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DESIGN AND ANALYSIS OF SPLIT RING RESONATOR BASED MICROSTRIP PATCH ANTENNA FOR X-BAND APPLICATIONS

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Abstract
In this paper, a microstrip patch antenna for X band application is proposed and designed. The proposed antenna is designed with slots in order to achieve the narrow bandwidth. The FR4 substrate with the thickness of 0.8mm is employed in this design. The proposed antenna resonates at 11.2GHz with the return loss and voltage standing wave ratio of -29.5288dB and 1.005, respectively. The dimension of the antenna is 10mm and 7.7mm. Slots are taken in this design in order to enhance the bandwidth. The slots are used in the shape of split ring resonator with the radius of 0.85mm and 1.25mm for inner ring and outer ring, respectively. The major advantage of the proposed antenna is its compactness and bandwidth.

Keywords:
Microstrip Patch, Split Ring Resonator, Return Loss, FR4, X Band, Narrow Band

1. INTRODUCTION

Communication between two different places has been a challenge for mankind since Stone Age. Communication has evolved from smoke signals to today's wireless technology [1]. An antenna plays a vital role in wireless communication. There is a wide range of antenna available for wireless communication like microstrip patch antenna [2], reflector antenna [3], aperture antenna [4], travelling wave antenna [5], vertical antenna [6] and etc. Even then microstrip patch antenna guarantees low profile, compact and affordable manufacturing for real time applications [7]. These antennas are often mounted on the exterior of aircraft and spacecraft, or are incorporated into mobile radio communications devices. These antennas can be developed light weight, low volume, low manufacture cost and can be effortlessly coordinated with Microwave Integrated Circuits (MICs). However, microstrip patch antennas possess a major threat of narrow bandwidth and low gain, which can be enhanced by using slot techniques [8].

Slotting is one of the best strategies used to build up the execution of microstrip patch antenna. Utilizing particular shape of slot, the execution has been upgraded in terms of gain, bandwidth, directivity and size reduction. The length and position of a specific slot may influence the impedance and bandwidth of antenna. By stacking appropriate slots along the radiating edges of a patch the bandwidth of patch antenna is made strides [9]. Narrow band alludes to information correspondence and broadcast communications devices, advancements and administrations that use a narrower set or band of frequencies in the correspondence channel. These use the channel frequency that is viewed as level or which will utilize a lesser number of frequency sets. The microstrip antenna is mostly used for satellite communications, direct broadcast television, missile systems and military purposes. This antenna provides huge advantages of printed circuit board and it has some limitations such as low efficiency, low gain and low bandwidth [10]. The microstrip feed line is one of the less demanding strategies to manufacture as it is a simply leading strip associating with the patch and in this manner can be consider as expansion of the patch. It is easy to model and simple to coordinate by controlling the inset position.

The X band is a section of the microwave radio area of the electromagnetic range. At times, for example, in correspondence designing, the recurrence scope of the X band is fairly inconclusively set at roughly 7.0 to 11.2GHz. In radar designing, the frequency range is indicated by the IEEE standards at 8.0 to 12.0GHz. Generally, the X-band is used for radar, satellite communication, wireless computer networks and Terrestrial communications and networking.

It is essentially utilized by the military and radar applications including continuous-wave, pulsed, single-polarization, dual-polarization, synthetic aperture radar and phased arrays [11].

In the literature, there are numerous techniques is employed to design the microstrip antenna with multiband [12], dual band [13] and broad band properties [10] to analyze the functional parameters such as return loss, gain and bandwidth. The antenna was designed with different shapes namely T-shaped microstrip patch antenna [14], Rectangular, Circular and Triangular shaped antenna [15], P-shaped resonator [16], Triangular microstrip patch antenna [17], Polygon patch antenna [18], W-shaped microstrip patch antenna [19] and it is used in various applications such as wireless communication system [13], Satellite communication [18], [19] and WLAN or WiMax [20]. Further, fractal antenna [21], array antenna [22], dielectric resonator antenna [23] is developed recently for WLAN applications. From the reported papers, it is investigated that the return loss is low; the bandwidth is wider and also bigger in size for chosen of frequency band and structure of antennas. In order to mitigate aforementioned issues, in this attempt circular Split Ring Resonator (SRR) based microstrip patch antenna is proposed and designed.

