A Substantial Rectangular Shaped X-band Slot antenna for Satellite and Terrestrial Applications

Ch. Priyanka, K. Ranjith Kumar, B. Sonia, Deepak Kumar Nayak

Abstract*: *A substantial rectangular shaped X-band slot antenna for Satellite and Terrestrial Applications is presented in this paper. The antenna has an ascertain dimensions of 18.5mm × 8.95mm × 0.72mm which indicates that the proposed antenna has low profile when compared with typical slot antennas. A resonating microstrip feeding line method is provided to excite the antenna. The proposed antenna covers the frequency range of 7.5GHz to 15.5GHz. The antenna has a peak return loss value of -24.77dB at 11.1GHz when operated at 8.5GHz frequency in the X band. The antenna is designed on FR4 epoxy substrate with a dielectric constant of 4.4 and has a loss tangent of 0.02. This antenna can be used in the fields of terrestrial, Radio Detection and Ranging(RADAR) and satellite Communication. The designed antenna works efficiently in the frequency range of X band(8GHz to 12GHz) and covers 41% of Ku band frequency range additionally. The proposed antenna is simpler to design.

Index Terms*: *X-band, Satellite and Terrestrial Applications, Slot antenna, Radio Detection and Ranging(RADAR).

I. INTRODUCTION

The urge of the rectangular shaped slot antennas is increasing exponentially in the fields of antennas as it became an emanating technology in the recent times. As the slot antennas transmit high amount of power with a simpler design and with less complexity therefore it sustained its place in the application field of radar, space and terrestrial communications. One of the appreciable nature of slot antennas is that by revamping the shape, design of the aperture and resizing the slot size the antenna operation can be tuned optimally.

In the previous literature papers, the following methods are reported, a Barium Strontium Titanate technology is used to achieve X-band [1], where the patch is loaded with a thin film BST layer to achieve a desired high-power handling capacity.A good harmony of parameters like antenna efficiency of 96%, aperture efficiency of 40% and a gain of 21.6dBi at 10.5GHz operating frequency is reported in [2]. A spiral Conical shaped disc backed antenna in the field of X-band applications is discussed in [3], which has an efficient impedance matching and enhanced 3dB axial ratiowhere the height of the cone and substrate controls the antenna operation. A circularly polarized microstrip antenna consisting of a broader impedance bandwidth with a 3dB AR(Axial Ratio) bandwidth of 12.8%, low side lobe of -15dB and with a gain of 17.5dBic in X band is discussed in [4]. The antennas which are discussed above in the survey are holding appreciable outcomes in the wireless communication. One of the major limitations commonly found in almost all the literature papers is that they possess lengthy and broader dimensions. The dimensions of the different antennas collected from the survey are shown in the Table 1. The dimensions of the proposed antenna is very minimal than the antennas which are proposed in the literature survey. The minimum space occupation of the proposed antenna makes it a major advantageous antenna to select in satellite applications where less volume occupying components are needed. The added advantage for the proposed antenna is the coverage of Ku band range along with the X-band range. The proposed antenna mainly sticks strictly in the X band range applications of radar and satellite technology, it covers some part of the Ku band which makes the proposed antenna tangible for some of the Ku band applications.

Ref	Dimensions(mm^3)	ε_r
2	144× 144× 0.508	6.15
4	110× 110× 3	1.92
1	45.5×45.5× .43	3.55
3	40× 10× 1.5	3.6
Presented in this paper	18.5× 8.95× 0.72	4.4

Table 1: Comparison of the dimensions of the antennas in the literature survey

The proposed letter contains an antenna which well suits in the application area of military, satellite, terrestrial, radar and civilian applications in the X band which is designed using High Frequency Structure Simulator (HFSS). This letter is organized as Section II which discusses the Antenna Design Procedure, followed by Section III which presents the Results and Discussion and Section IV concludes the paper with Conclusion.

Revised Manuscript Received on May 06, 2019

Ch. Priyanka, Department of ECE, KLEF, Guntur, Andhra Pradesh, India.

