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Design and Development of Metamaterial Antenna for Multi Band Applications

Geetharamani G[1], *Aathmanesan T[2]
[1]Mathematics, Anna University, Tamilnadu, India
[2*]ICE, Anna University, Tamilnadu, India

ABSTRACT

Antenna design plays major role in wireless product development. In this paper novel metamaterial structure is added in the circular patch antenna for operating in multiband frequency applications. "Meta" is a Greek word which means "beyond" the materials provides properties beyond the conventional materials. A circular patch antenna is provided with the novel metamaterial structure in its ground plane 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 compact dimension such as 24 mm length and 24 mm width. This metamaterial antenna is designed with an integral based solver simulation software called CST Microwave studio v2018 and obtained VSWR <1.5, Return loss of -15 to -30 dB and Bandwidth of 120-220 MHz, gain of 4.5-6.4 dBi at the resonant frequencies of 5.3 GHz, 7 GHz and 7.7 GHz. This metamaterial antenna is suitable for C band WLAN and X band radar applications.

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

I. INTRODUCTION

Antenna design plays the vital role in any wireless product development. WLAN is the wireless local area network standard defined by IEEE for the use of wireless communication for both personal and commercial applications. 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 multiband frequency which is useful for WLAN and 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 5.8 GHz Wi-Fi applications is presented in [8]. Metamaterial antenna for 5.5 GHz Wi-Max applications is presented in [9]. Metamaterial antenna for 3 GHz RADAR applications is presented in [10]. Quad-band circularly polarized antenna for 2.4/5.3/5.8 GHz WLAN and 3.5 GHz WiMAX applications is discussed in [11]. Multiband fractal microstrip patch antenna for wireless applications is discussed in [12]. A compact UWB antenna with 7.5 GHz band notch characteristics is discussed in [13]. Gain enhancement of patch antenna using l-slotted mushroom EBG is discussed in [14]. A Dual-band quasi-yagi wearable antenna with high directivity is discussed in [15].

In this paper novel metamaterial structure is added in the ground plane of circular patch antenna is presented. 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 circular patch configuration which is made of 0.045 mm thickness copper with electrical conductivity of 5.8e+007. The back view consists of novel metamaterial structure.

The entire antenna is designed on the low cost 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.

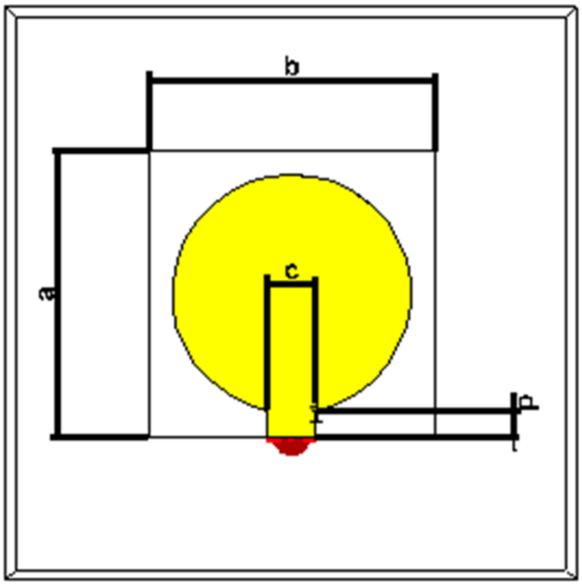

Fig.1 Front view of the metamaterial antenna

The Front view consists of a circular shaped copper patch in which inset feeding is used for the excitation. 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 2.2 mm and the width 4 mm. The circular patch is having 100 mm diameter. 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	24
b	24
c	4
d	2.20

