RECTANGULAR PATCH ANTENNA WITH RECTANGULAR CUTS AND SLOTS FOR SATELLITE COMMUNICATION APPLICATIONS

Konuru Sainath, PG Scholar, Department of ECE, JNTUA College of Engineering Pulivendula, A.P, India.
R Ramana Reddy, Professor, Department of ECE, JNTUA College of Engineering Pulivendula, A.P, India.

Abstract: A rectangular patch antenna with cuts and slots is proposed in this paper with a wide bandwidth suitable for satellite communication applications. The proposed antenna dimensions are $18.5 \times 21.8 \times 1.6$ mm^3 and patch dimensions are 8.9×12.2 mm^2. The proposed antenna is a wideband antenna, resonating at 4.49 GHz, 7.10 GHz, 12.56 GHz, and 14.91 GHz with a bandwidth of 60 MHz (4.46-4.52 GHz), 310 MHz (6.95-7.26 GHz), 2010 MHz (10.97-12.98 GHz) and 1130 MHz (14.25-15.44 GHz) respectively. Incorporation of rectangular DGS the proposed antenna offers a wide band with a bandwidth of 5.84 GHz (10.63-16.47 GHz) with a peak gain of 3.44 dBi. The proposed antenna is operating in the Ku band useful for satellite communication applications. Simulations are carried out using Ansys HFSS software.

Keywords: Rectangular Patch (RP), Rectangular Cut (RC), Slot, Defective Ground Structure (DGS).

I. Introduction

Ranging from complex phased arrays to the light weighted Body Worn Antenna (BWA) the military and navy systems require antennas with wideband to gather information across a broad spectrum of frequencies. A meta surface-based antenna has a high gain, large bandwidth, and low profile is presented. A crossed slot in the modified square patch is used to obtain large bandwidth [1]. An ultra-wideband (UWB) uniplanar antenna with unidirectional radiation is reported. Modifying a U-Shaped reflector to enhance the ratio of F/B in the lower band [2]. A miniaturized fractal butterfly antenna with a new structure provides high gain and wide bandwidth is utilized in several applications such as chemical and explosive detection, medical imaging tumour, and cancer cell detection is presented [3]. For UWB and multiband applications microwave and mm-wave antennas are presented. To obtain notches and multiband applications in millimetre waves, the conventional ground is swapped out for the ground of a variety of patches and mushrooms [4].

An antenna with triband based on CSRR loading is presented. The antenna covers three operating bands for IEEE 802.11p, WiMAX, and WLAN applications by CSRR etching out from an inverted L Shaped monopole ground and changing feeding line geometry [5]. For UWB applications, a compact differential slot antenna is presented. The suggested antenna consists of a transverse structure that connects different feed lines to a CSRR slot. Throughout the full transmitting UWB, this antenna exhibits strong common mode rejection [6]. The Swastik slotted hexagonal patch antenna (SSHPA) with metamaterials based on CSRR and SSHPA works in Ku and K bands. The same antenna with meta metamaterial operates in X, Ku, and K bands presented [7]. A novel dual-polarized reflector array is introduced to cover two distinct frequency bands, and the architecture offers very small cell sizes and thin layer structures [8]. A magnetoelectric (ME) dipole antenna with wideband and pattern reconfiguration on the E-plane is presented. The radiation patterns of the ME-dipole antenna can switch between three distinct states due to the division of each arm of the electric dipole into three parts that are connected in series by twelve PIN diodes that are connected to a basic biasing network [9].
An antenna design consisting of a tuning fork fractal structure for CP radiation is presented. The 3rd iterative fractal DGS CP antenna is simulated [10]. A double band and dual circular polarized radial

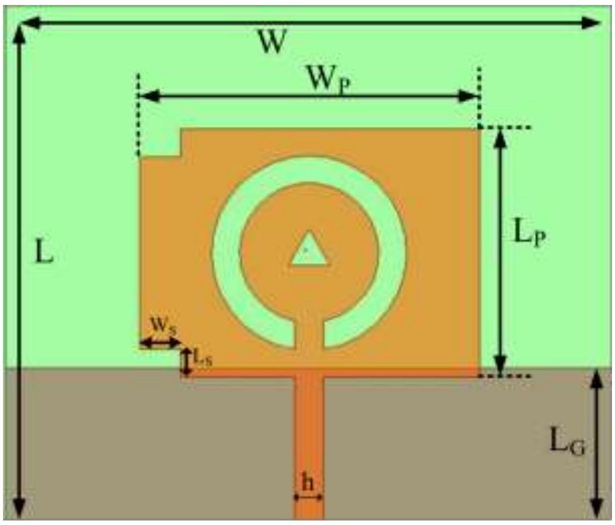
line slot antenna fed by a broadband feeding network is presented. The fundamental benefit of this antenna is that it maintains a low profile, high efficiency, and low axial ratio [11]. A 5G millimeter wave band antenna array miniaturization design is reported. The EBG-ground antennas are mounted side by side with good matching, lower mutual coupling, and effective radiation. It is compatible with mobile terminals that support 5G mm-Wave communication [12]. For WLAN applications, a miniaturized double-band monopole antenna has been presented. The non-uniform folded meander line's fundamental and higher-order modes are excited to produce its lower and upper bands [13].

Dual Asymmetric L-slot cylindrically coupled DRAs for multiband applications are proposed. Three bands obtained for DRA-1 in those second band is operated at CP mode. Four bands obtained for DRA-2 in those third and fourth bands are operated at CP mode [14]. A planar dual-LP antenna consisting of concentrically arranged four dipoles has been reported. To achieve stable radiation performances in the antenna by a simple and compact structure, across a wide bandwidth. A wideband coupler is integrated into the gap between the reflector and the radiators to create a dual-CP antenna based on the dual LP antenna configuration [15]. A new methodology for the electromagnetic characterization of magneto-dielectric materials is reported, and it is based on a novel CSRR sensor. By localizing the magnetic and electric fields in two distinct zones, the ground plane's field distribution is monitored by CSRR [16].

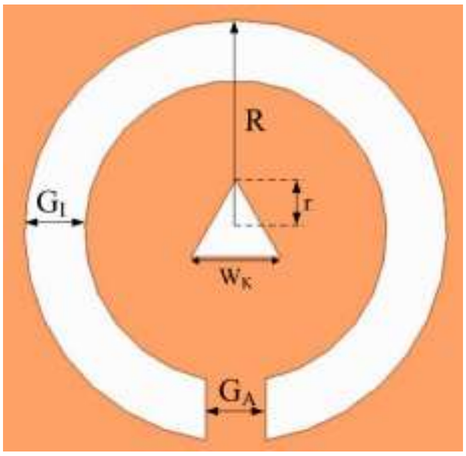
In this paper, a rectangular patch antenna with corner cuts and slots is designed for satellite communication applications. The following sections include the design steps and simulation results of the proposed antenna.

II. Antenna Design

A square patch antenna is proposed with two rectangular cuts, an Inverted C-shaped slot with a triangular slot, and a rectangular DGS. The proposed antenna dimensions are given in Table 1. The radiating element size of the RP antenna is 8.9 x 12.2 mm^2. The geometry of the proposed wideband antenna is shown in Figure 1.



(a)



(b)

Figure 1. Geometrical design of the (a) proposed antenna, (b) Expanded view of the slots.

Table 1. Dimensions of the proposed antenna with rectangular DGS.

Parameter	**Values (mm)**	**Parameter**	**Values (mm)**
W	21.8	**L**	18.5
W_P	12.2	**L_P**	8.9
W_S	1.5	**L_S**	1
L_G	5.5	**h**	1
R	3.5	**r**	0.85
G_A	1	**G_I**	1
W_K	1.47		

The following session discussed the evolution procedure and parametric analysis of the proposed antenna.

III. Evolution of proposed antenna with parametric analysis

RP antenna with rectangular cuts at the corners is presented in Figure 2(a-d). Effects of the rectangular cuts on the RP antenna are analyzed and the corresponding return loss plots are presented in Figure 3.

3.1 Effect of Rectangular cuts

(a) (b)

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Figure 2. RP antenna with a rectangular cut at (a) single corner (b) double corner (c) triple corner (d) quadruple corner.