K. Ranjith Kumar,Department of ECE, KLEF, Guntur, Andhra Pradesh, India.

B. Sonia,Department of ECE, KLE F, Guntur, Andhra Pradesh, India.**Deepak Kumar Nayak**, Department of ECE, KLEF, Guntur, Andhra Pradesh, India.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

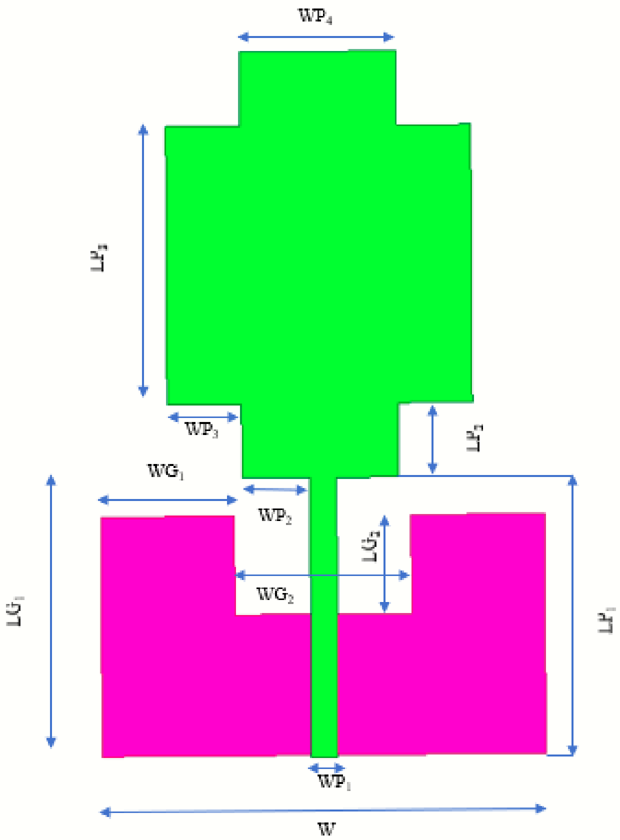
II. DESIGN PROCEDURE OF ANTENNA

The proposed antenna model is evolved from three stage design model. The first antenna model gives the basic design idea of the proposed antenna. The first design model consists of a patch which is rectangularly cascaded with two rectangles of different dimensions. The upper rectangle has got notches of a 1.5mm × 1.5mm sized squares at the four corners on the boundaries of the rectangle. The ground of the first design model is constructed using a rectangle of size 4.85mm × 8.95mm andslotted with a small rectangle of 2mm × 3.57mm at the center on the top of the ground's main rectangle. The second design model is an upgraded version of the first version where the patch remains same, but the ground is mounted with an inverted L shaped stubs vertically on the top of the ground rectangle on either sides. The third design model is the final design which is the fabricated design and is introduced with two circular notches with one on the patch and another on the ground. The radius of the circular slot on the patch is 2.08mm and the radius of the circular slot on the ground is 1mm. The circular slots on both patch and the ground are etched at the center of the rectangles. The proposed antenna has the dimensions of 18.5mm × 8.95mm × 0.72mm. The antenna occupies an area of $165.575mm^2$and avolume of $119.214mm^3$ which is quite less than the conventional slot antennas. The fabricated antenna is designed on FR4 epoxy material substrate with a dielectric constant of 4.4, Lande G factor of 2 and a loss tangent of 0.02. The antenna uses one of the mostly used and easily fed microstrip feeding line method, where the width of the line is 0.535mm which is used to match the impedance of 50 ohm coaxial line. To maintain the desired characteristics of the antenna at the operating frequency the antenna is designed with a width of 8.95mm and the length is chosen 2.06 times the measurement of the width. By using the parametric analysis approach the evolution models are designed. The designs which are designed in the software are shown in the Figure 1. The dimensions of the antenna models are given in Table 2.