In this paper, a microstrip patch antenna based on split ring resonator is proposed and designed for X band applications. The designed microstrip patch antenna consists of both slot and splits which are often used as radiating element. This antenna is designed with FR4 substrate with 0.8mm thickness and the width and length of the substrate is 10mm and 7.7mm, respectively. The length and width of the patch are 8.2mm and 6mm, respectively.

This paper organized as follows. Section 2 describes the design calculation of antenna. Section 3 presents structure of proposed antenna. The simulation results of the proposed antenna are given in section 4. Parametric analysis in section 5. Finally, section 6 presented the conclusions.

2. DESIGN CALCULATIONS

For the most part, the execution of microstrip patch antenna relies on upon its measurements. The measurements relying on the working frequency, and parameters, for example, gain, directivity, radiation pattern and VSWR. In microstrip patch antenna, the width and length are most vital parameters which are ascertained as takes after [24].

Width of the Patch Antenna

$$W = \frac{c}{2 f_r \sqrt{\frac{(\varepsilon_r + 1)}{2}}} \tag{1}$$

where, c = speed of light=3*10^{8}m/s, ε_r = dielectric constant = 4.4 and f_r = resonant frequency = 11.2GHz

$$W = 8.2\text{mm}$$

Actual Length of Patch

$$L = L_{eff} - 2\Delta L = 5.3614\text{mm} \tag{2}$$

Effective Length of the Patch Antenna

$$L_{eff} = \frac{c}{2 f_r \sqrt{\varepsilon_r}} = 6\text{mm} \tag{3}$$

where, c = speed of light=3*10^{8}m/s, f_r = resonant frequency = 11.2GHz, ε_r = dielectric constant = 4.4.

Extension of the Length

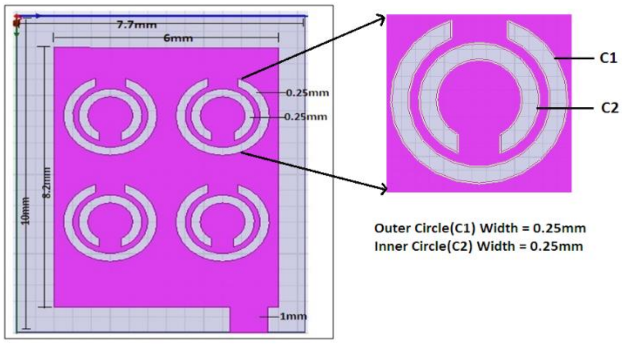
$$\Delta L = 0.412h \frac{(\varepsilon_{reff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{w}{h} + 0.8\right)} = 0.31918\text{mm} \tag{4}$$

where, ΔL = extension of the length, h = thickness of substrate = 0.8mm, w = width of antenna = 8.2mm and ε_{reff} = effective dielectric constant = 4.4.

From the above Eq.(1), Eq.(2), Eq.(3) and Eq.(4), the width (W), extension length (ΔL), actual length (L) and effective length (L_{eff}) of the patch antenna is calculated which are 8.2mm, 0.31918mm, 5.3614mm and 6mm, respectively. The aforementioned calculated values are employed in the proposed work.

3. ANTENNA DESCRIPTION

The Fig.1(a) shows the schematic representation of proposed microstrip antenna and the sectional view of circular SRR is depicted in Fig.1(b). Four similar SRR slots are used in the patch. The FR4 substrate is used with the dimension of 10mm width and 7.7mm length. The patch dimension is calculated for the operating frequency using the respective formula which gives the dimension as 8.2mm of width and 6mm of length. The thickness of the substrate is chosen as 0.8mm with the loss tangent of 0.02. Microstrip feeding technique is used in the design with the thickness of 1mm. All the four SRR slots have uniform dimensions. The circular SRR is composed two circles namely inner circle and outer circle. The thickness of inner and outer circle is same, 0.25mm.

