International Journal of Scientific Research in Mechanical and Materials Engineering
© 2018 IJSRMME | Volume 2 | Issue 1 | ISSN : 2457-0435

Design and Development of Metamaterial Antenna for Ku band Satellite Applications

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ABSTRACT

Antenna Design plays a key role in Satellite Communication. In this paper Metamaterial structure is added in patch antenna design to work for ku band satellite applications. “Meta” is a Greek word which means “beyond" the materials provides properties beyond the conventional materials. A rectangular patch antenna is provided with the metamaterial ground structure which helps to increase the performance of the regular patch antenna. Here FR4 substrate with dielectric permittivity of 4.4 and height of the substrate is 1.6 mm is used for designing the metamaterial antenna. The Proposed antenna having dimension 54.59 mm length and 59.14 mm width. This metamaterial antenna is designed with an integral based solver simulation software called CST Microwave studio v2018 and obtained VSWR 1.08, Return loss -27.40 dB and Bandwidth of 1.7 GHz, Directivity of 5.71 dB, gain of 5.84 dBi. This metamaterial antenna is suitable for Ku band Satellite applications.

Keywords : Metamaterial, Micro Patch Antenna, Ku Band, Satellite Application.

I. INTRODUCTION

The growth of telecommunication increases the need for research in the areas of satellite communication antennas. Ku band frequencies are widely used for satellite communications. In this paper metamaterial and patch antenna were merged for developing a new kind of antennas called metamaterial antennas. In literature review fundamentals of designing Patch antenna have been discussed in [1-3], Metamaterial is first invented by V. G. Veselago [4] and its basic understanding has been discussed in [5] the contribution of metamaterial in electromagnetics has been discussed in [6-7]. Various metamaterial antennas using split ring resonators has been discussed in [8-13]. In this metamaterial structure is used with rectangular patch antenna configuration.

The software used for the development of antenna is CST Microwave studio v2018. The CST microwave studio is an Electromagnetic field simulation software which is based on finite integration technique and for analysis of patch antennas time domain solver is used. This CST microwave studio is selected based on its simple user interface with a capability of simulating complex structures such as metamaterials.

II. ANTENNA DESIGN

In this Proposed antenna simple rectangular patch antenna is enhanced using metamaterial structure. Fig 1 and 2 shows the front and back view of the proposed metamaterial antenna. The Front Side Consists of rectangular patch made of copper with thickness 0.045mm having electrical conductivity of 5.8e+007 and the back view consists of ground part which is modified into metamaterial structure. This antenna is designed over FR4 Substrate with thickness 1.6mm with permittivity of 4.3 and loss tangent 0.02. Inset Feeding with 50-ohm reference impedance is used in simulation.

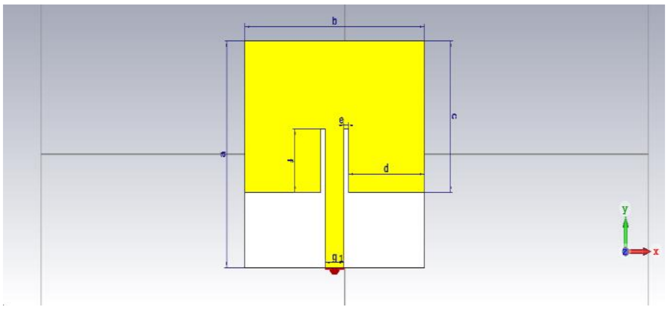

Figure 1. Front view of the metamaterial antenna

The Front view consists of a rectangular patch in which inset feeding is used. Inset feeding is used to provide better impedance matching. The length of inset feed is 33.359mm and the width is 6.06mm.the rectangular patch is having 59.14 mm length and 36.39mm dimension. All dimensions for front view have been presented in Table 1.

