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Design and Development of Metamaterial Antenna for 3 GHz Radar Applications

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ABSTRACT

Antenna design plays the key role in development of wireless communication technology. In this paper novel triangular metamaterial structure is added in the rectangular patch antenna for operating in 3 GHz radar 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 triangular metamaterial structure which is used to improve the performance of the regular patch antenna. In this research FR4 substrate with dielectric permittivity of 4.4 and height of the substrate is 1.6 mm is used for developing the metamaterial antenna. The Proposed antenna having dimension 30 mm length and 32 mm width. This metamaterial antenna is designed with an integral based solver simulation software called CST Microwave studio v2018 and obtained VSWR 1.58, Return loss of -12.94 dB and Bandwidth of 10 MHz, Directivity of 4 dB, gain of 3.84 dBi at the resonant frequency 3 GHz. This metamaterial antenna is suitable for 3 GHz radar applications.

Keywords : Metamaterial, Micro Patch Antenna, Radar, Wireless Communication.

I. INTRODUCTION

Antenna design plays key role in developing the wireless communication technology to support the faster growth of data communication. RADAR (Radio Amplification Detection and Ranging) is a system for detecting the presence, direction, distance, and speed of aircraft, ships, and other objects, by sending out pulses of radio waves which are reflected off the object back to the source. Radar systems contains a wide range of disciplines such as building works, heavy mechanical and electrical engineering, high power microwave engineering, and advanced high-speed signal and data processing techniques. The unavoidable part of any radar system is the radar antenna which needs to be designed with the highest possible accuracy for the best operation of the radar system.

Micro patch antennas are low profile antennas which are easy for design and fabrication [1]. Metamaterials are materials with different structures which poses enhanced properties than the ordinary materials which are used for the design of various semiconductor devices such as antennas.

Therefore, in this paper metamaterial antenna is developed for operating in resonant frequency of 3 GHz useful for radar applications. In literature review fundamentals of designing Patch antenna have been studied using [2-3], Metamaterial structures was first invented by V. G. Veselago [4] and its basic design fundamentals has been given in [5] and the contribution of metamaterial in electromagnetics has been given in [6-7].

Metamaterial Antenna for Ku band is suitable for operating in 13 GHz to 15 GHz Ku band frequency in satellite applications is presented in [8]. Metamaterial antenna which operates on 5.8 GHz frequency band Wi-Fi applications presented in [9]. Metamaterial antenna which operates on 5.5 GHz frequency band Wi-Max applications presented in [10]. Design and Analysis of a 3GHz Printed Dipole Antenna for radar and wireless communications is presented in [11]. Direct 3-D Printing of Non-Planar Linear Dipole Phased Array Antennas for multi-mission applications is presented in [12]. Triple Band MIMO Antenna for MIMO communication application is presented in [13]. Normal Mode 3.3GHz Bifilar Helical Antenna for Wireless Communication for wireless communication have been demonstrated numerically and experimentally in [14]. Designing Dipole Antenna for TV application and rectangular microstrip antenna working at 3 GHz for Radar Application for 2.9715GHz – 3.0278GHz GHz (S-band) for radar communication Standard is presented in [15].

In this research triangular metamaterial structure is used along with the regular rectangular micro patch antenna. 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

The front view of the proposed metamaterial antenna is given in Fig.1. The back view is given in Fig.2. The front view consists of rectangular patch configuration which is made of 0.045 mm thickness copper with electrical conductivity of 5.8e+007. The back view consists of triangular metamaterial structure. The complete antenna is designed on the surface of the FR4 material with the characteristics of thickness 1.6 mm with permittivity of 4.3 and loss tangent 0.02. Inset feeding with 50-ohm input impedance is used in the excitation of the proposed metamaterial antenna.