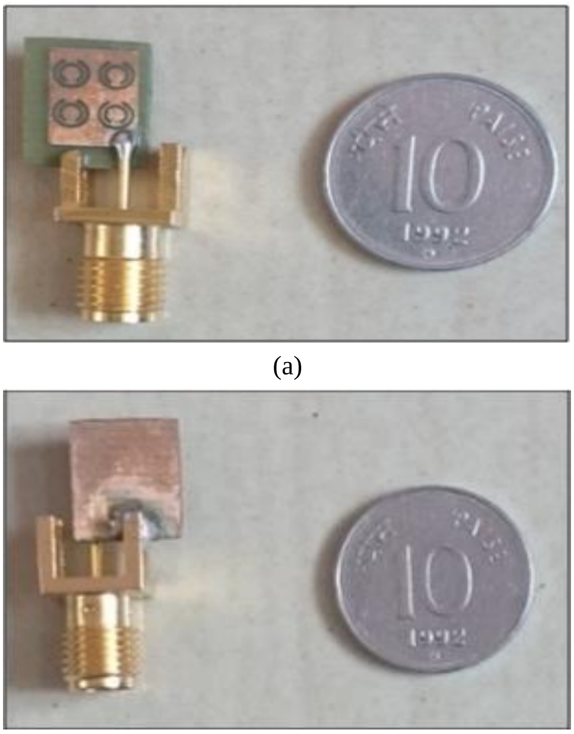


(a) (b)

Fig.1. Schematic representations of (a) proposed microstrip patch antenna and (b) circular split ring resonator

Table.1. Structural details of microstrip patch antenna

Particulars	Size
Feed width	1mm
Outer and Inner Circle radius	1.25mm and 0.85mm
Outer and Inner Circle Width	0.25mm and 0.25mm
Patch Width and Length	8.2mm and 6mm
Substrate Thickness (FR4)	0.8mm
Substrate Width and Length	10mm and 7.7mm



(a)

(b)

Fig.2. Fabricated microstrip patch antenna (a) front view (b) back view

The SRR concept is used in slot in order to enhance the performance of the proposed antenna. The SRR is formed by using two circular rings with on open in each in alternate directions [13], [14]. Shield or cavity around the SRR is used for enhancing the performance. The performance also includes dimensions, material, electrical and mechanical properties. Generally, performance is measured in terms of quality factor of an antenna which is measuring the radiation efficiency of the antenna and resonant frequency [25]. The detailed structural parameters of the proposed SRR based microstrip patch antenna are listed in Table.1. The Fig.2(a) and Fig.2(b) show the front and back view of proposed fabricated antenna which is compared with the size of the small ten paise coin. It seems very small, about 10mm×7mm microstrip patch antenna.

4. RESULTS AND DISCUSSION

The Fig.3 depicts the return loss of microstrip patch antenna. The return loss of proposed antenna with SRR is -29.52dB at 11.2GHz. Generally, the return loss is the ratio of incident power to the reflected power and it denotes the antenna performance.

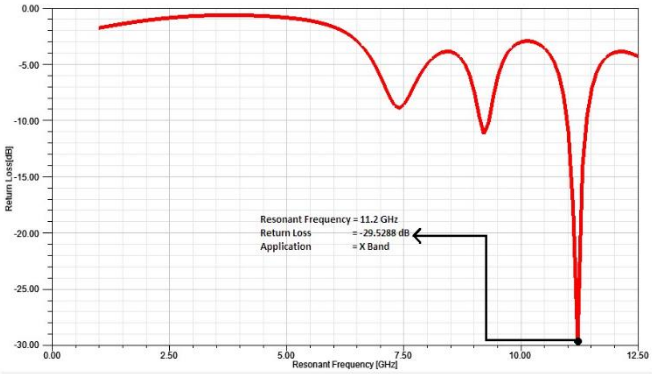


Fig.3. Return loss of the proposed antenna

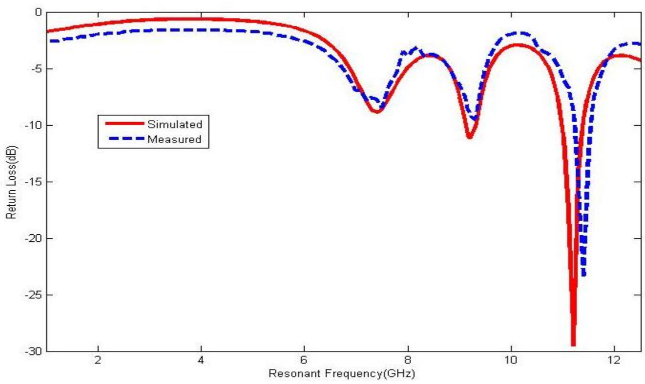


Fig.4. Comparison of return loss of simulated and fabricated antenna

The return loss comparison of simulated antenna and fabricated antenna is shown in Fig.4. The return loss and resonant frequency of the fabricated antenna is 24.17dB and 11.21GHz. It is noticed that there is a trivial variation of return loss and resonant frequency due to the SMA connector and fabrication tolerance.