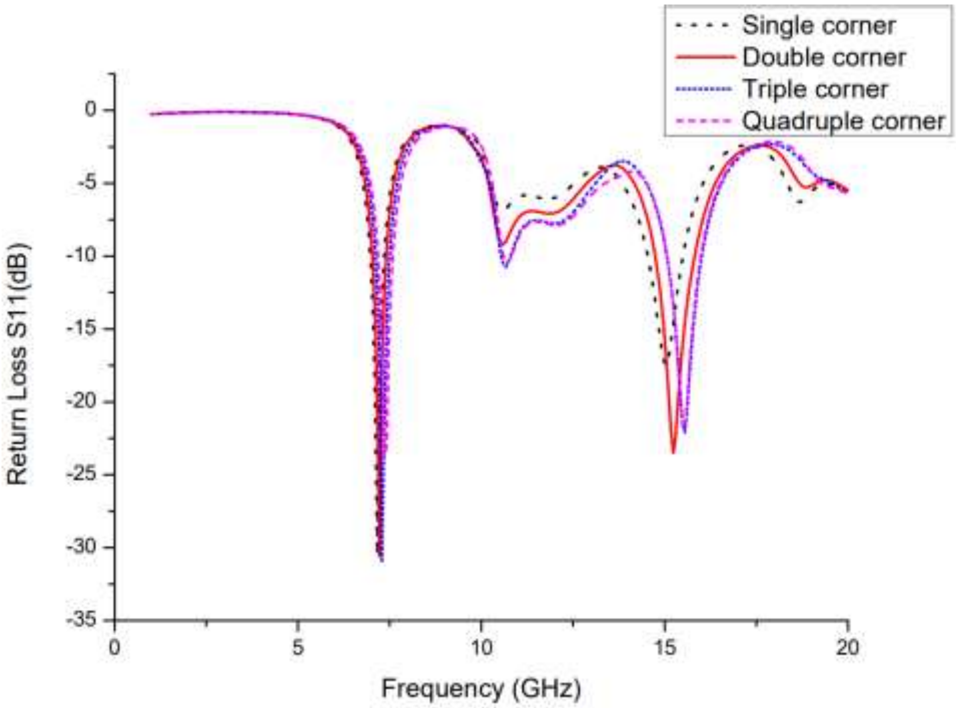

Figure 3. Return loss of RP antenna rectangular cuts.

The dimension of all corner cuts is done with similar cuts 1 x 1.5 mm^2. When a single rectangular cut is made on the bottom left corner as shown in Figure 2(a), the antenna offers dual bands at 6.97-7.35 GHz and 14.54-15.50 GHz with bandwidths of 380 MHz and 960 MHz respectively. The gain obtained is 5.50 dBi and 4.22 dBi at 7.16 GHz and 15.04 GHz. When two rectangular cuts are made on the bottom-left and top-left corners as shown in Figure 2(b), the antenna offers dual bands at 7.03-7.41 GHz and 14.74-15.82 GHz with bandwidth 380 MHz and 1080 MHz respectively. The gain obtained is 5.51 dBi and 5.19 dBi at 7.22 GHz and 15.23 GHz. When triple rectangular cuts are made on the bottom-left, top-left, and top-right corners, as shown in Figure 2(c), the antenna offers three bands at 7.11-7.50 GHz, 10.54-10.80 GHz and 15.06-16.01 GHz with bandwidth390 MHz, 260 MHz and 950 MHz respectively. The gain obtained is 5.50 dBi, 4.87 dBi, and 3.62 dBi at 7.29 GHz,10.65 GHz, and 15.55 GHz. When four rectangular cuts are made on all four sides of the RP as shown in Figure 2(d), the antenna offers three bands at 7.18-7.59 GHz, 10.60-10.82 GHz, and 15.06-15.98 GHz with bandwidth410 MHz, 220 MHz, and 920 MHz respectively. The gain obtained is 5.49 dBi, 4.93 dBi, and 3.48 dBi at 7.35 GHz,10.72 GHz, and 15.55 GHz.