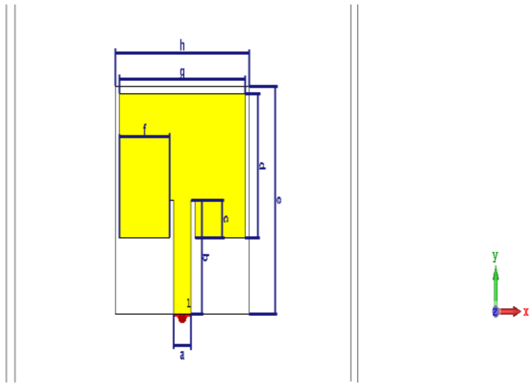

Fig.1 Front view of the metamaterial antenna

The Front view consists of a simple rectangular shaped copper patch in which inset feeding is used for the excitation purpose. Inset feeding selected because it is used to provide better impedance matching than the other kinds of feeding methods. The length of inset feed is 15 mm and the width 4 mm. The rectangular patch is having 19 mm length and 30 mm 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 (mm)
a	4
b	15
c	5
d	19
e	30
f	12
g	30
h	32

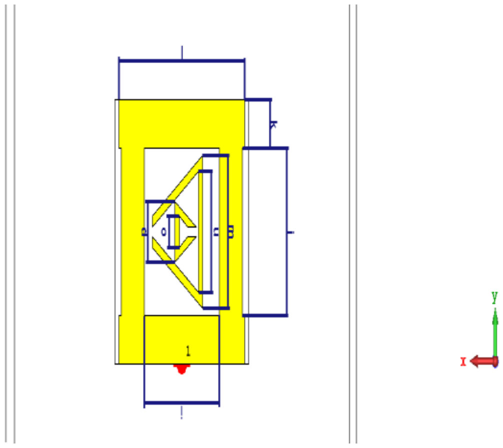

Fig.2 Back view of the metamaterial antenna

The back view of the proposed antenna having triangular metamaterial structure which consists of two triangular rings consists of the outer ring with 17.32 mm outer radius and 13.86 mm inner ring and another inside ring which is of 6.93 mm outer radius of 3.46 mm and inner radius. All dimensions used in the back view have been presented in Table 2.

TABLE 2
GEOMETRICAL PARAMETERS OF BACK VIEW OF THE PROPOSED ANTENNA

Parameter	Dimension (mm)
i	17.90
j	19
k	5.50
l	30
m	17.32
n	13.86
o	3.4
p	6.93

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

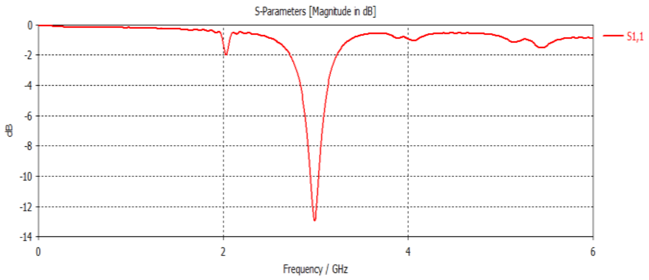

Fig.3 Return Loss

The minimum return loss obtained at 3 GHz is -12.94 dB for the proposed metamaterial antenna to operate in 3 GHz band radar applications which is given in Fig.3.

3.2 VSWR

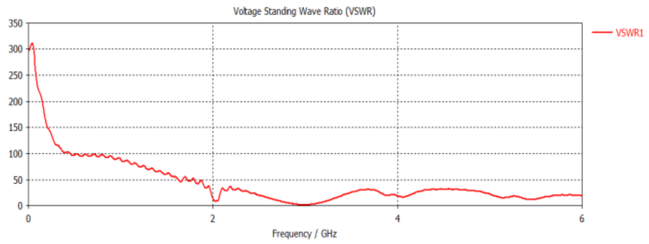

Fig.4 VSWR

The minimum Voltage Standing Wave Ratio VSWR obtained at 3 GHz is 1.58 for the proposed metamaterial antenna which is given in Fig.4.