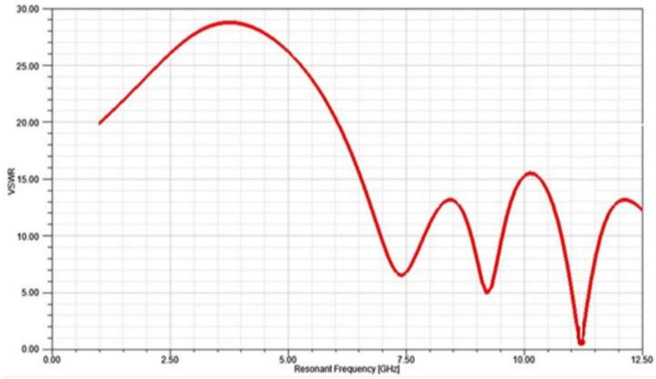


Fig.5. VSWR of the proposed antenna for with SRR

The Fig.5 depicts the VSWR for proposed microstrip patch antenna at the resonant frequency of 11.2GHz. It calculating how well impedance are matched over the operating band. The VSWR of proposed antenna with circular SRR is 1.005 at 11.2GHz.

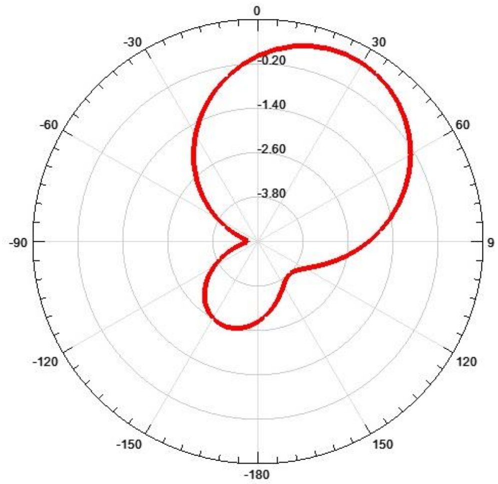


Fig.6. Radiation pattern of proposed antenna

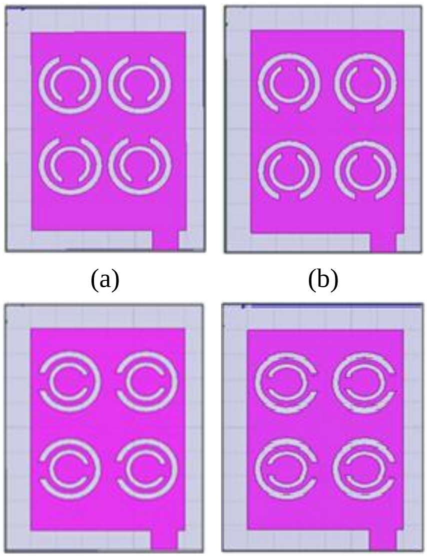
The Fig.6 shows the simulated radiation pattern of proposed antenna at the frequency 11.2GHz. It defines the variation of the power radiated by an antenna as a function of the direction away from the antenna. The proposed microstrip patch antenna can be represents the unidirectional radiation pattern.

5. PARAMETRIC ANALYSIS

In this section, the effect of change of return loss while varying the direction of the SRR is analyzed.

5.1 IMPACT OF SRR DIRECTIONS

The Fig.7(a), Fig.7(b), Fig.7(c) and Fig.7(d) show the schematic representation of proposed antenna with up, down, right and left SRR directions, respectively. The thickness and position of the feed is fixed at 1mm and right for all the SRR directions. The radius of the inner and outer rings is fixed at 0.8mm and 1.25mm, respectively.



(a) (b)

(c) (d)

Fig.7. Schematic representation of proposed antenna with different SRR directions (a) up direction (b) down direction (c) left direction and (d) right direction

The impact of return loss of the proposed antenna while varying the SRR direction is shown in Fig.8. The return loss and resonant frequency are listed in Table.2. From the table, it is clearly stated that there is change in resonant frequency when the direction of SRR is changed. The required frequency of 11.2GHz is obtained with down direction. Hence its accounted.

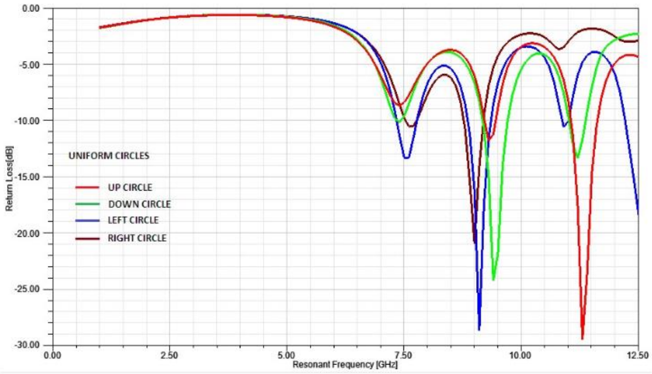


Fig.8. Impact of return loss for different SRR configuration

Table.2. Resonant Frequency and Return Loss of Up, Down, Left and Right Configuration of SRR

SRR Directions	Resonant Frequency (GHz)	Return Loss (dB)
Up	9.4 11.3	-11 -25
Down	9.5 11.2	-24 -29
Left	9.1 10.9	-28.05 -11
Right	9 10.8	-2 -3

5.2 IMPACT OF DOWN CIRCLE DIMENSIONS

The width of inner rings is changed as 0.85mm and 0.8mm and outer rings are changed as 1.25mm and 1.3mm. The variation in return loss for changing the inner and outer circle ring width is shown in Fig.9. The change in return loss and resonant frequency for different dimensions of down circle configurations are listed in the Table.3. It is noticed that the resonant frequency is shifted from its center frequency while varying the thickness of the inner and outer ring. The return loss is varied from -24dB to -29dB and the resonant frequency is shifted from 10.8 to 11.3GHz.

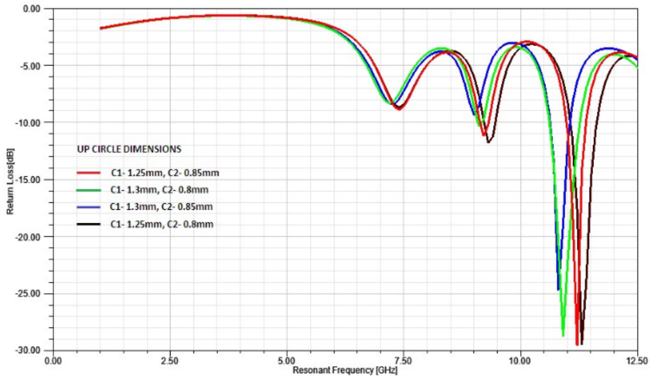


Fig.9. Impact of return loss for up circle dimensions with SRR configuration

Table.3. Resonant Frequency and Return Loss of Up Circle Dimensions of SRR Configuration

Width of SRR rings	Resonant Frequency (GHz)	Return Loss (dB)
C1 - 1.25, C2 - 0.85	11.2	-29
C1 - 1.3, C2 - 0.8	10.9	-28
C1 - 1.3, C2 - 0.85	10.8	-24
C1 - 1.25, C2 - 0.8	11.3	-29

5.3 IMPACT OF UP CIRCLE DIMENSIONS

The impact of return loss while varying the inner and outer ring width for up circle configuration is shown in Fig.10.The return loss and the resonant frequency of the up circle SRR configuration is varying from -24dB to -29dB and 9GHz and 9.8GHz, respectively. It is also noticed that there is a shift in resonant frequency and reduction in return loss is observed.

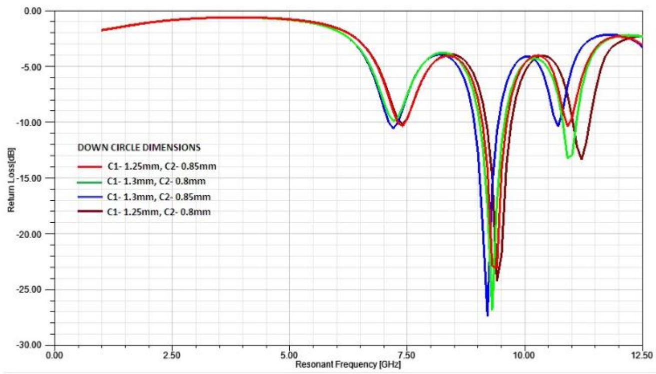


Fig.10. Impact of return loss for down circle dimensions with SRR configuration

5.4 IMPACT OF LEFT CIRCLE DIMENSIONS

The variation in return loss for changing the inner and outer circle width for left circle configuration is shown in Fig.11. The return loss is varied from -24dB to -42dB and its resonant frequency is changed from 8.9 to 9.1GHz. When c1=1.3mm and c2 = 0.85mm, the significant improvement of return loss is about -42dB observed at 9GHz.