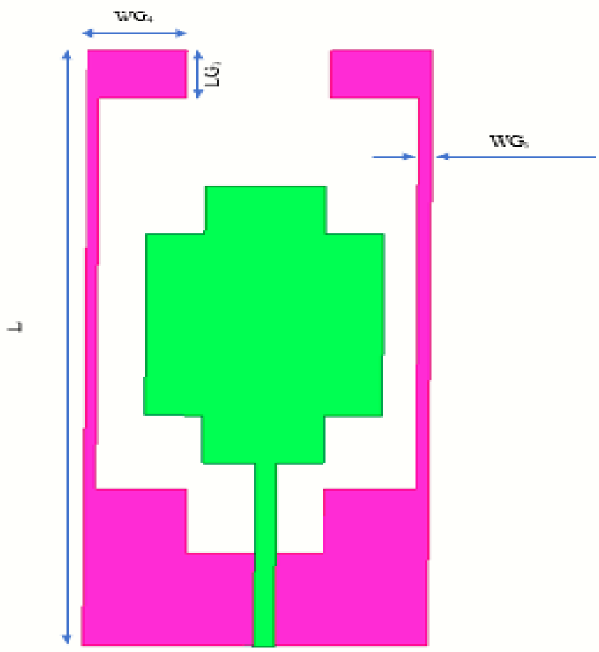
Parameter	Measurement(in mm)
L	18.5
W	8.95
LP_1	5.67
LP_2	1.5
LP_3	5.63
LP_4	1.5
WP_1	0.53
WP_2	1.25
WP_3	1.5
WP_4	3.16
WG_1	2.33
WG_2	3.57
WG_3	0.4
WG_4	2.6
LG_1	4.85
LG_2	2
LG_3	1.49
RP	2.08
RG	1

Table 2: Dimensions of the designed antenna

The hardware fabrication is done on the FR4 epoxy material and the hardware design is interfaced with an edge mounted Subminiature(Version A) connector.

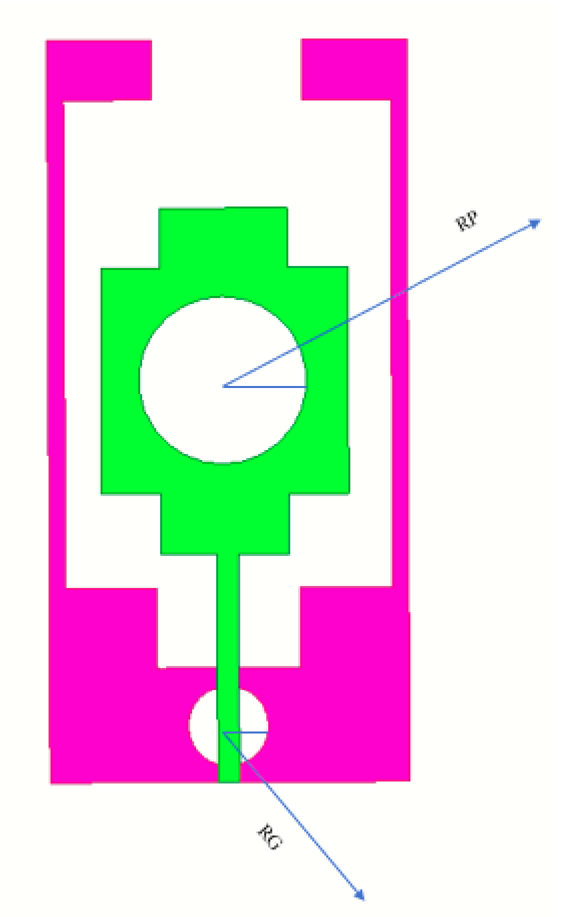


(a)



