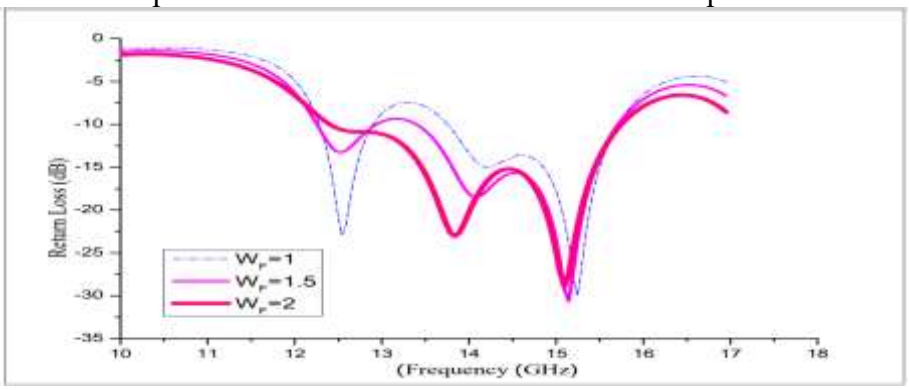

Figure 4. The return loss of different widths of the feedline

2. SINGLE CIRCULAR RING PATCH ANTENNA (SCRPA)

The parametric analysis of the SCRPA varying the radius of R_2=1.4mm, R_2=1.5mm, and R_2=1.6mm is done in Figure 5. The proposed SCRPA radius of 1.6mm offers a better bandwidth of 2.32GHz (13.51GHz – 15.83 GHz) with a return loss of -16.66dB at 14.24GHz and -13.20dB at 15.39GHz.The return loss plot for the different radius of the SCRPA is presented in Figure 6.