Table 1. Geometrical Parameters Of Front View Of The Proposed Antenna

Parameter	Dimension in mm
a	54.59
b	59.14
c	36.39
d	25.02
e	1.52
f	15.16
g	6.07

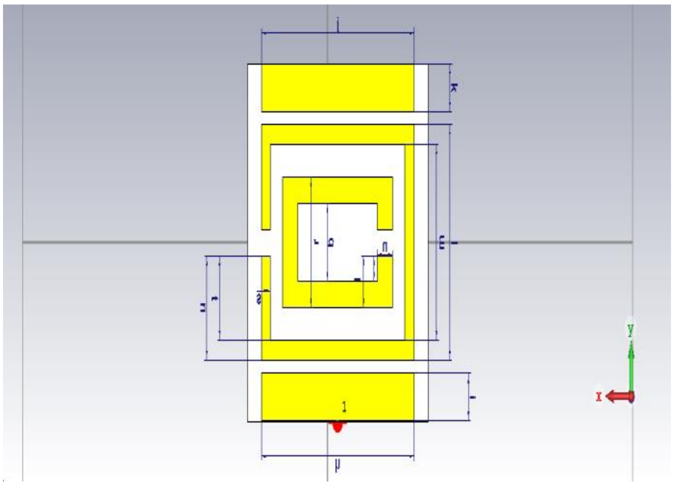

Figure 2. Back view of the metamaterial antenna

The back view of the proposed antenna having split ring resonator and rods of metamaterial structure. In this Split Ring Resonator is designed at the center along with the rods at both top and bottom of the split ring resonator structure. All dimensions for back view have been presented in Table 2.

Table 2. Geometrical Parameters of Back View Of The Proposed Antenna

Parameter	Dimension in mm
h	50
i	7.29
j	7.29
k	50
l	36
m	30
n	5
o	4
p	8
q	12
r	20
s	3
t	13
u	16

III. RESULTS AND DISCUSSION

The proposed metamaterial antenna is designed and simulated in CST Microwave studio v2018 and its results were discussed below.

3.1 Return Loss

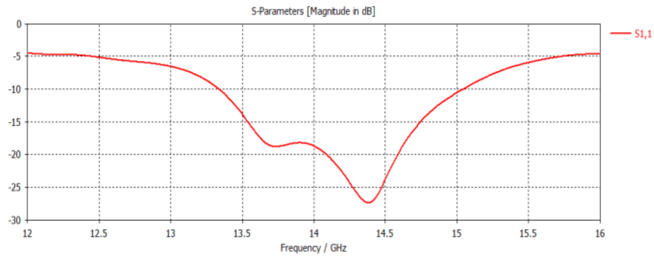

Figure 3. Return Loss

The minimum return loss obtained at 14.38 GHz is -27.40 dB and from 13.33 GHz to 15.04 GHz is under -10 dB for the proposed metamaterial antenna to operate in Ku band Satellite applications which is given in Figure 3.

3.2 VSWR

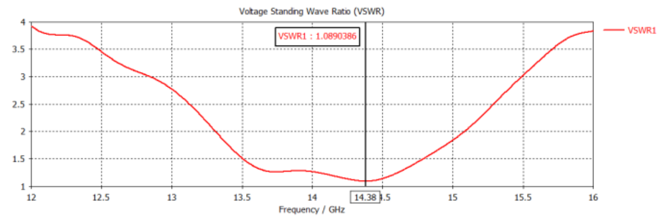

Figure 4. VSWR

The minimum VSWR (Voltage Standing Wave Ratio) obtained at 14.38 GHz is 1.08 for the proposed metamaterial antenna which is given in Figure 4.

3.3 Bandwidth

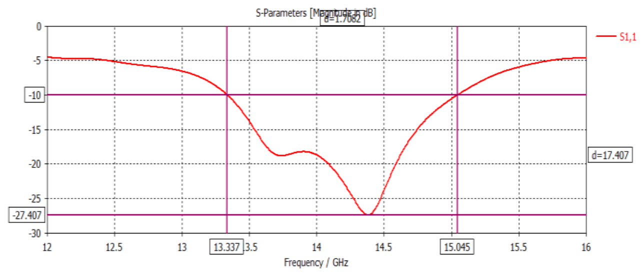

Figure 5. Bandwidth

The -10dB Bandwidth obtained at 14.38 GHz is 1.7GHz for the proposed metamaterial antenna which is given in Figure 5.