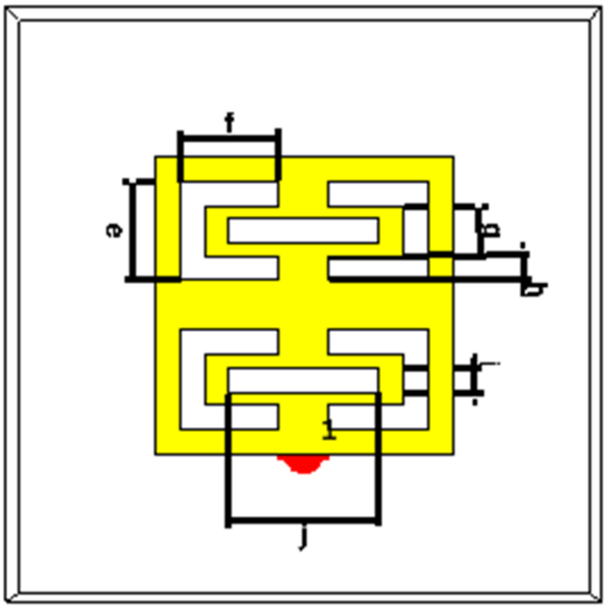

Fig.2 Back view of the metamaterial antenna

The back view of the proposed antenna having novel metamaterial structure which consists of two identical structures stacked over one another. The dimensions were optimised using the simulation software and the optimised 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)
e	8
f	8
g	4
h	2
i	2
j	12

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

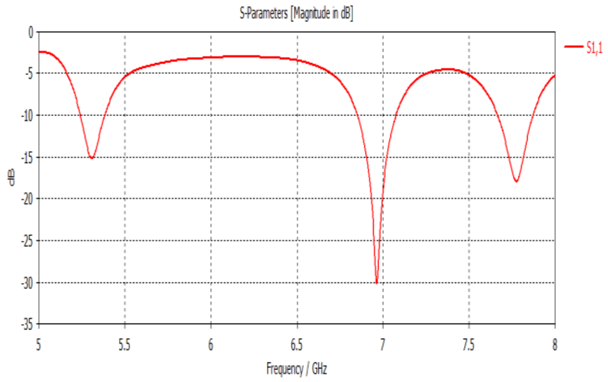

Fig.3 Return Loss

The minimum return loss obtained -15.4 dB in 5.3 GHz, -30 dB in 7 GHz and -17.85 dB in 7.7 GHz for the proposed metamaterial antenna which is given in Fig.3.

3.2 VSWR

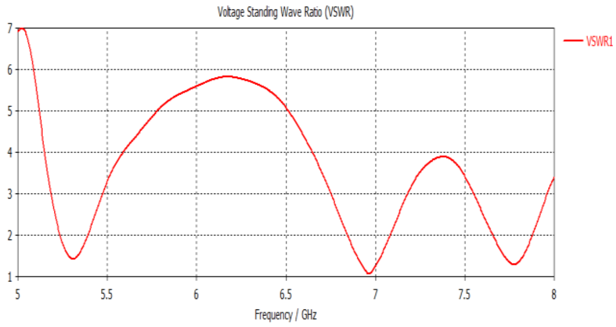

Fig.4 VSWR

The minimum Voltage Standing Wave Ratio VSWR obtained 1.42 in 5.3 GHz, 1.07 in 7 GHz and 1.29 in 7.7 GHz for the proposed metamaterial antenna which is given in Fig.4.

3.3 Efficiency

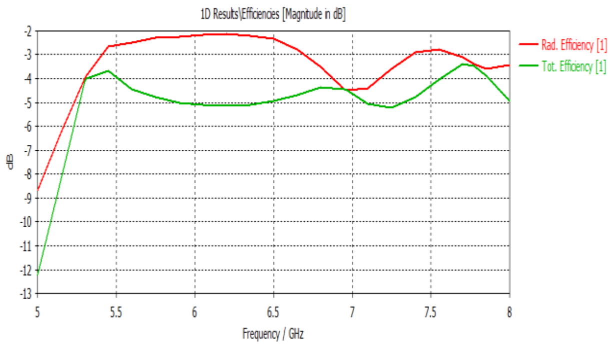

Fig.5 Efficiency

The Maximum Efficiency obtained at 3 GHz is 40 % of total efficiency and 39 % of radiation efficiency for the proposed metamaterial antenna which is given in Fig.5.

3.4 Front to Back Ratio

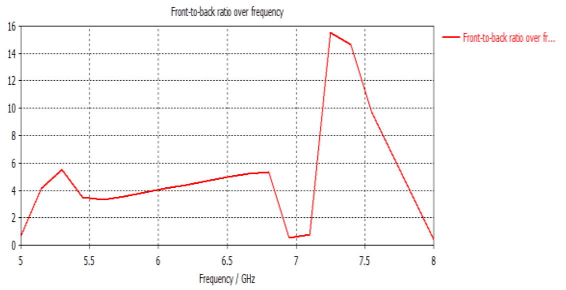

Fig.6 Front to Back Ratio

Front to Back Ratio is the ratio of power gain between the front and rear of a directional antenna. Front to back ratio for the proposed metamaterial antenna is given in figure 6.