Figure 5. Single circular ring patch antenna

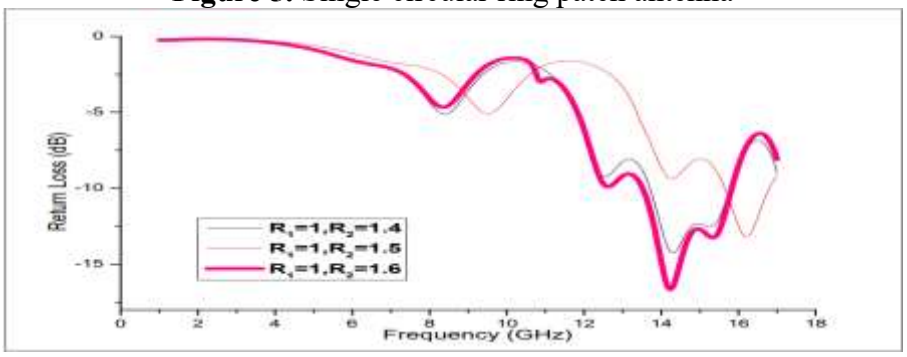

Figure 6. The return loss of different radius of the SCRPA

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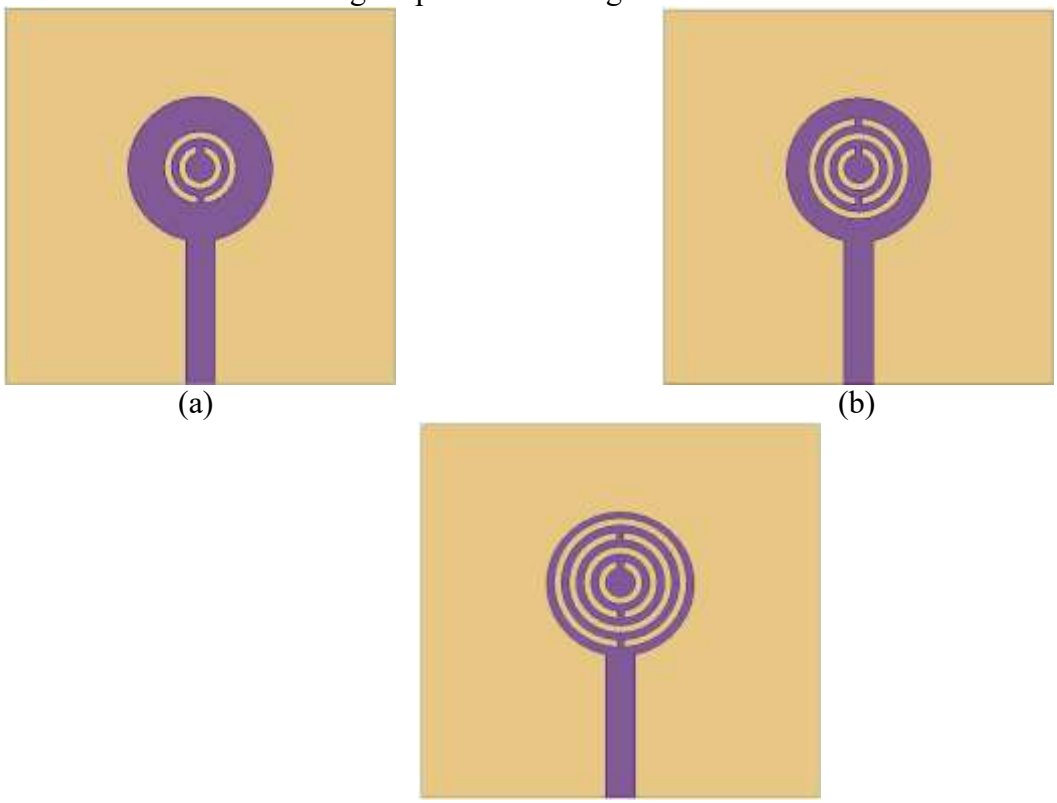
3. CPA WITH MULTI-CIRCULAR RINGS:

A CPA with Multi circular rings is presented in Figure 7.



(a) (b)

(c)

Figure 7. CPA with Multi Circular Rings (a)Double Circular Ring Patch Antenna (DCRPA), (b)Triple Circular Ring Patch Antenna (TCRPA), and (c) Quadruple Circular Ring Patch antenna (QCRPA)

DCRPA is offering a bandwidth of 50MHz(5.31GHz–5.36GHz) with a return loss of -10.66dB at 5.3GHz.TCRPA is offering a bandwidth of 930MHz(11.40GHz-12.33GHz) and 880MHz(14.35GHz-15.23GHz) with a return loss of -19.03dB at 12.03GHz, and -29.53dB at 14.79GHz.QCRPA is operating over a frequency range of 9.92GHz to 10.04GHz,12.14 to 12.58GHz,14.34GHz to 14.78GHz, and 16.10 to 16.66GHz providing a bandwidth of 120MHz,440MHz,440MHz, and 560MHz. The return loss plot for DCRPA, TCRPA, and QCRPA is presented in Figure 8.

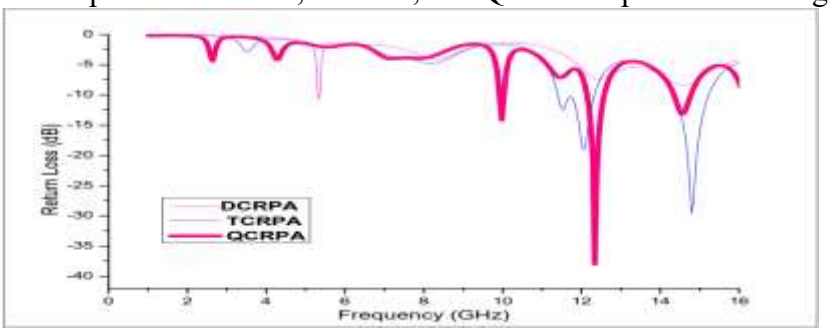


Figure 8. The return loss of DCRPA, TCRPA, and QCRPA

4. EFFECT OF DGS H_G:

The parametric analysis of varying the heights of the DGS 6mm,7mm, and 9mm is done in fig 7(c).In Figure 9,H_G=9mm is obtained better performance with a bandwidth of 1.04GHz(4.89GHz-5.93GHz),330MHz(6.73GHz-7.06GHz), 4.17GHz(8.43GHz to 12.60GHz), 970MHz (13.34GHz - 14.31GHz) with a return of -23.61dB at 5.3GHz,-16.34dB at 6.81GHz,-34.09dB at 11.43GHz and -27.12dB at 13.84GHz.The return loss plot of different heights of DGS on the CPA is presented in Figure 10.