3.3 Bandwidth

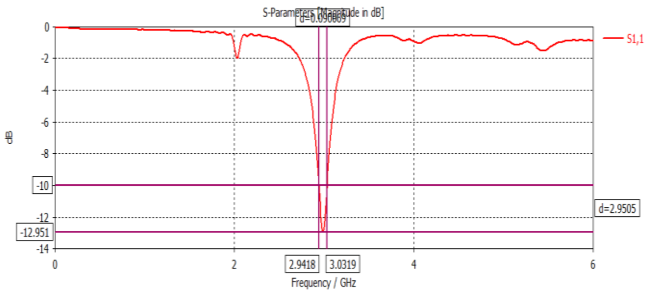

Fig.5 Bandwidth

The -10 dB Bandwidth obtained at 3 GHz is 10 MHz for the proposed metamaterial antenna which is given in Fig.5

3.4 Efficiency

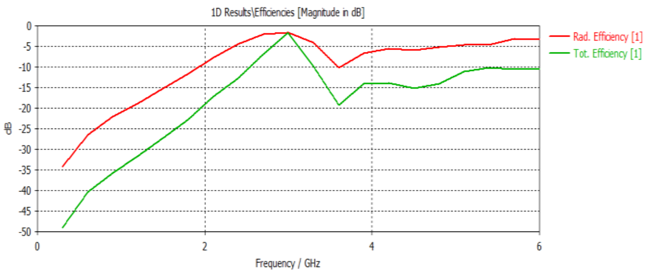

Fig.6 Efficiency

The Maximum Efficiency obtained at 3 GHz is 25 % for the proposed metamaterial antenna which is given in Fig.6.