3.5 Farfield Plots

3.5.1. Farfield Gain at 5.3 GHz

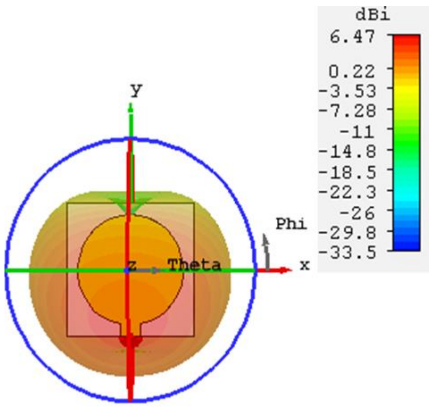

Fig.7 Farfield Gain at 5.3 GHz

3.5.2. Farfield Gain at 7 GHz

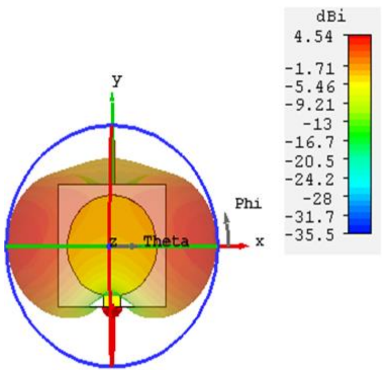

Fig.8 Farfield Gain at 7 GHz

3.5.3. Farfield Gain at 7.7 GHz

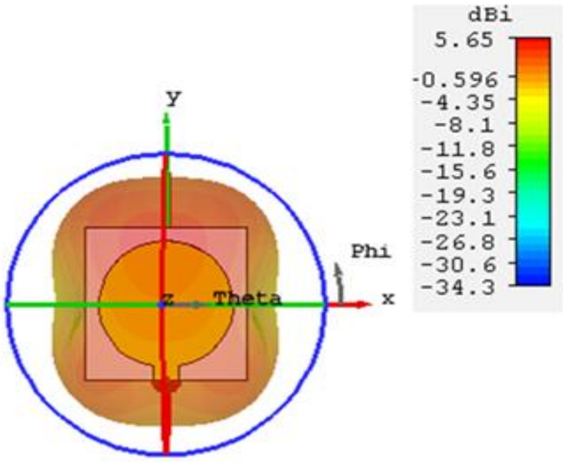

Fig.9 Farfield Gain at 7.7 GHz

3.5.4. Overall Gain at 5 to 8 GHz

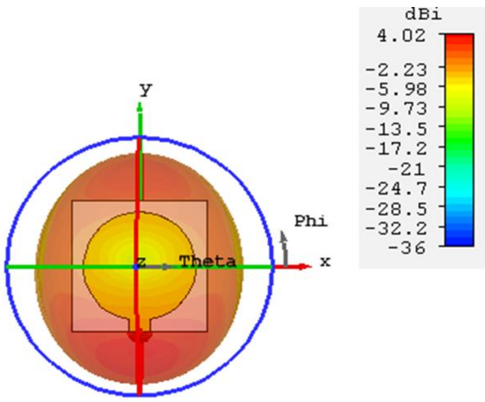

Fig.10 Farfield Gain at 5.3 GHz