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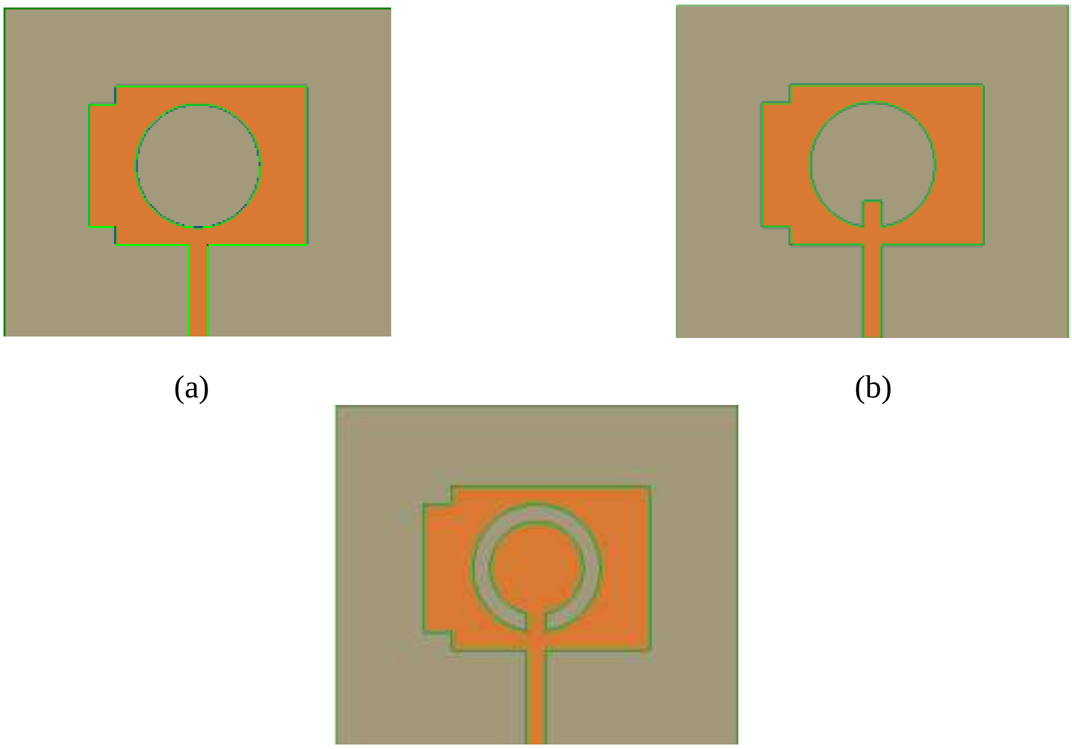
The results obtained when rectangular cuts made at 2 corners have better bandwidth and gain compared to other rectangular cut antennas. Variations in return losses are compared.

3.2 Effect of circular slots on rectangular cut rectangular patch antenna.

To study the effect of slots on Rectangular Cut Rectangular Patch (RCRP) antenna with three types of slots there are circle cut, a circle with a strip, and an inverted C-Shaped cut are considered as shown in Figure 4(a-c).



(a) (b)

(c)

Figure 4. corner cut RP antenna with a) Circle cut, b) Circle with strip, c) inverted C-Shaped cut.

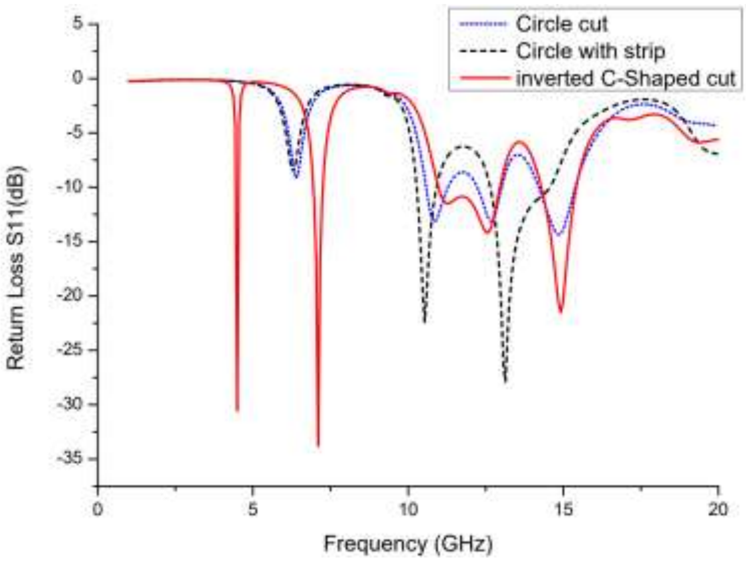


Figure 5. Return loss of circular slots.