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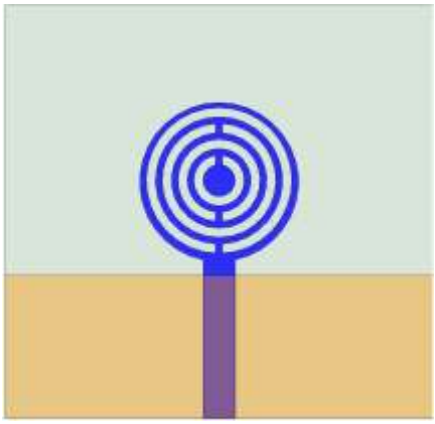


Figure 9: Defected Ground Structure

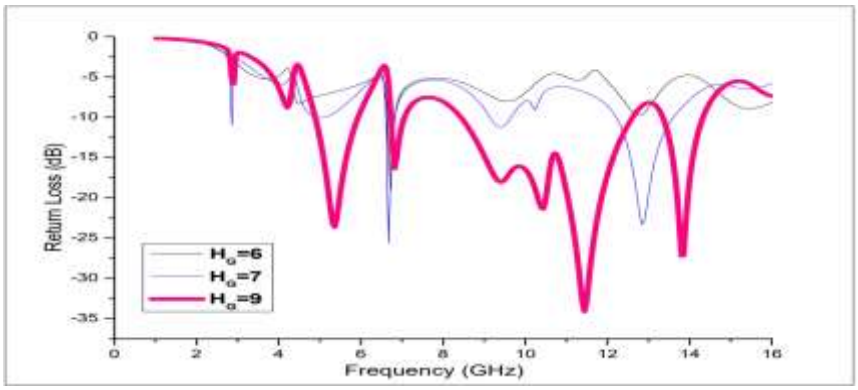


Figure 10. The return loss of different heights of DGS

5. EFFECT OF RECTANGULAR SLIT DGS (RSD):

The parametric analysis for Vary the width of the slit (W_{SL}) is 2mm, 3mm, and 5mm, and the height of the slit H_{SL} is 0.5mm,1.2mm, and 1mm is done for Figure 9. For W_{SL}=3mm is offering a frequency bandwidth of 1.23GHz (4.78GHz – 6.01GHz),590MHz(6.62GHz-7.21GHz), and6.66GHz (7.95GHz - 14.61GHz) with a return loss of -20.69dB at 5.43GHz, -18.83dB at 5.3GHz, -22.33dB at 6.7GHz, and -18.48dB at 13. 84GHz.The return loss plot for different RSD on the QCRPA is presented in Figure 11.

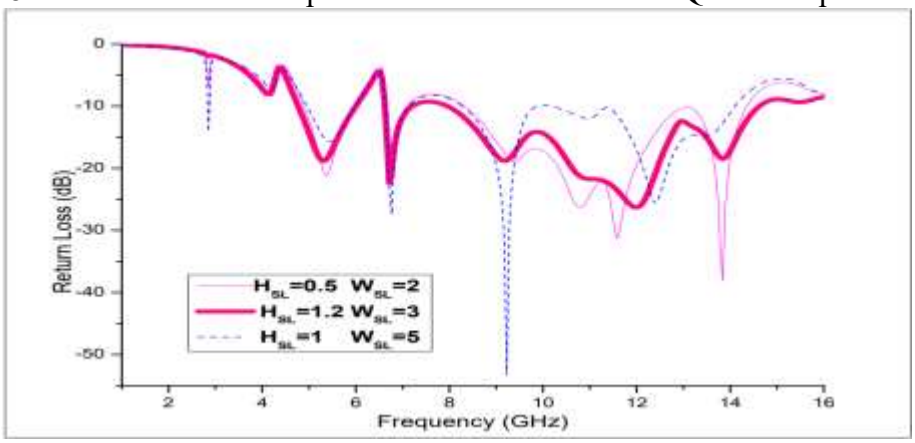


Figure 11. The return loss of different RSD

IV. RESULT AND ANALYSIS

RETURN LOSS:

The proposed QCRPA with RSD is operating with a frequency bandwidth 1.23GHz (4.78GHz – 6.01GHz),590MHz(6.62GHz-7.21GHz), and 6.66GHz (7.95GHz -14.61GHz) and exhibits return loss

of -18.83dB at 5.31GHz, -22.33dB at 6.7GHz, and -18.48dB at 13.84GHz. The return loss plot for the proposed antenna is presented in Figure 12.