3.4 Efficiency

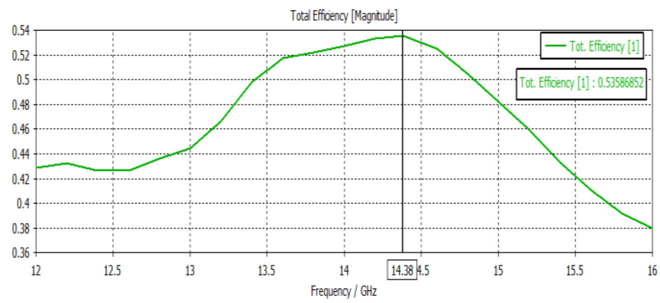

Figure 6. Efficiency

The Maximum Efficiency obtained at 14.38 GHz is 53% for the proposed metamaterial antenna which is given in Figure 6.

3.5 Farfield Plots

3.5.1 Farfield Directivity, Abs Phi=0

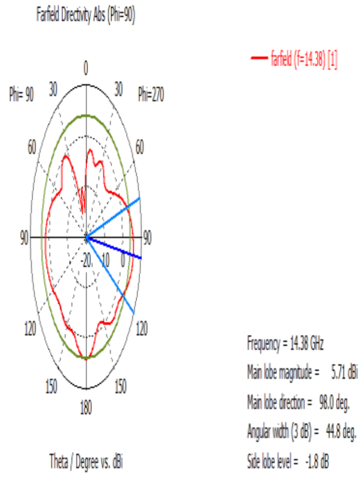

Figure 7. Farfield Directivity, Abs Phi=0

3.5.2 Directivity, constant Phi=0

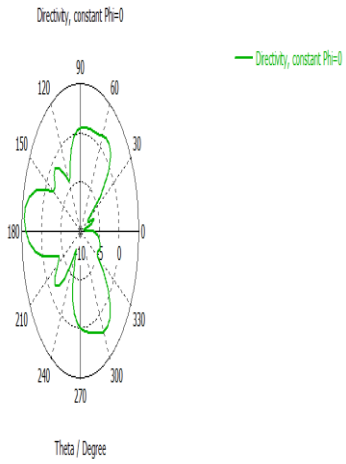

Figure 8. Directivity, constant Phi=0

3.5.3 Farfield Gain at 14.38GHz

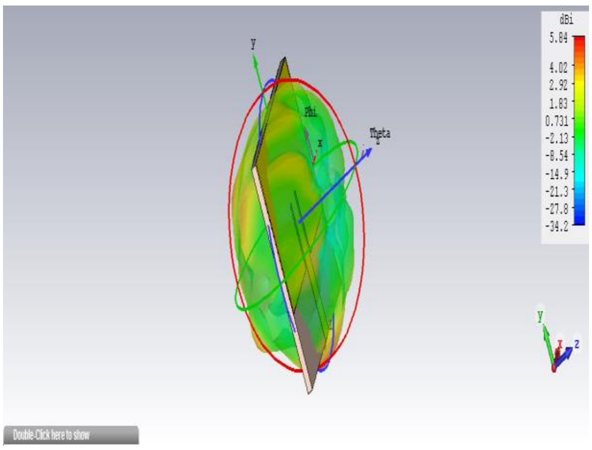

Figure 9. Farfield Gain at 14.38GHz

3.5.4 Total Farfield Gain from 12 to 16 GHz

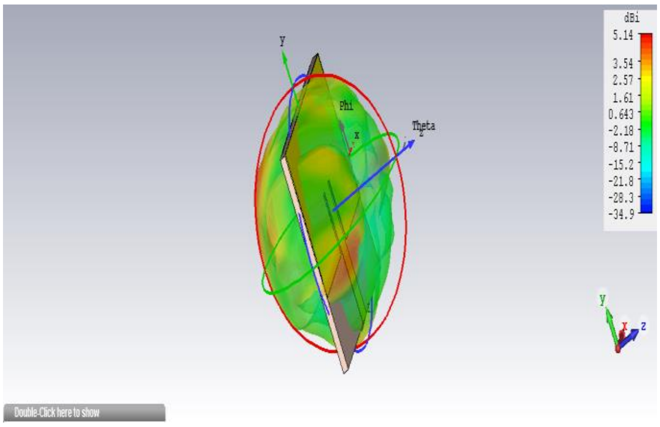

Figure 10. Total Farfield Gain from 12 to 16 GHz

3.5.5 Farfield Directivity Plot at Phi=90

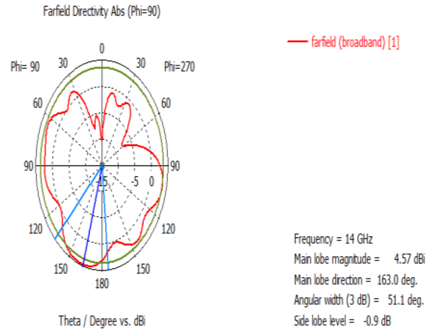

Figure 11. Farfield Directivity Plot at Phi=90

3.6 Front to Back Ratio

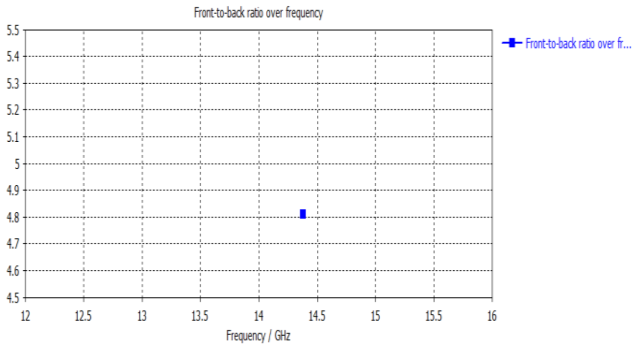

Figure 12. Front to Back Ratio

Front to Back Ratio is the ratio of power gain between the front and rear of a directional antenna. Front to back ratio at 14.38 GHz is 4.8 for the proposed antenna.