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The return loss plots of the RCRP antenna with different slots are presented in Figure 5. When a circular cut is made on the patch as shown in Figure 4(a), the antenna offers triple bands at 10.58-11.29 GHz, 12.23-13.01 GHz, and 14.21-15.38 GHz with bandwidths 710 MHz, 780 MHz, and 1170 MHz respectively. The gain obtained is 5.35 dBi, 4.90 dBi, and 4.75 dBi at 10.84 GHz,12.69 GHz, and 14.85 GHz. When a circular cut with a strip is made on patch shown in Figure 4(b), the antenna offers dual bands at 10.28-10.91 GHz and 12.65-14.57 GHz with bandwidth 630 MHz and 1920 MHz respectively, the gain obtained is 4.97 dBi and 4.68 dBi at 10.53 GHz and 13.13 GHz. The Rectangular Cut Rectangular Patch antenna with inverted C-Shaped Slot (RCRPCS) as shown in Figure 4(c), offers four bands at 4.45-4.54 GHz, 6.95-7.26 GHz,10.97-12.96 GHz and 14.29-15.42 GHz with bandwidth 90 MHz, 310 MHz,1990 MHz and 1130 MHz respectively. The gain obtained is 5.22 dBi, 5.26 dBi, and 3.65 dBi at 7.10 GHz,12.56 GHz, and 14.91 GHz.

(a) (b)

Figure 6. a) RCRPCS antenna with triangle slot, b) RCRPCS with Diamond slot.

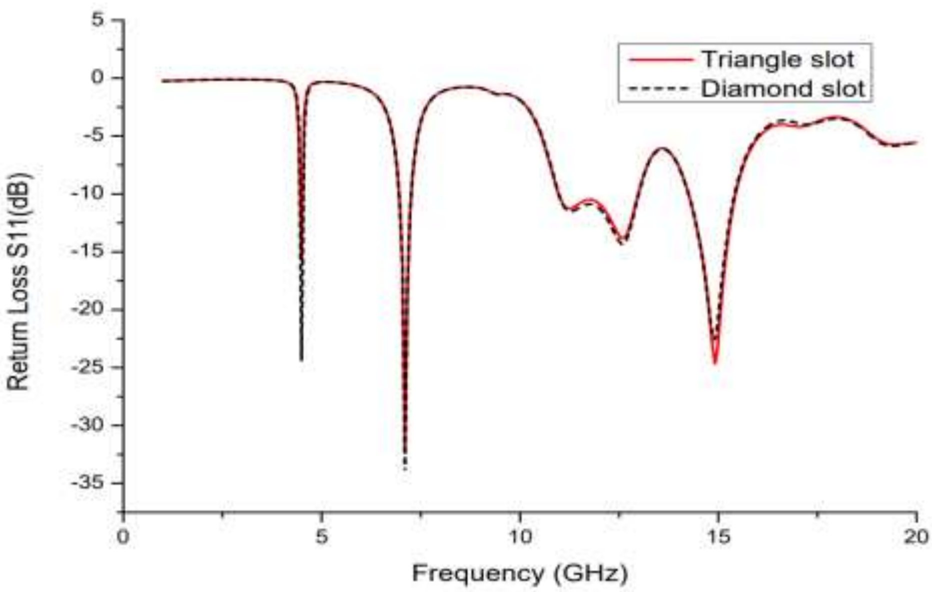


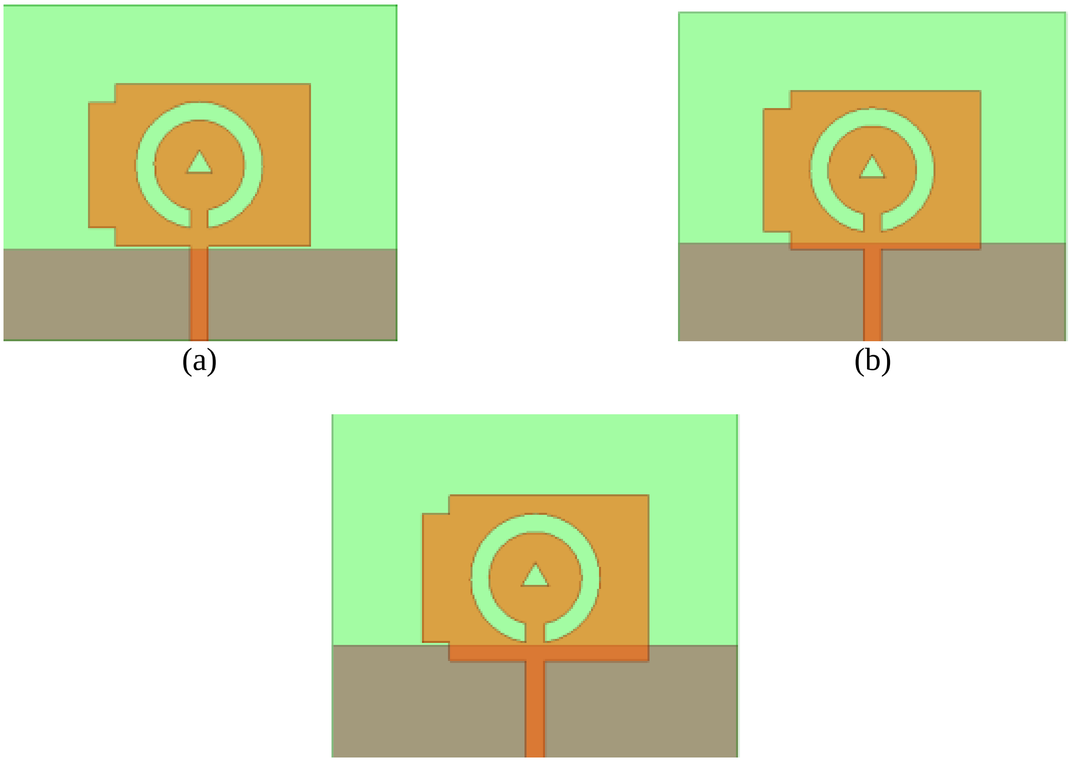
Figure 7. Return loss of a) RCRPCS antenna with triangle slot, b) RCRPCS with diamond slot.

The return loss of the triangle and diamond-shaped slots in RCRPCS antennas is presented in Figure 7. When a triangular slot is incorporated shown in Figure 6(a), the proposed antenna with a triangular slot offers four bands at 4.46-4.52 GHz, 6.95-7.26 GHz, 10.97-12.98 GHz, and 14.25-15.44 GHz with bandwidth 60 MHz, 310 MHz, 2010 MHz and 1190 MHz respectively. The gain obtained is 5.24 dBi, 5.28 dBi, and 3.85 dBi at 7.10 GHz,12.56 GHz, and 14.91 GHz. When a diamond-shaped slot is made on patch shown in Figure 6(b), the proposed antenna offers four bands at 4.45-4.54 GHz, 6.95-7.26

GHz, 10.98-12.99 GHz, and 14.25-15.41 GHz with bandwidth 90 MHz, 310 MHz,2010 MHz and 1160 MHz respectively. The gain obtained is 5.23 dBi, 5.23 dBi, and 4.08 dBi at 7.10 GHz,12.56 GHz, and 14.91 GHz.

3.3 Effect of DGS

DGS is creating a defect in the ground to disrupt the current flow in the antenna, using the suitable structures and shapes we can modify the antenna performance parameters like operating frequency bandwidth and gain.



(a) (b) (c)

Figure 8. a) L_G =5 mm, b) L_G =5.5 mm, and c) L_G =6 mm.

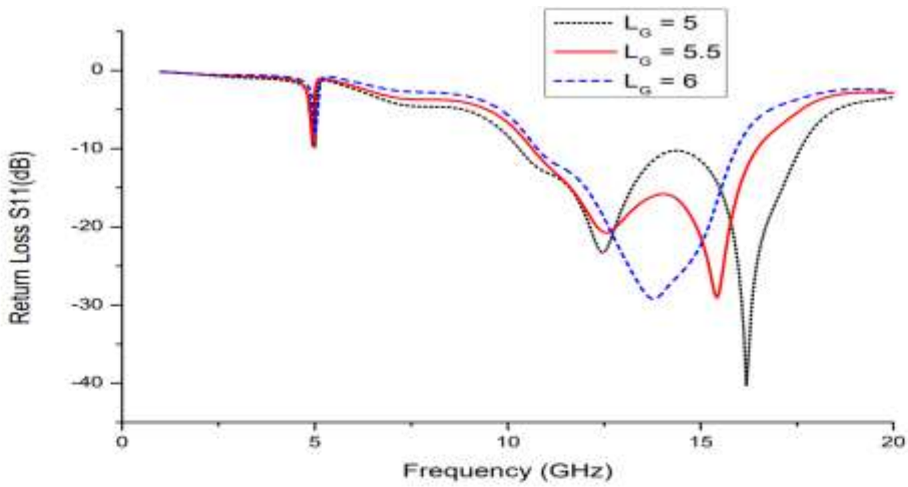


Figure 9. Return loss of variations in L_G.