3.5.5. Farfield Directivity, Abs Phi=0

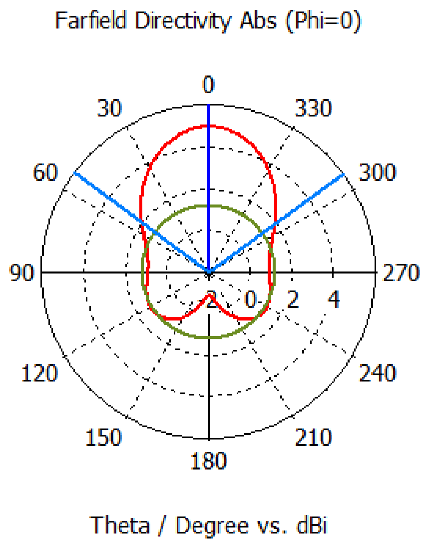

Fig.11 Farfield Directivity, Abs Phi=0

3.5.6. Directivity, constant Phi=90

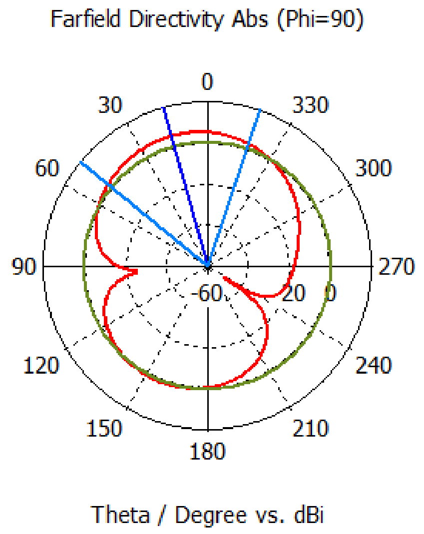

Fig.12 Directivity, constant Phi=90

3.5.7. Farfield Directivity Plot at Theta=0

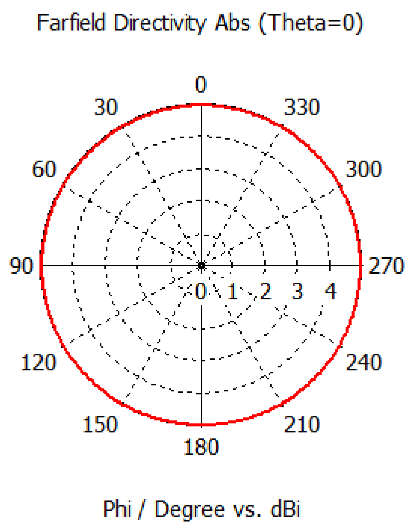

Fig.13 Farfield Directivity Plot at Theta=0

3.5.8. Farfield Directivity Plot at Theta=90

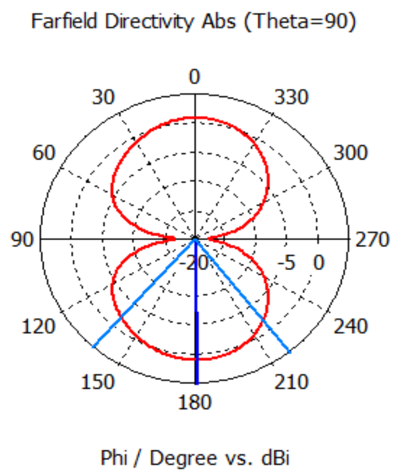