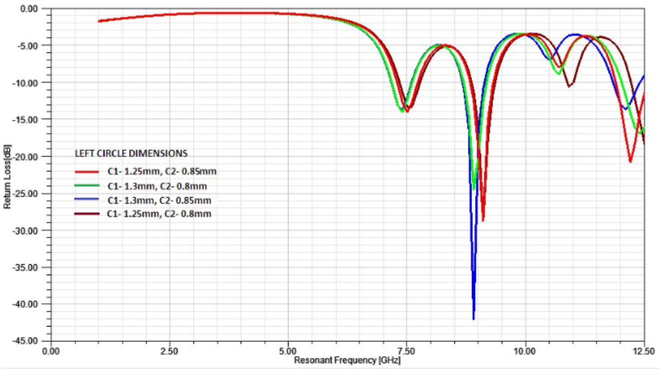


Fig.11. Impact of return loss for left circle dimensions with SRR configuration

5.5 IMPACT OF RIGHT CIRCLE DIMENSIONS

The Fig.12 shows the variation in return loss for changing the inner and outer circle ring width of right circle configurations. The return loss and the resonant frequency of the right circle SRR configuration is varied -16dB to -20dB and 8.7GHz to 9GHz, respectively.

The limitations of the proposed work are low efficiency due to dielectric losses and conductor losses, radiates from feeds and other junction points, narrow bandwidth, radiation efficiency deteriorates as frequency and antenna size, Lower power handling capacity and poor isolation between the feed and the radiating elements.

The functional parameters of reported SRR based antenna is compared with proposed SRR based antenna and it is listed in Table.4. From the Table.4, it is clearly seen that the better return loss performance is attained. And the size of the antenna is also small. The proposed split ring resonator has a compact size and the return loss is good compare than previous work.

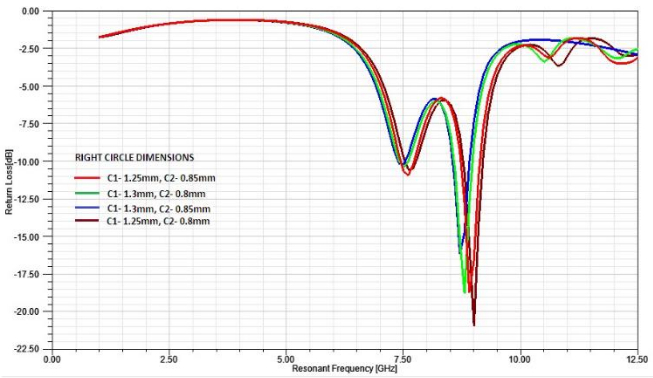


Fig.12. Impact of return loss for right circle dimensions with SRR configuration

Table.4. Comparison of reported work with proposed one

SRR Type	Return Loss	Resonant Frequency	Size	Targeted Applications
Complementary Split Ring Resonator (CSRR) [13]	-22dB	4 to 5GHz	18.43×23.68 mm	Wireless Communications
Metamaterial Split Ring Resonator [14]	-20dB	4.97GHz	7.5×7.5mm	Public Safety Band
Metamaterial Split Ring Resonator	-10dB	3.5GHz	40×40mm	Wireless Communications
Metamaterial Split Ring Resonator	-6dB	3.8GHz	20×20mm	LTE and WiMAX
Complementary Split Ring Resonator (CSRR)	-10dB	5.2GHz	14×14mm	Airborne and Space borne applications
Proposed Split ring resonator (SRR)	-29dB	11.2GHz	10×7.7mm	X band application

6. CONCLUSIONS

In this attempt, a circular split ring resonator based microstrip patch antenna is proposed and designed. The functional characteristics of the proposed antenna namely return loss, VSWR and directivity are investigated. The designed antenna is resonating at 11.2GHz, with the return loss and VSWR of about, -29dB and 1.005, respectively. The measured antenna is resonating at 11.21GHz with return loss of about -24.17dB. The dimension of the proposed antenna is 10×7.7mm. The size of the proposed antenna is small and meets the requirements for X band applications. Hence it could be incorporated for satellite applications.

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