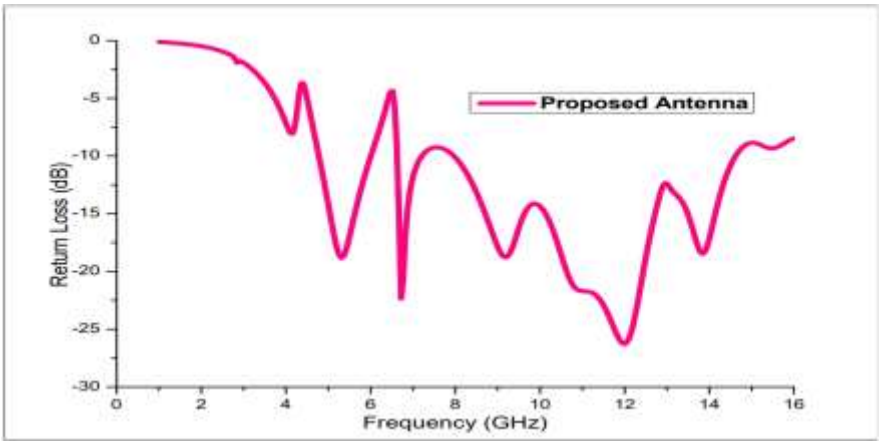
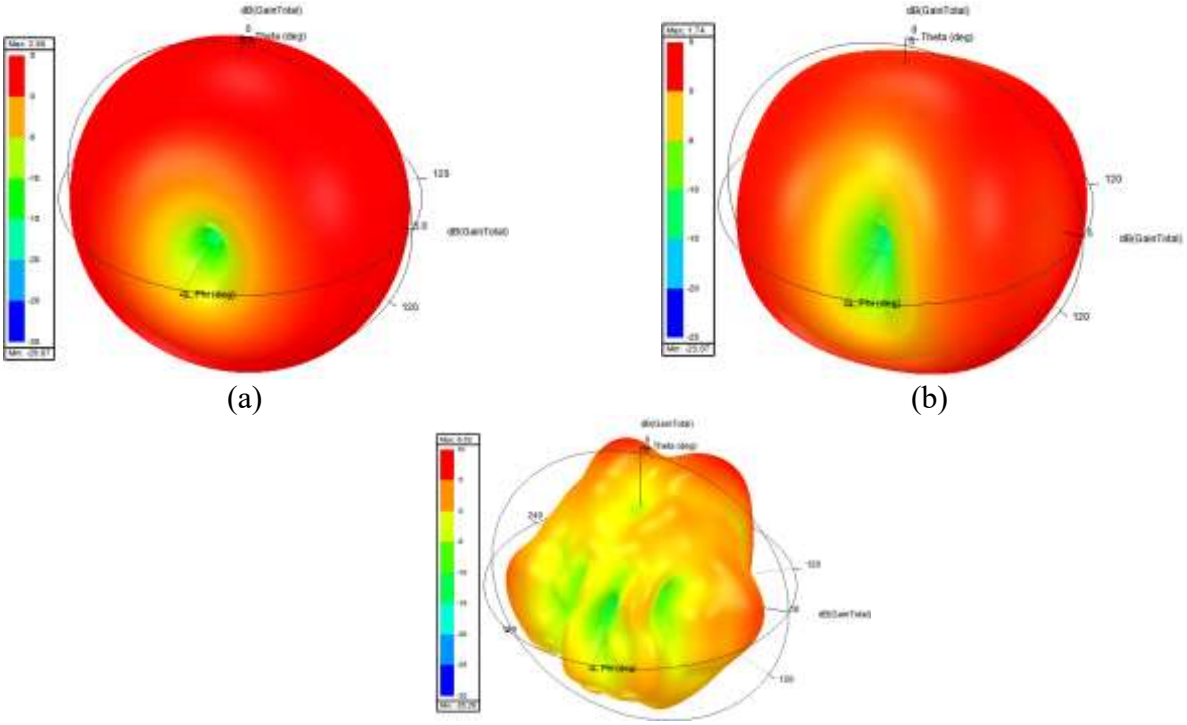


Figure 12. The simulated return loss plot of the proposed antenna design

GAIN:

The gain of the proposed QCRPA with RSD is achieved with 2.88dBi at 5.31GHz,1.74dBi at 6.71GHz, 4.24dBi at 9.38GHz,4.95dBi at 11.79GHz, and 6.03dBi at 13.84GHz respectively. The gain plot of QCRPA with RSD is presented in Figure 13(a-c).



(a) (b)

(C)

Figure 13. Gain plot at (a) 5.31GHz, (b) 6.71GHz, and (c)13.84GHz

RADIATION PATTERN:

The simulated far-field patterns of the proposed Quadruple circular ring patch antenna (QCRPA) with rectangular slit DGS(RSD) of both E- plane and H-planes are presented in Figure 14(a-c) respectively.

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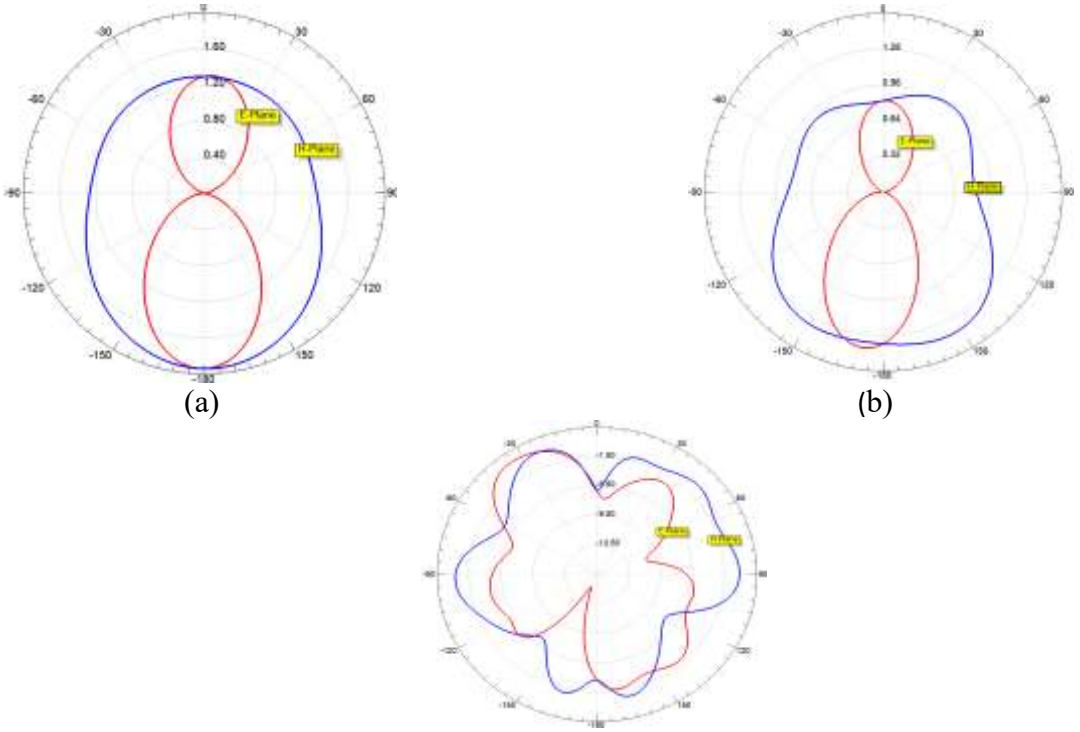