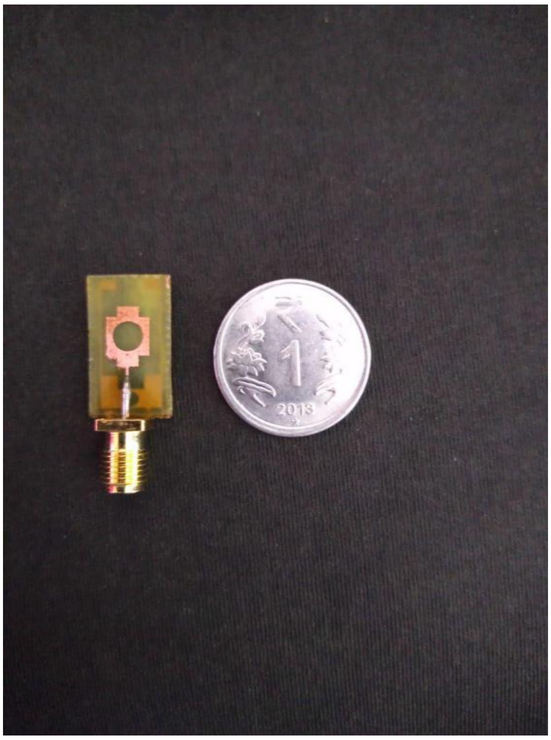
(b)

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

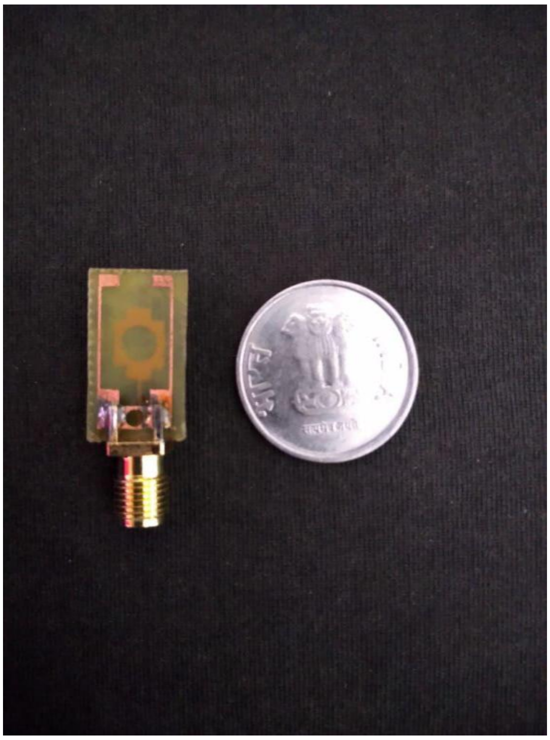


(c)

Figure 1: Evolution Design (a)Design Model_1 (b) Design Model_2 (c) Design Model_3



(a)



(b)

Figure 2: Hardware Design Model (a) Patch(Top View) (b) Ground (Bottom View)

III. RESULTS AND DISCUSSION

The simulation of the proposed antenna is done in HFSS tool. The fabricated antenna is represented in Figure 2. The S11 return loss plots of the three models is presented in Figure 3. The fabricated antenna occupies less volume and area which makes it compatible for limited space occupation in any application and makes it tangible for many conventional uses. The hardware model is tested practically, and the results mapped almost all with the simulated results in the software in the X band. The E field distribution of the antenna is shown in Figure 4 of both patch and ground plane. The J field surface current distribution is shown in Figure 5 of both patch and the ground plane respectively. The current through the probes excites the antenna. The probes are connected to the Spectrum Analyzer to measure the antenna's performance. Some minimum variations in the results are observed in the software and hardware results when compared with each other due to fabrication inaccuracy and improper calibration of the device. In spite of all these factors the proposed antenna holds good for all the X band applications including terrestrial and satellite communication. The designed antenna covers 41% of the Ku band frequency range along with the X band frequency range.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