3.7 E Field

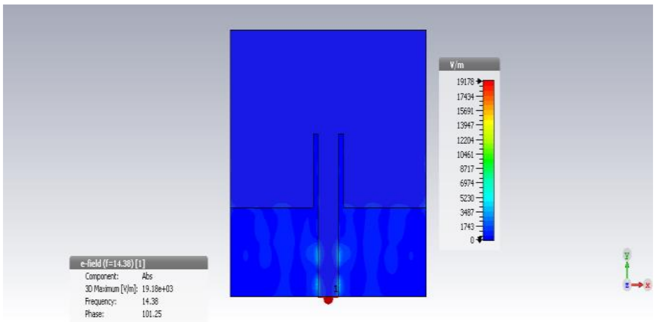

Figure 13. E Field Front View

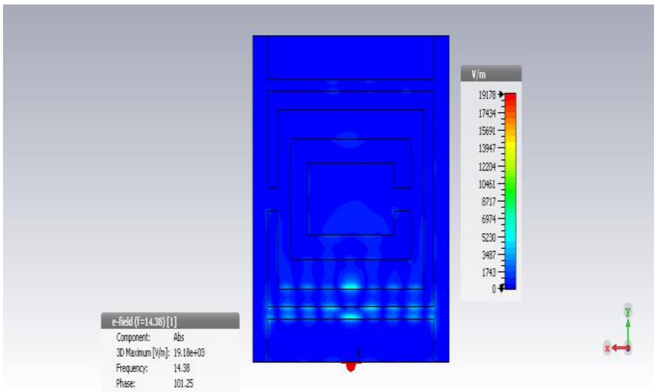

Figure 14. E Field Back View

3.8 H Field

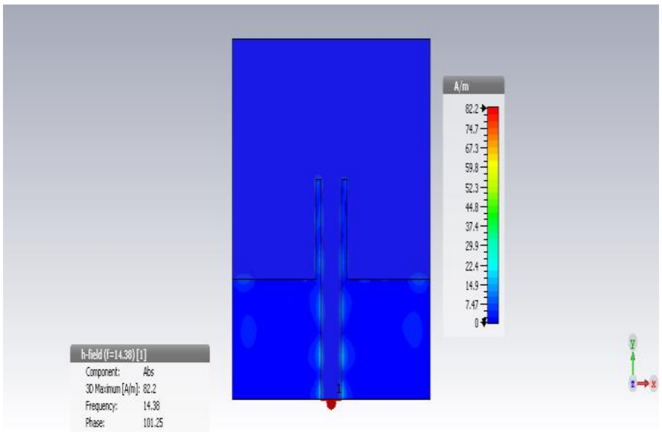

Figure 15. H Field Front View

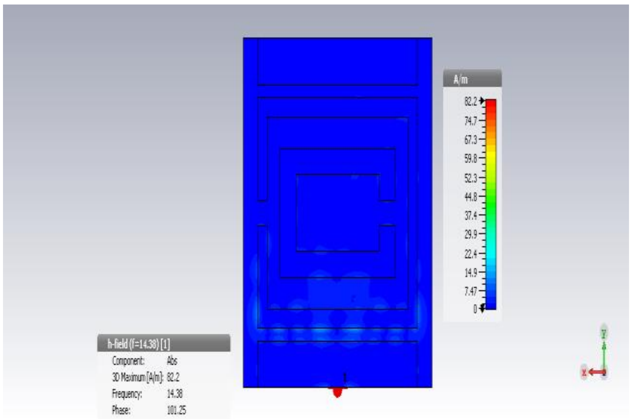

Figure 16. H Field Back View

3.9 Surface current a distribution

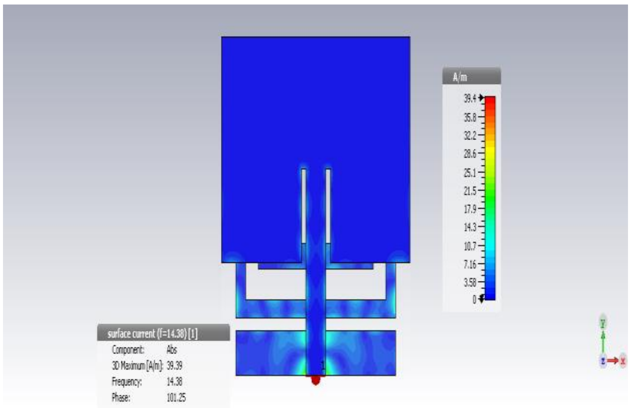

Figure 17. Surface current a distribution Front View

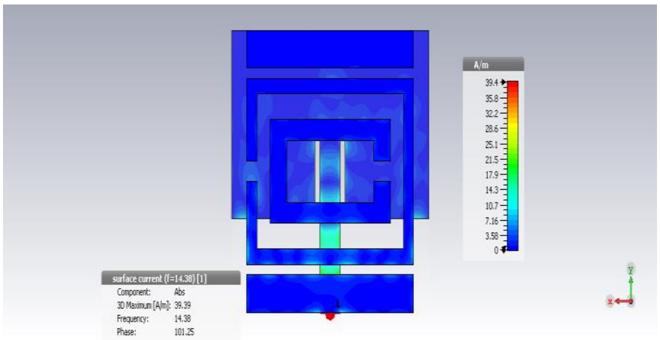

Figure 18. Surface current a distribution Back View

The Overall Results have been presented in Table 3.

Table 3. Overall Results

Parameter	Value
Operating Band of Proposed Metamaterial Antenna	13.33 GHz to 15.04 GHz
Center frequency	14.38 GHz
Return Loss	-27.40 dB
VSWR	1.08
Bandwidth	1.7GHz
Efficiency	53%
Directivity	5.71 dB
Gain	5.84dBi
Front to Back Ratio	4.8

IV. CONCLUSION

The proposed metamaterial antenna achieved better performance such as VSWR 1.08, Return loss -27.40 dB and Bandwidth of 1.7GHz, Directivity of 5.71 dB, gain of 5.84 dBi at 14.38 GHz in 54.59 *59.14 mm compact size in the simulation environment. This antenna is suitable for operating in 13 GHz to 15 GHz Ku band frequency in satellite applications.

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