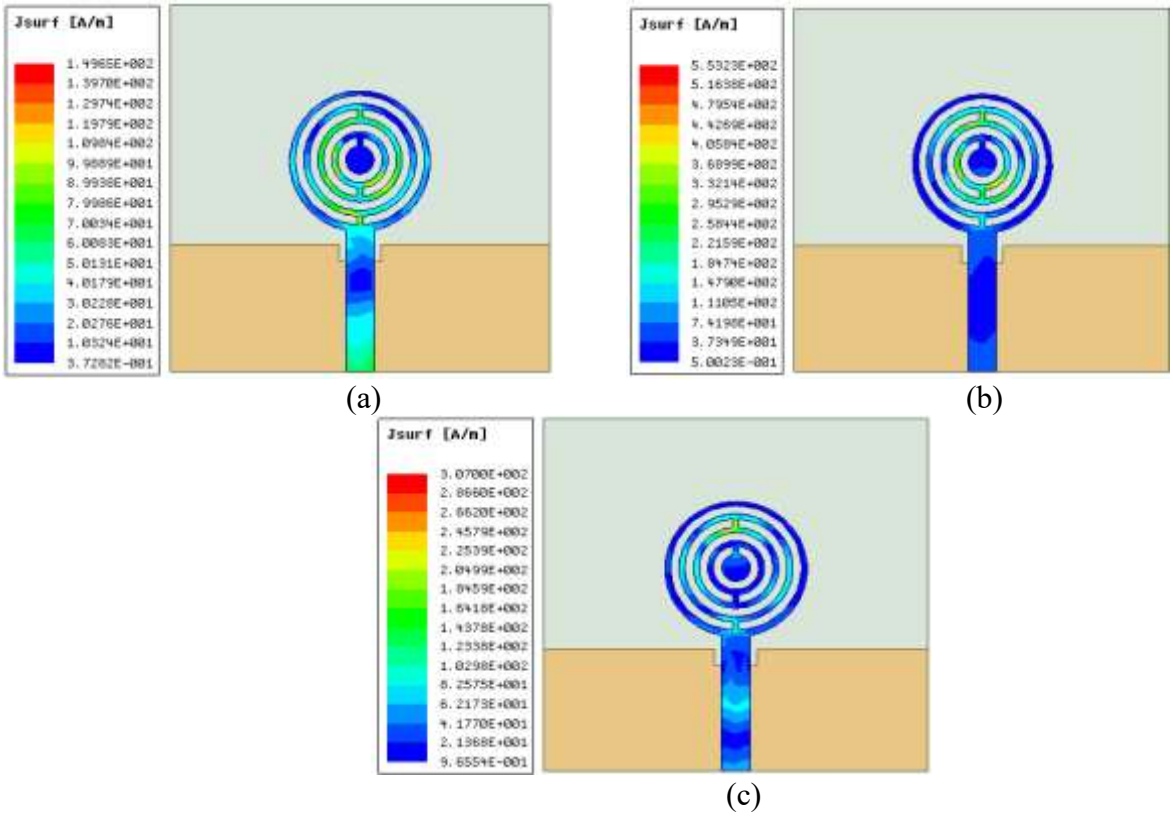
(a) (b)

(c)

Figure 14. E-plane and H-plane radiation patterns at (a) 5.31GHz, (b) 6.71GHz, and (c)13.84GHz

SURFACE CURENT DISTRIBUTION:

The surface current distribution of the proposed QCRPA with rectangular slit DGS is operating at 5.31GHz,6.71GHz, and 13.84GHz is presented in Figure 15(a-c) respectively.



(a) (b)

(c)

Figure 15. The surface current distribution of the proposed antenna at (a) 5.31 GHz, (b) 6.71 GHz, and (c)13.84GHz

V. CONCLUSION

Proposed Antenna	Operating frequencies in (GHz)	Bandwidth	Peak Gain (dBi)
CPA	12.45 to 15.80	3.35GHz	5.13
QCRPA	9.92 to 10.04 12.14 to 12.58 14.34 to 14.78 16.10 to 16.66	120MHz 440MHz 440MHz 560MHz	5.36
QCRPA WITH DGS	4.89 to 5.93 6.73 to 7.06 8.43 to12.60 13.34 to 14.31	1.04GHz 330MHz 4.17GHz 970MHz	5.61
QCRPA WITH RSD	4.78 to 6.01 6.62 to 7.21 7.95 to 14.61	1.23GHz 590MHz 6.66GHz	6.03

Table 2. Comparison of performance parameters of the proposed antennas

In this paper, A Triple-band CPA with circular rings and DGS is proposed. A CPA with QCRPA is offering a bandwidth of 120MHz(9.92GHz-10.04GHz),440MHz(12.14GHz12.58GHz) 440MHz(14.34GHz-14.78GHz), and 560MHz (16.10GHz - 16.66GHz) and offering a peak gain of 5.33dBi at 12.33GHz. The proposed antenna with a rectangular slit DGS(RSD) operates over a frequency range of 4.78GHz to 6.01GHz, 6.62GHz to 7.21GHz, and 7.95GHz to 14.61GHz with a corresponding bandwidth of 1.23GHz, 590MHz, and 6.66GHz respectively. The peak gain offered is 6.03dBi at 13. 8GHz.It operates in C, X, and Ku bands. It is used in satellite and radar applications.

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