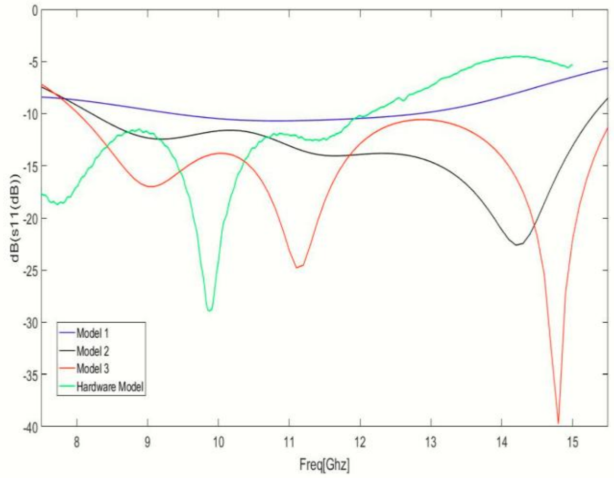
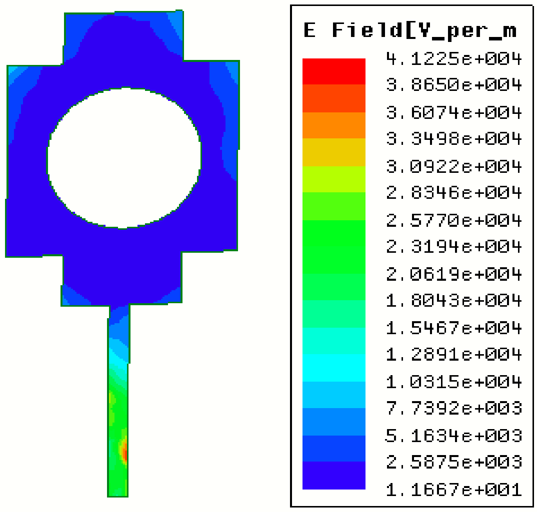
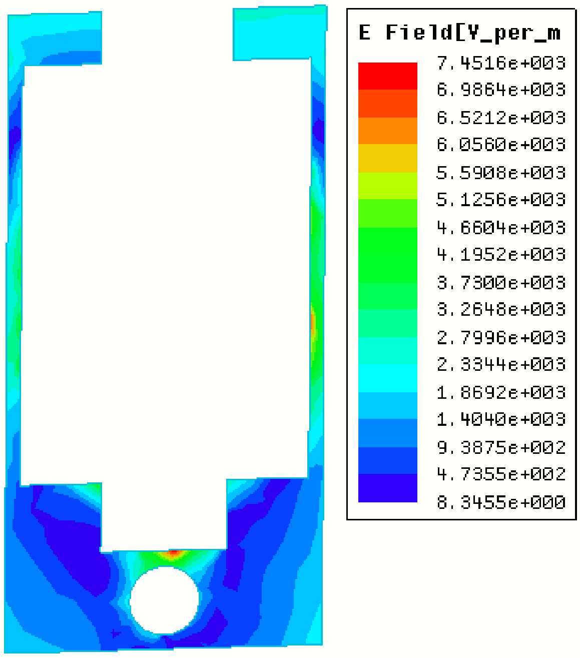


Figure 3: Reflection Loss Coefficient plot(Return Loss S_{11} plot)

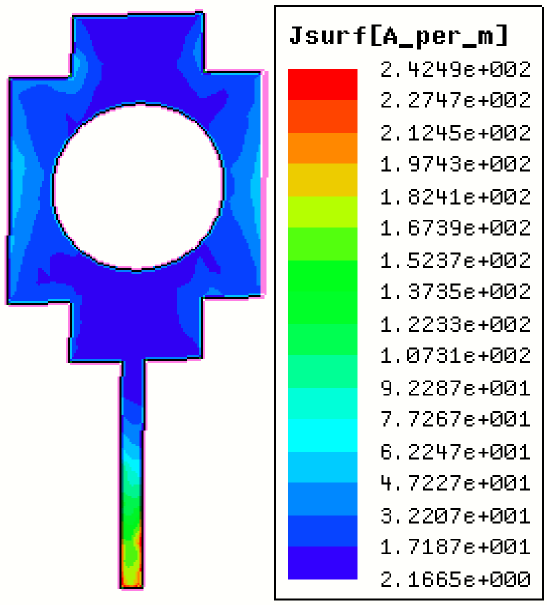


(a)