The return loss plots of the RCRPCS antenna by varying lengths of ground (L_G) as shown in Figure 9. When L_G = 5 mm as shown in Figure 8(a), the antenna offers single bands at 10.29-17.59 GHz with bandwidth 7.3 GHz respectively. When L_G = 5.5 mm shown in Figure 8(b), the antenna offers a single band at 10.63-16.47 GHz with a bandwidth of 5.84 GHz respectively. When L_G = 6 mm as shown in Figure 8(c), offers a band at 10.76-15.93 GHz with a bandwidth of 5.17 GHz respectively.

IV. Results and analysis

The simulated return loss (|S11|) of the antenna is shown in Figure 10.

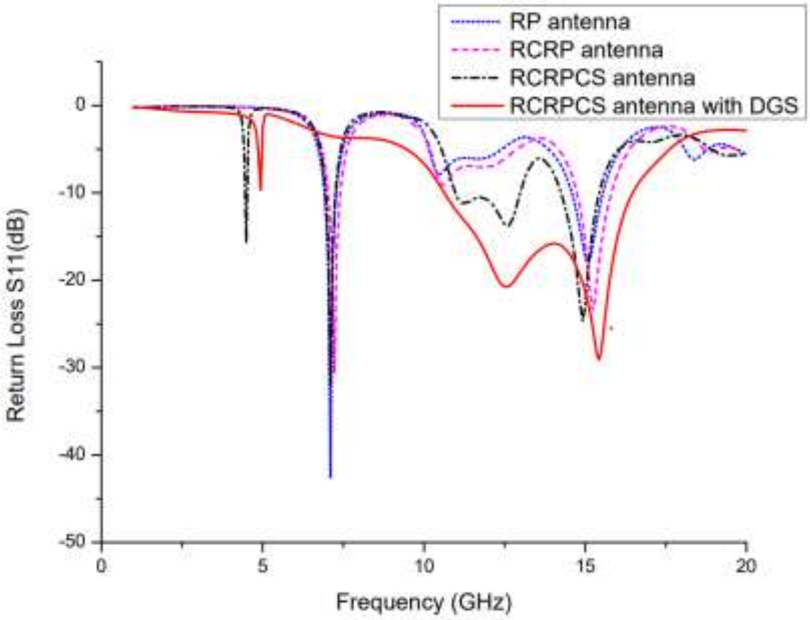


Figure 10. Return loss of the proposed antenna.

RP antenna offers dual bands at 6.91-7.28 GHz and 14.58-15.55 GHz with bandwidths of 370 MHz and 970 MHz respectively. The gain obtained is 5.48 dBi and 4.30 dBi at 7.10 GHz and 15.10 GHz respectively. The RCRP antenna shown in Figure 2(b), offers a double band at 7.03-7.41 GHz and 14.74-15.82 GHz with bandwidths of 380 MHz and 1080 MHz respectively. The gain obtained is 5.51 dBi and 5.19 dBi at 7.22 GHz and 15.23 GHz. RCRPCS antenna with triangle slot shown in Figure 6(a), offers four bands at 4.46-4.52 GHz, 6.95-7.26 GHz, 10.97-12.98 GHz, and 14.25-15.44 GHz with bandwidth 60 MHz, 310 MHz, 2010 MHz and 1190 MHz respectively. The gain obtained is 5.24 dBi, 5.28 dBi, and 3.85 dBi at 7.10 GHz, 12.56 GHz, and 14.91 GHz. RCRPCS antenna with triangle slot and rectangular DGS as shown in Figure 8(b), offers a wide band at 10.63-16.47 GHz with a bandwidth of 5.84 GHz respectively. The gain obtained is 3.44 dBi at 15.42 GHz. The proposed antenna operated in the Ku band. The return loss of the above-discussed antennas proposed by two rectangular cuts and inverted C slot antennas with DGS is presented in Figure 10. A comparison of the performance parameters of the proposed antennas is shown in Table 2.

As shown in Figure 11 gain of the RCRPCS antenna with a triangle slot and rectangular DGS is 3.44 dBi at a frequency of 15.42 GHz.

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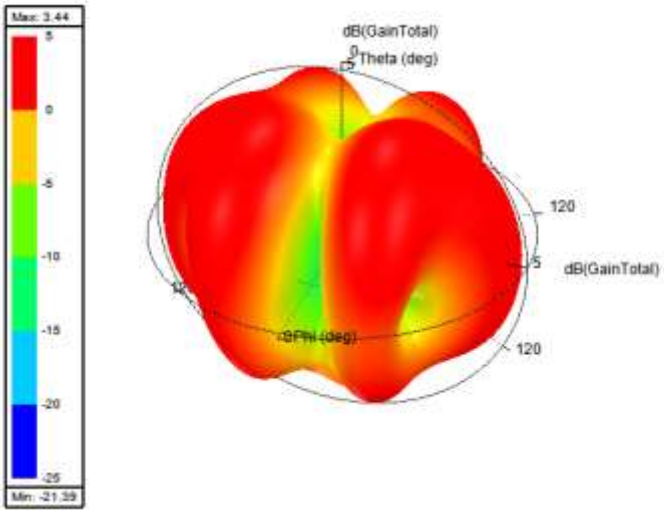

Figure 11. Gain plot at 15.42 GHz

The proposed antenna E plane and H plane patterns at 15.42 GHz are shown in Figure 12.

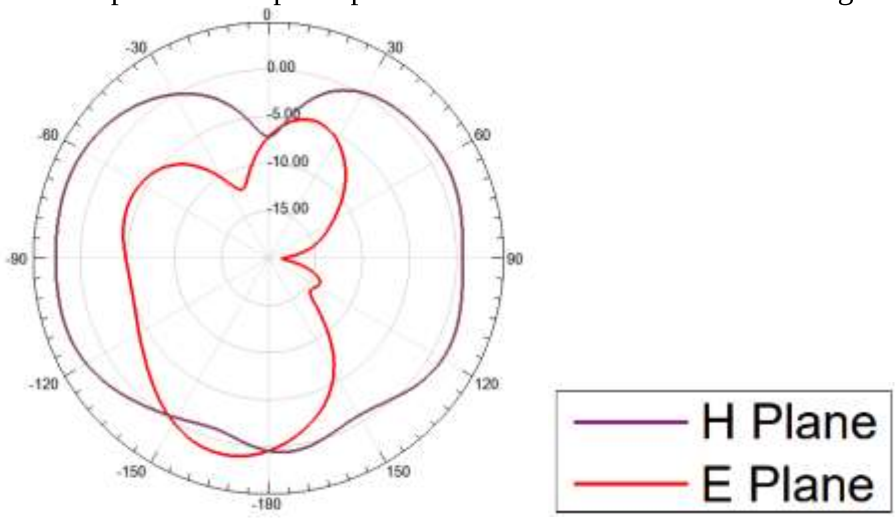

Figure 12. E plane and H plane patterns at 15.42 GHz.

Table 2. Comparison of performance parameters of the proposed antennas.

Proposed Antenna	**Bandwidth and operating frequencies**	**Gain (dBi)**
RP antenna	6.91-7.28 GHz 14.58-15.55 GHz	5.48 at 7.10 GHz 4.30 at 15.10 GHz
RCRP antenna	7.03-7.41 GHz 14.74-15.82 GHz	5.51 at 7.22 GHz 5.19 at 15.23 GHz
RCRPCS antenna with Triangle slot	4.46-4.52 GHz 6.95-7.26 GHz 10.97 - 12.98 GHz 14.25-15.44 GHz	5.24 at 7.10 GHz 5.28 at 12.56 GHz 3.85 at 14.91 GHz
RCRPCS antenna with Triangle slot and rectangular DGS	10.63-16.47 GHz	3.44 at 15.42 GHz

V. Conclusion

In this paper, a rectangular cut rectangular patch antenna with an inverted circular C-Shaped slot is proposed for a wide band operating in Ku-band. The peak gain obtained at 15.42 GHz is 3.44 dBi respectively. Bandwidth and return loss are improved by applying rectangular DGS to the RCRPCS antenna with a triangular slot suitable for satellite communication applications.

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