3.5 Farfield Plots

3.5.1. Farfield Gain at 3 GHz

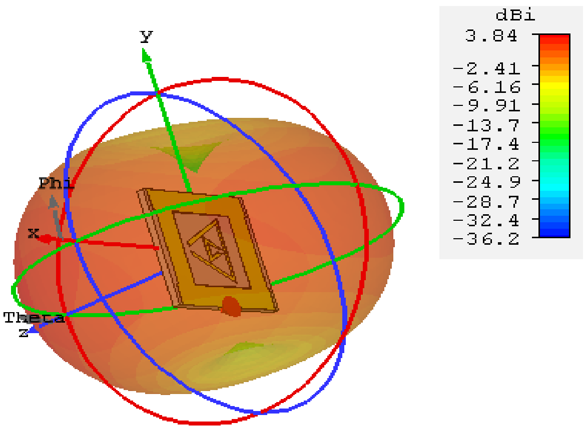

Fig.7 Farfield Gain at 3 GHz

3.5.2. Farfield Directivity, Abs Phi=0

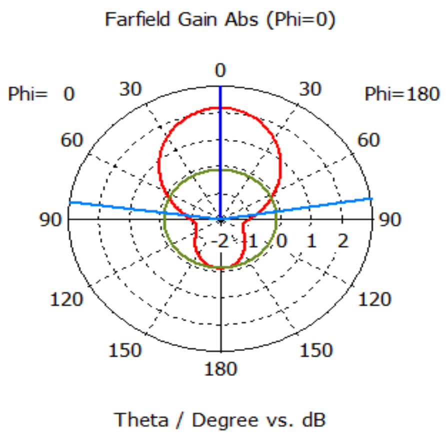

Fig.8 Farfield Directivity, Abs Phi=0

3.5.3. Directivity, constant Phi=90

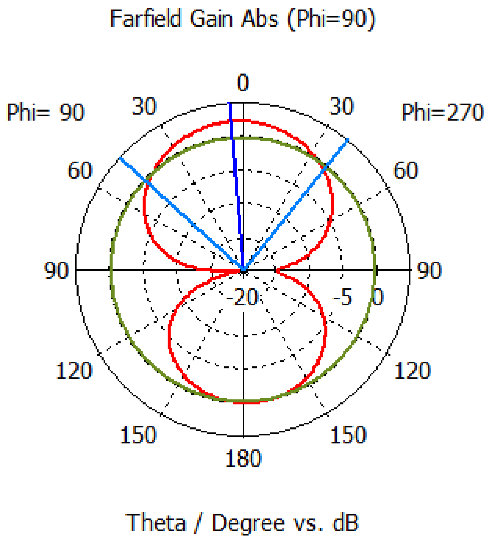

Fig.9 Directivity, constant Phi=90

3.5.4. Farfield Directivity Plot at Theta=0

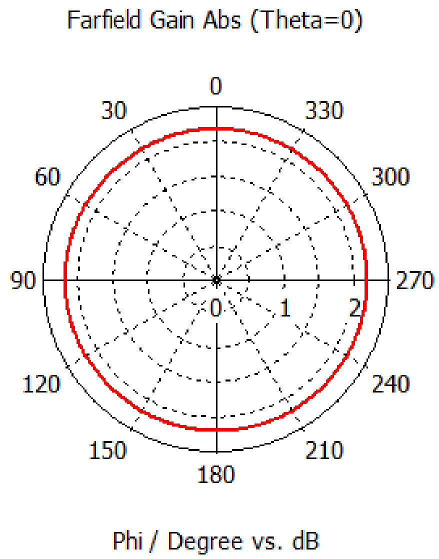

Fig.10 Farfield Directivity Plot at Theta=0

3.5.5. Farfield Directivity Plot at Theta=90

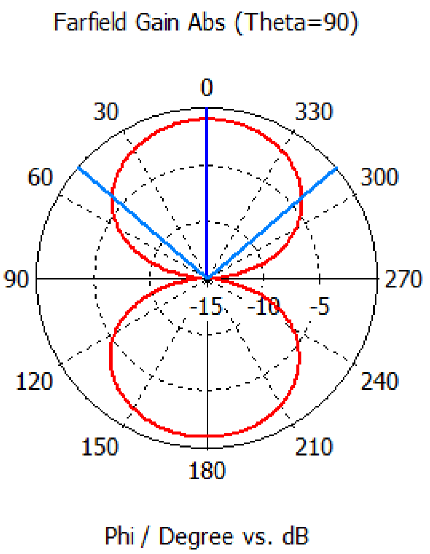

Fig.11 Farfield Directivity Plot at Theta=90

3.6 Front to Back Ratio

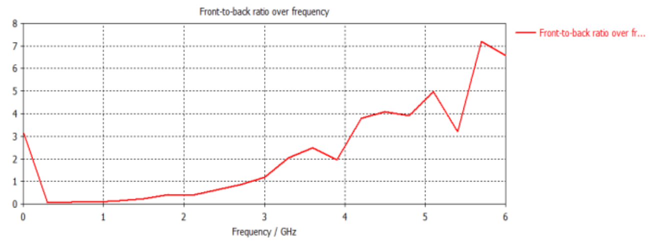

Fig.12 Front to Back Ratio

Front to Back Ratio is the ratio of power gain between the front and rear of a directional antenna. Front to back ratio at 3 GHz is 1.2 for the proposed metamaterial antenna.

3.7 E Field

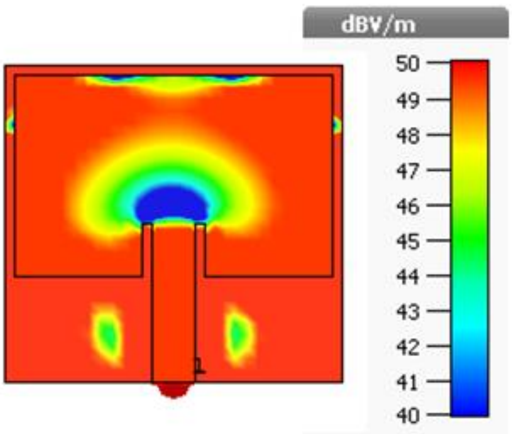

Fig.13 E Field Front View

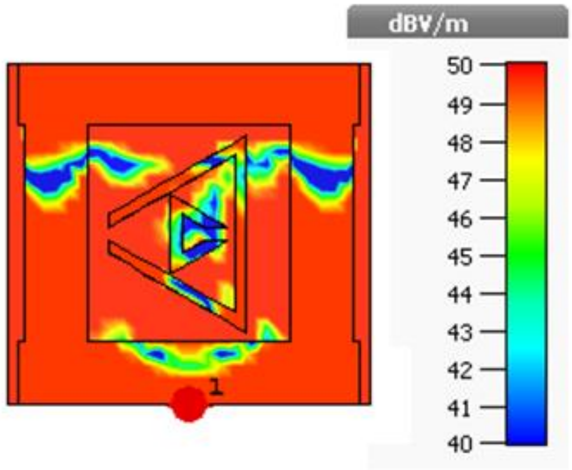

Fig.14 E Field Back View

3.8 H Field

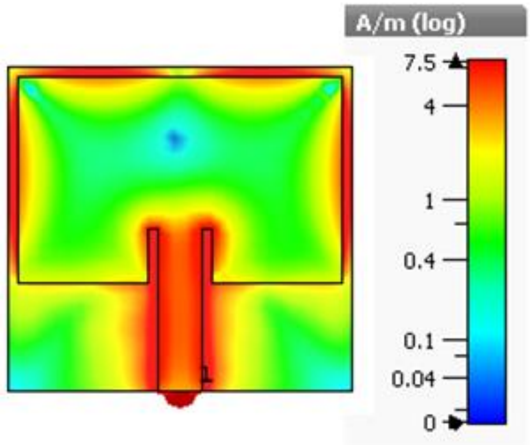

Fig.15 H Field Front View

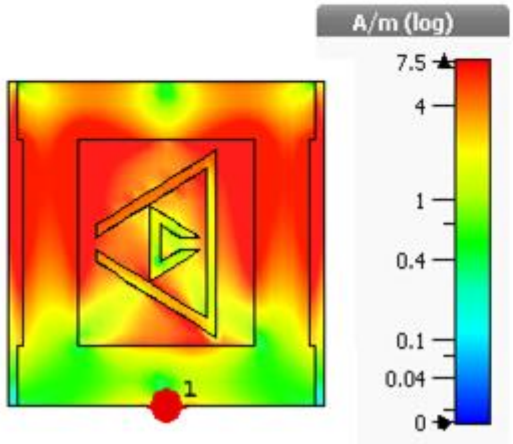

Fig.16 H Field Back View

3.9 Surface current a distribution

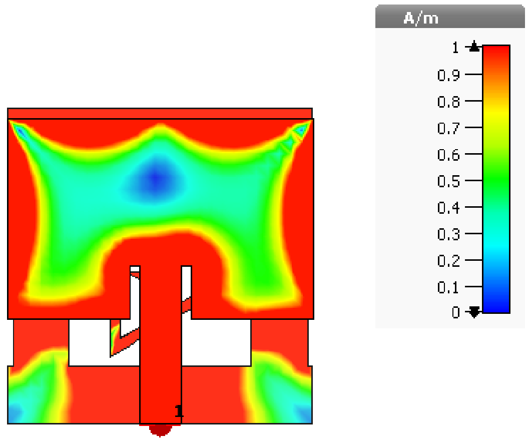

Fig.17 Surface current a distribution Front View

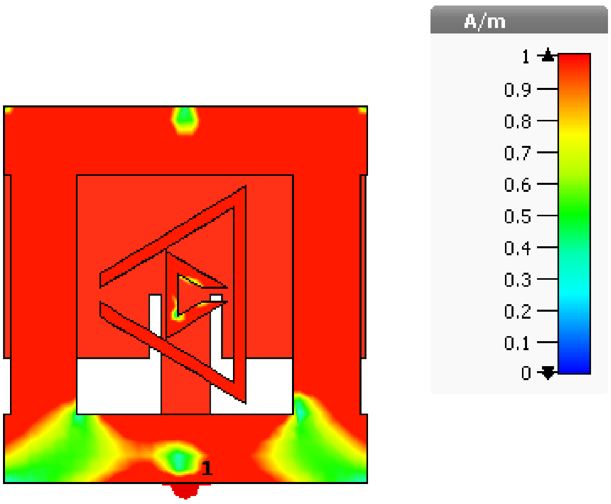

Fig.18 Surface current a distribution Back View

The Overall Results have been presented in Table 3.

TABLE 3
OVERALL RESULTS

Parameter	Value
Operating Frequency	3 GHz
Return Loss	-12.94 dB
VSWR	1.58
Bandwidth	10 MHz
Efficiency	40 %
Directivity	4 dB
Gain	3.84 dBi
Front to Back Ratio	1.2

IV. CONCLUSION

The proposed metamaterial antenna achieved better radiation characteristics at the resonant frequency 3 GHz with the VSWR of 1.58, Return loss -12.94 dB and Bandwidth of 10 MHz, Directivity of 4 dB, gain of 3.84 dBi with 30*32 mm lowest dimension. This antenna is suitable for operating in radar applications which operates on 3 GHz frequency band.

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