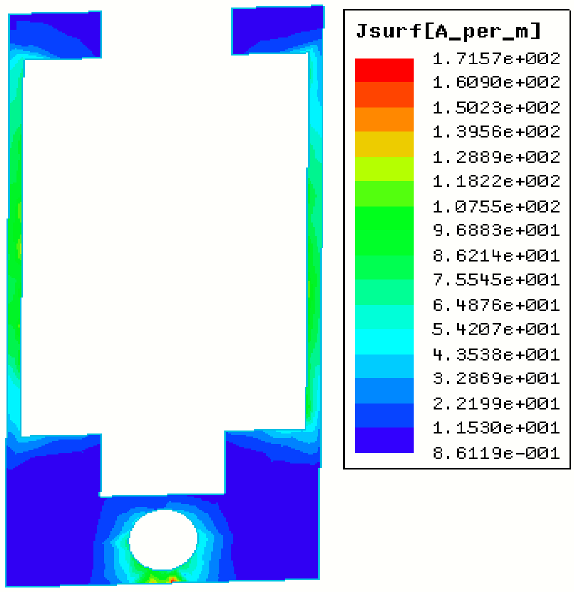
(b)

Figure 4: E-field plots of (a) Patch (b) Ground Plane



(a)

\



(b)

Figure 5: J-field plots of (a) Patch (b) Ground Plane

The VSWR(Voltage Standing Wave Ratio) is shown in Figure 6 to know where the standing waves occur. The Voltage Standing Wave Ratio measures the loads matched impedance to the Z_0(characteristic impedance). The E-field plots summarizes the Polarization as polarization is the locus of E-field. The J-field current distributions shown in the figure imply that the antenna radiates with required characteristics in the X-band.

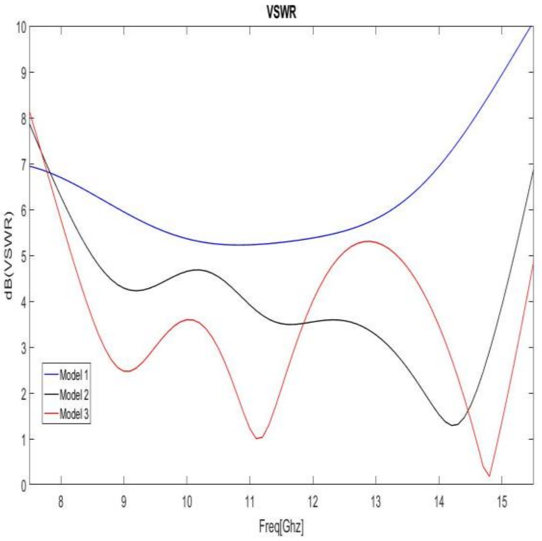


Figure 6: Voltage Standing Wave Ratio of the designed Antenna.

IV. CONCLUSION

A small size X band antenna is proposed in this letter which is easily affordable in versatile applications in the X band. The antenna covers total X band and 41% of Ku band with an appreciable return loss less than -10dB. The operating frequency of the proposed antenna is 8.5GHz where a maximum peak of -24.77dB is observed at 11.1GHz frequency in the X band. At 14.8GHz a maximum peak of -39.72dB is observed in the Ku band frequency range. The proposed antenna suits best in the fields of terrestrial and satellite communication in X band operation. A high correlation is observed between the simulated and measured results of the proposed antenna in the X-band. As the antenna occupies less volume it suits in the applications where space occupation is a constraint.

REFERENCES

1. Karnati K. K., Shen Y., Trampler M. E., Ebadi S., Wahid P. F., & Gong X.A BST-Integrated Capacitively Loaded Patch for Ka and X-band Beamsteerable Reflectarray Antennas in Satellite Communications. IEEE Transactions on Antennas and Propagation, 63(4), 1324-1333.
2. Bodur H., Unaldı S., Cimen S., &Cakir G. (2018). Broadband single-layer reflect array antenna for X-band applications. IET Microwaves, Antennas & Propagation, 12(10), 1609-1612.
3. Ur-Rehman M., Safdar G. A., Yang X., & Chen X. Design and study of a circular polarised conical-disc-backed spiral antenna for X-Band applications. IEEE Access, 5, 21344-21354.
4. Mao C. X., Gao S., Wang Y., Chu Q. X., & Yang X.X. DualBand Circularly Polarized Shared-Aperture Array for C, X-Band Satellite Communications. IEEE Transactions on Antennas and Propagation, 65(10), 5171-5178.
5. https://www.xtar.cc

*Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication*