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A Novel Dual Hexagonal SRR Antenna Design for Ku-Band Wireless Applications

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Abstract: This paper presents a design aimed at achieving optimal performance within the designated frequency range of 12GHz to 18GHz.The proposed antenna exhibits low side lobes, high bandwidth, high gain, and good impedance matching. This antenna was created using EM simulation software (CST Microwave Studio) and features a rectangular patch with two HSRR (Hexagonal Split Ring Resonator) slots that can be utilized to increase bandwidth and gain. The design features an 8mm x 5mm microstrip patch with FR4 substrate for the Ku band applications. The antenna achieves gains of 4.11dBi and 3.51dBi, a VSWR of 1.01 and a wide bandwidth of 4.8GHz. This antenna resonates with dual frequencies at 13.33GHz and 15.854GHz.

Keywords: Ku-band, Satellite Communication, Microstrip Patch Antenna, Antenna Design, Gain, Side Lobes, Impedance Matching, Return Loss, Radiation Pattern, CST Microwave Studio.

I. INTRODUCTION

The wireless communication, especially satellite communication and radar, require antennas that are compact, efficient, and capable of working at high frequencies. The Ku band (12–18 GHz) is widely used in these systems because it supports high data rates and wide bandwidth. Microstrip patch antennas are popular due to their small size, low weight, and easy fabrication, but they often have problems like narrow bandwidth and low gain.

The antenna consists of a rectangular radiating patch printed on a dielectric substrate with a ground plane on the opposite side. The microstrip configuration is preferred due to its compact size, ease of fabrication, and planar geometry. The dielectric substrate used has a moderate dielectric constant (e.g., FR4 or Rogers RT/Duroid), balancing between size reduction and radiation efficiency.

To improve frequency agility and bandwidth, slots are etched into the patch and/or ground plane. These slots alter the current path, introducing additional resonances without significantly increasing antenna dimensions. In this design, Hexagonal Split Ring Resonator (HSRR) slots are embedded within the patch surface. The slots act as band-stop filters, allowing better control over the resonant frequency and suppressing surface wave propagation, which enhances radiation efficiency.

SRRs are metamaterial structures consisting of concentric rings with splits on opposite sides. When placed on or near the patch, they introduce negative permeability at specific frequencies. The SRRs in this design Enhance resonant behaviour by introducing local inductive-capacitive (LC) effects. Improve impedance bandwidth and gain. Enable multi-resonance, allowing the antenna to cover a wider frequency range within the Ku band. The use of two HSRR units placed symmetrically on the patch allows for optimized electromagnetic coupling and improved return loss.

The antenna uses a microstrip line feed or coaxial probe feed depending on the design preference Microstrip line feed offers a planar connection and easy integration with RF circuits. It is placed on the same substrate layer and connected directly to the patch. Coaxial probe feed provides better impedance matching and reduces surface wave loss. It connects through the substrate to the centre or offset of the patch.

II. LITERATURE REVIEW

The integration of metamaterials, such as split ring resonators (SRRs), into microstrip patch antennas has gained significant attention in recent years due to their ability to enhance antenna performance. Various studies have explored the use of SRRs to overcome the limitations of conventional rectangular patch antennas, such as narrow bandwidth, low gain, and large physical size.

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For instance, studies in the Ku band range (12–18 GHz) have shown that SRR-loaded antennas can effectively achieve resonance at lower frequencies, allowing for compact designs suitable for high-frequency applications like satellite communications, radar, and space systems. Additionally, the resonant properties of SRRs help in improving return loss and impedance matching, which are crucial for efficient signal transmission and reception. Several designs in the literature also highlight how the placement, orientation, and dimensions of SRRs significantly influence antenna parameters such as bandwidth, directivity, and efficiency.

III. DESIGN OF A DUAL HEXAGONAL SPILT RING RESONATOR

A compact patch antenna operating at 14 GHz in the Ku-band is designed using FR-4 substrate and an in set-fed rectangular patch.

A single hexagonal split ring resonator (SRR) is integrated into the patch to enhance resonance and electromagnetic field confinement. The design ensures impedance matching and improved performance using classical microstrip antenna equations.

$$\text{Width of the patch, W} = \frac{c}{2fo\sqrt{€r+1/2}}$$

Effective dielectric constant,

$$€\text{eff} = \frac{€r+1}{2} + \frac{€r-1}{2}\left[1+12\frac{h}{w}\right]^{-\frac{1}{2}}$$

$$\text{Effective Length, } Leff = \frac{c}{2fo\sqrt{€eff}}$$

$$\text{Extent in Length, } \Delta L = 0.412h + \frac{(€eff+0.3)(\frac{W}{h}+0.264)}{(€eff-0.258)(\frac{W}{h}+0.8)}$$

$$\text{Length of the patch, L} = \text{Leff} - 2\Delta\text{L}$$

TABLE 1
PARAMETERS OF PROPOSED ANTENNA

DUAL Hexagonal Split Ring Resonators Dimensions (in mm)	
Patch	
Width	8
length	5
Substrate	
Width	14
Length	14
Feedline	
Width	-1.0
Length	-2.5
Slot 1(Outer Slot)	
Inner Radius	2.2
Outer Radius	2
Slot 2(inner slot)	
Inner Radius	1.5
Outer Radius	1.3

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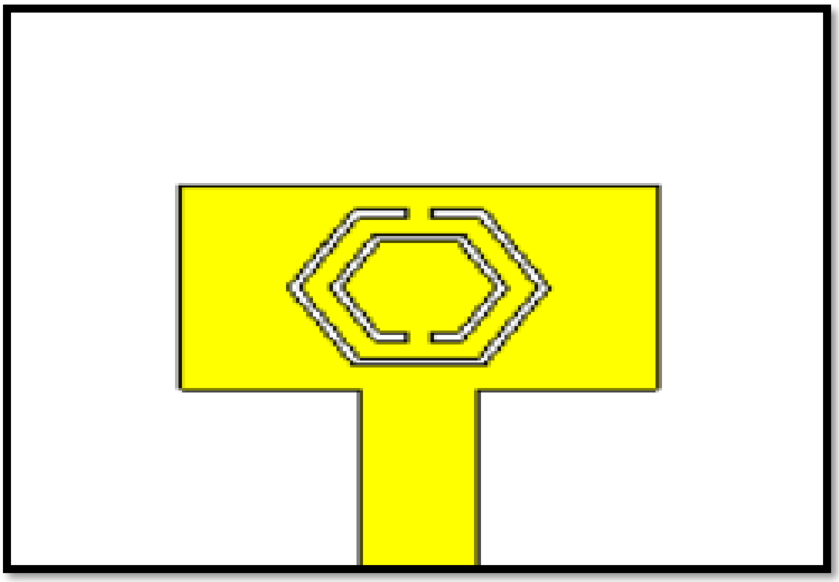

Fig 1. Dual Hexagonal Split Ring Resonator Antenna Design

Fig 2. The given image shows an S-Parameter plot representing the magnitude of the S_{11} parameter in decibels (dB) across a frequency range of 10 GHz to 20 GHz. The S_{11} parameter indicates the return loss at Port 1, which reflects how much power is reflected back toward the source due to impedance mismatch. Lower (more negative) values of S_{11} suggest better impedance matching and less reflected power. In the graph, significant dips are observed at around 13.34 GHz and 15.86 GHz, indicating resonant frequencies where the device performs efficiently. At 13.34 GHz, the return loss reaches a minimum value of approximately -38.48 dB, showing excellent matching. Additional markers show return losses of -9.88 dB at 12.867 GHz and -10.09 dB at 17.68 GHz, which are near the threshold for acceptable performance. This type of plot is commonly used in RF and microwave engineering to evaluate the performance of antennas, filters, and other high- frequency components by identifying their operating frequencies and efficiency.

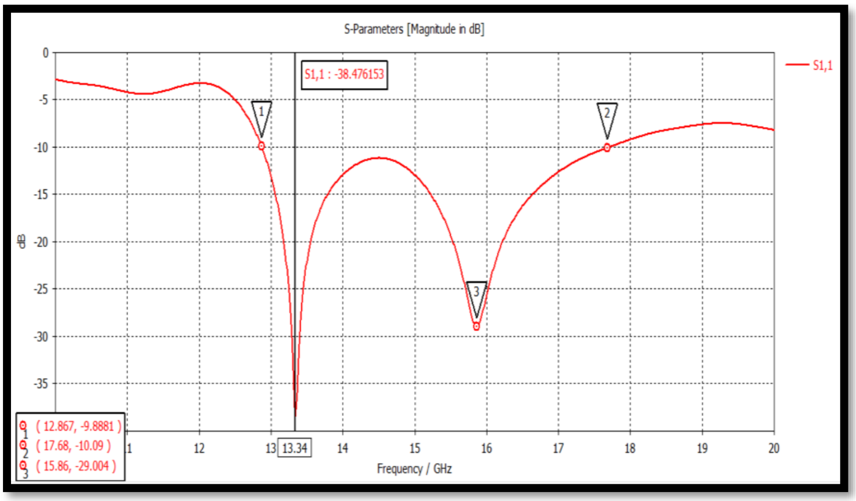

Fig 2. Return loss of proposed antenna

Fig 3. The VSWR graph indicates the impedance matching of proposed antenna performance of the system over a frequency range of 10 GHz to 20 GHz. The minimum VSWR value observed is 1.024 at 13.34 GHz, which signifies excellent impedance matching and minimal signal reflection at this frequency. This makes 13.34 GHz the optimal operating frequency for the system, where maximum power transfer occurs. Away from this frequency, the VSWR increases significantly, reaching values as high as 6, indicating poor matching and higher signal reflection. Overall, the system performs best around 13.34 GHz, with impedance mismatch becoming more pronounced at the lower and higher ends of the frequency range.

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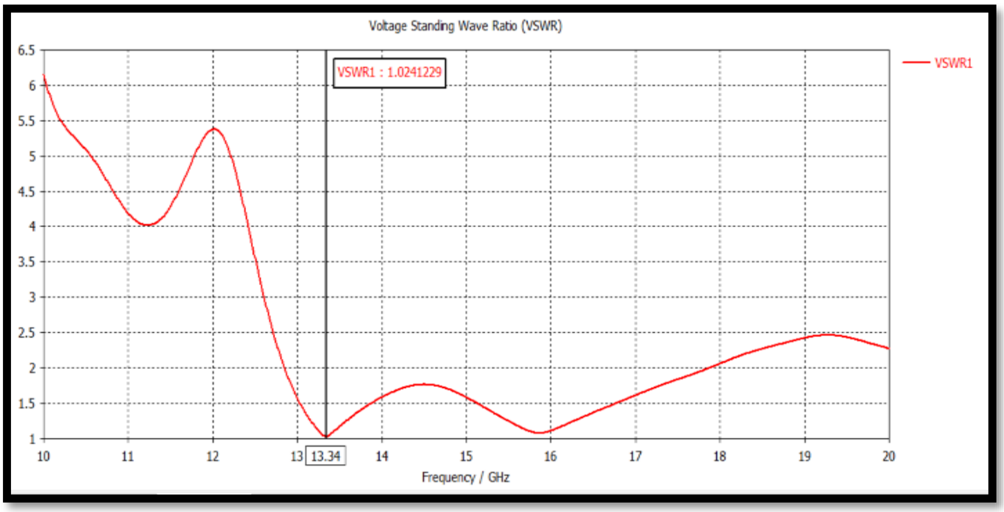

Fig.3 VSWR Plot of proposed antenna

Fig 4. The figure illustrates the 3D radiation pattern of an antenna, presented in dBi. The plot is color-coded to represent the gain intensity, with red indicating the highest gain region and blue representing the lowest. The maximum gain observed is approximately 3.96 dBi, as seen in the colour legend on the right. The pattern appears nearly omnidirectional in the X-Y plane (Theta = 0° to 360°), indicating that the antenna provides relatively uniform radiation in all azimuth directions, which is ideal for applications requiring broad coverage. The coordinate system indicates the directions of the Theta and Phi angles, and the primary lobe is centred around the Z-axis, suggesting the main radiation direction is along that axis.

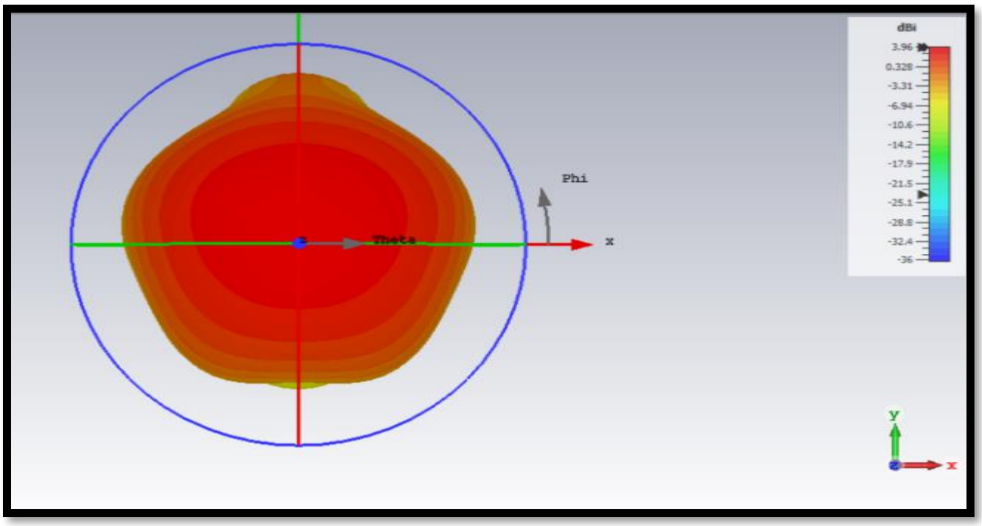

Fig 4.3D polar plot of proposed antenna at 13.34GHz

Fig 5. The provided image displays the far-field radiation pattern of an antenna at a frequency of 13.34 GHz, specifically showing the absolute gain in dBi for a constant phi (azimuth) angle of 90 degrees. The polar plot illustrates how the antenna radiates power in different directions in the theta (elevation) plane. The red curve represents the antenna's gain as a function of the theta angle, ranging from 0 to 180 degrees. The concentric circles represent gain levels in dB, with the outermost circle being 0 dB and moving inwards towards negative dB values. Key performance parameters are also provided: the main lobe magnitude is 3.97 dBi, indicating the peak gain of the antenna. The main lobe direction is at a theta angle of 7.0 degrees, signifying the direction of maximum radiation. The angular width (3 dB) is 78.0 degrees, representing the beamwidth of the main lobe where the gain is within 3 dB of its maximum value. Lastly, the beamwidth of the main lobe where the gain is within 3 dB of its maximum value. Lastly, the side lobe level is -5.7 dB, indicating the of the strongest radiation lobe outside the main lobe compared to the main lobe's peak gain.

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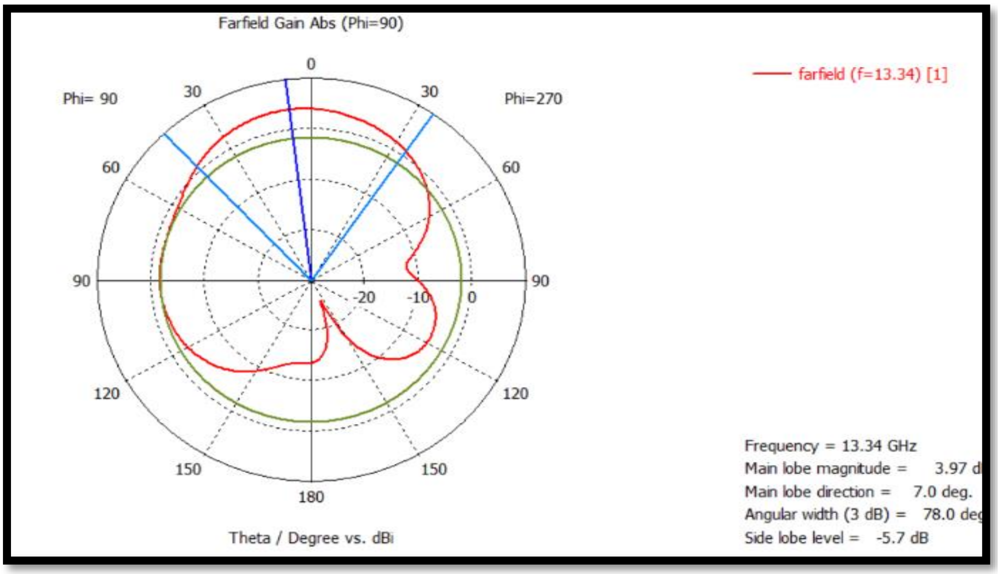

Fig 5. Radiation Pattern of proposed antenna at 13.34GHz

Fig 6. The image shows a 3D radiation pattern of an antenna, typically generated using electromagnetic simulation software. The plot illustrates how the antenna radiates energy in space, with the axes labelled as x, y, and z. The colour scale on the right, measured in dBi, indicates the gain of the antenna in different directions, with red and orange representing areas of higher gain and green to blue indicating lower gain. The pattern is doughnut-shaped, which is characteristic of a dipole antenna, showing maximum radiation perpendicular to the z-axis and minimum radiation along the axis itself. The maximum gain reaches approximately 3.42 dBi, as shown by the colour bar. This type of radiation pattern is essential in antenna design, as it helps engineers understand and optimize the directional properties and efficiency of the antenna for various wireless communication applications.

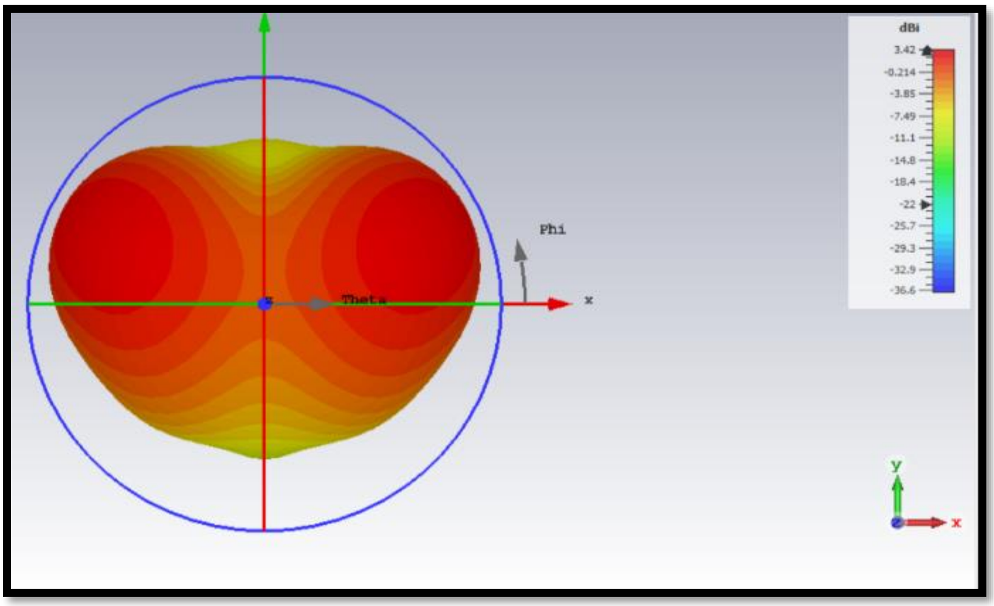

Fig 6. 3D polar plot of proposed antenna at 15.86 GHz

Fig 7. The image is a polar plot of the far-field gain of an antenna at a frequency of 15.86 GHz, measured with Phi set to 90 degrees. The red line indicates the far-field gain in dBi as a function of the angle Theta. The main lobe has a magnitude of approximately -0.47 dBi and is oriented at a direction of 9 degrees. The angular width of the main lobe, measured at the 3 dB points, is 65.7 degrees. The side lobe level is -6.7 dBi. This plot is used to analyse the antenna's radiation pattern, showing its directional properties and performance characteristics, which are crucial for optimizing antenna design in wireless communication systems.

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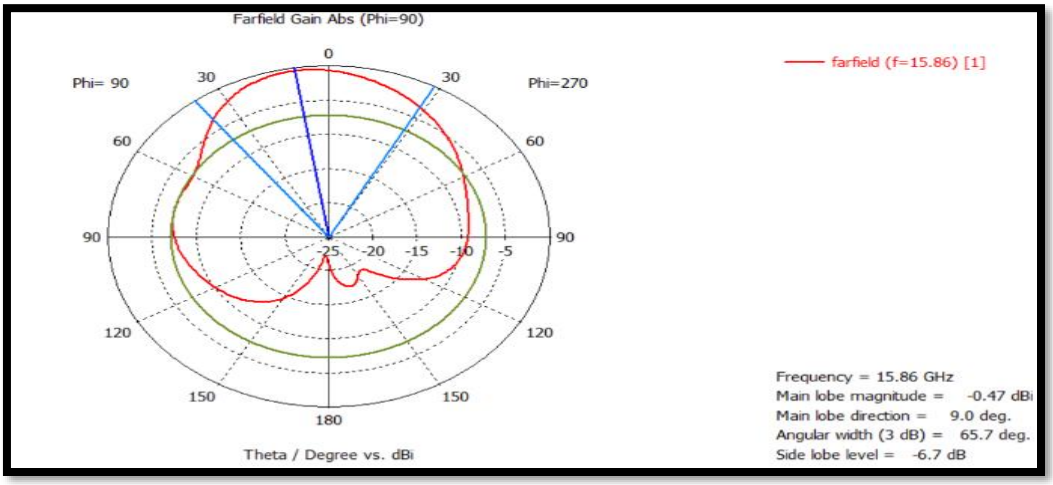

Fig 7. Radiation Pattern of proposed antenna at 15.86 6GHz

IV. CONCLUSION

The graph displays the S-parameters in decibels (dB) as a function of frequency in GHz for two antenna configurations: one "With Inner slot" and the other "With outer slot." The S-parameters indicate the reflection coefficient, which represents the amount of power reflected from the antenna. Lower S-parameter values indicate better matching and less reflection. The simulated results show that the designed antennas operate effectively at 13.34 GHz for Ku-band applications. The dual Hexagonal Split Ring Resonator configuration improved the performance with a bandwidth of 4.79 GHz and a gain of 3.96 dBi at 13.34 GHz and 3.42dBi at 15.86GHz compared to outer slot of the patc. 8h shown in fig

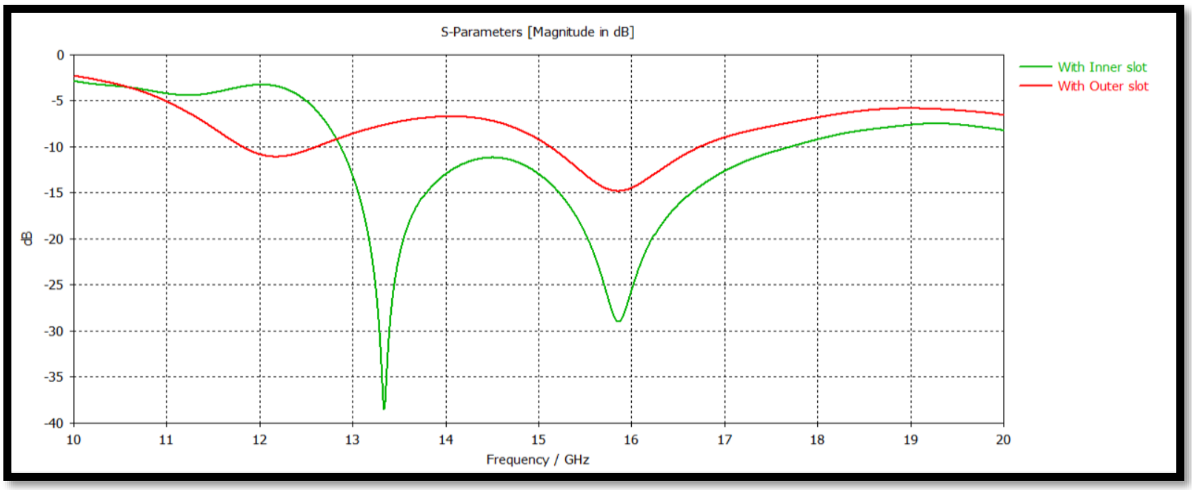

Fig 8. Bandwidth comparison plot for inner and outer slots

TABLE 2 RESULTS FOR PROPOSED ANTENNA

Antenna Parameters	With Inner Slot
S11	-14.82 dB at 15.85GHz
VSWR	1.4431dB at 15.85GHz
Gain	3.43 dB
Directivity	5.96dB

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REFERENCES

[1]. Bahl and P. Bhartia, “Microstrip Antennas”, Dedham, Ma, Artech house, 1981.
[2]. Yoon Jae Lee, Simon Tse, Yang Hao and Clive G. Parini “A Compact Microstrip Antenna with Improved Bandwidth Using Multiple Split-Ring Resonator Loading”, IEEE, pp. 5431-5434, 2007.
[3]. V eselago VG. the electrodynamics of substances with simultaneously negative values of ε and μ. Soviet Phys. Usp. 1968; 10:509–514.
[4]. Smith DR, Padilla WJ, Vier DC, et al. Composite medium with simultaneously negative permeability and permittivity. Phys. Rev. Lett. 2000; 84:4184–4187.
[5]. Patel SK, Kosta Y. Triband microstrip-based radiating structure design using split ring resonator and complementary split ring resonator. Microwave Opt. Technol. Lett. 2013; 55:2219–2222.
[6]. L i D, Szabo Z, Qing X, et al. A high gain antenna with an optimized metamaterial inspired superstrate. IEEE Trans. Antennes Propage. 2012 ;60 :6018–6023.
[7]. Ju J, Kim D, Lee WJ, et al. Wideband high-gain antenna using metamaterial superstrate with the zero refractive index. Microwave Opt. Technol. Lett. 2009; 51:1973–1976.
[8]. A. A.M. Ezanuddin F. Malek, P.J. Soh, “investigation of multiple split ring resonator with dielectric ring,” 2010 Loughborough antennas and propagation conference (LAPC), pp. 297-300, 2010.
[9]. H. Nornikman, F. Malek, P.J. Soh A.A.H. Azremi,” design a rice husk pyramidal microwave Absorbed with split ring resonator, the Asia- pacific symposium on applied electromagnetic and mechanics 2010.
[10]. D.J. Kern, D.H. Werner, A. Monorchio, L. Lanuza, M.J. Willhelm,” the design synthesis of multiband artificial magnetic conductor using high impedance frequency selective surfaces, “IEEE Transaction on antenna and propagation, vol.53, issue 1, part 1, pp.8-17, 2005.
[11]. J.B. Pendry, A.J. Holden, D.J. Robbins. Stewart, “magnetism from conductors and enhanced nonlinear phenomena, “IEEE trans. Microwaves theory tech, vol47, pp.2075-2084,1999.
[12]. Alici, K.B. and E. Ozbay, “Characterization and tilted response of a fishnet metamaterial operating at 100 GHz,” J. Phyos’d: Appl.Phys., Vol.41,13501,2008.
[13]. Gil, N., J. Bonache, J. Selga, J. Garcia – Garcia, and F. Nartin, “High pass‟ filters implemented by composite right/left-handed (CRLH) transmission lines based on complementary split rings resonators (CSRRs),” PIERS Online, Vol.3, No.3, 251-253, 2007.
[14]. Jiafu Wang, Shaobo Qu, Zhuo Xu, Jieqiu Zhang, Hua Ma, Yiming Yang, Chao Gu, “Broadband planar left-handed metamaterials using split-ring resonator pairs” Photonics and Nanostructures-Fundamentals and Applications, vol. 7, pp-108-113,2009.
[15]. J. Wei, X. Jiang, and L. Peng, "Ultrawideband and High-Gain Circularly Polarized Antenna with Double-Y-Shape Slot," IEEE Antennas and Wireless Propagation Letters, vol. 16, pp. 1508-1511, 2017.