Fig.14 Farfield Directivity Plot at Theta=90

3.6 E Field

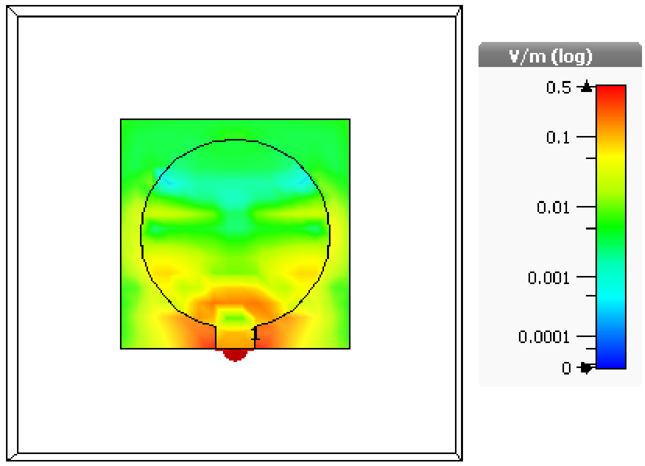

Fig.15 E Field Front View

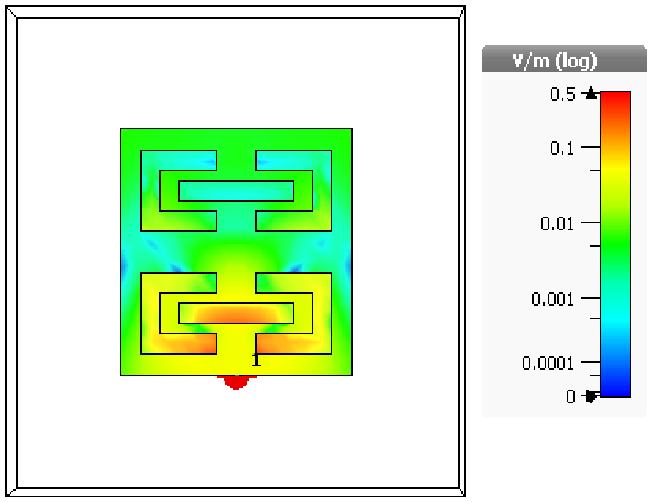

Fig.16 E Field Back View

3.7 H Field

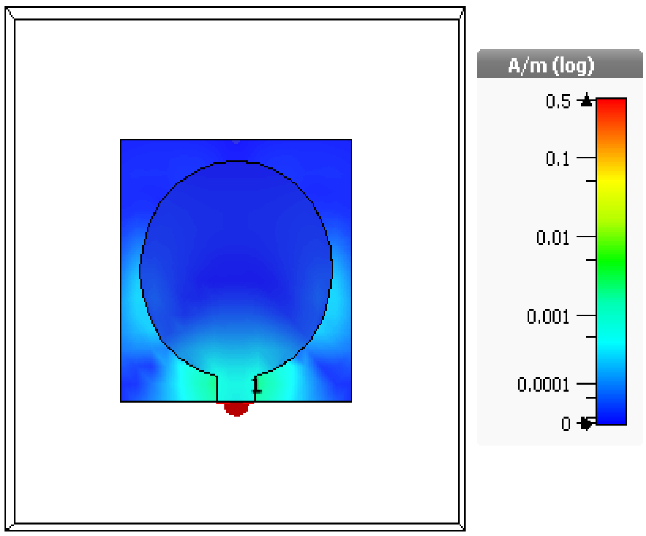

Fig.17 H Field Front View

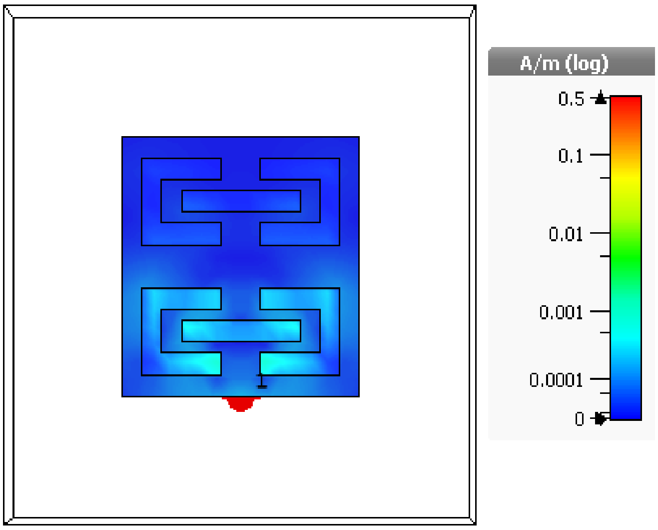

Fig.18 H Field Back View

3.8 Surface current a distribution

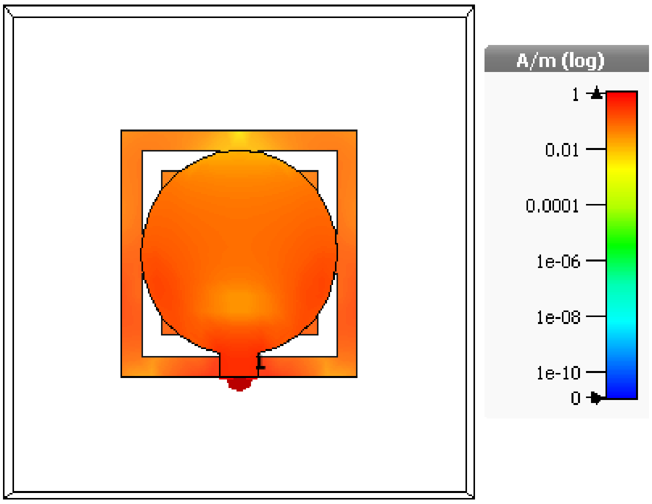

Fig.19 Surface current a distribution Front View

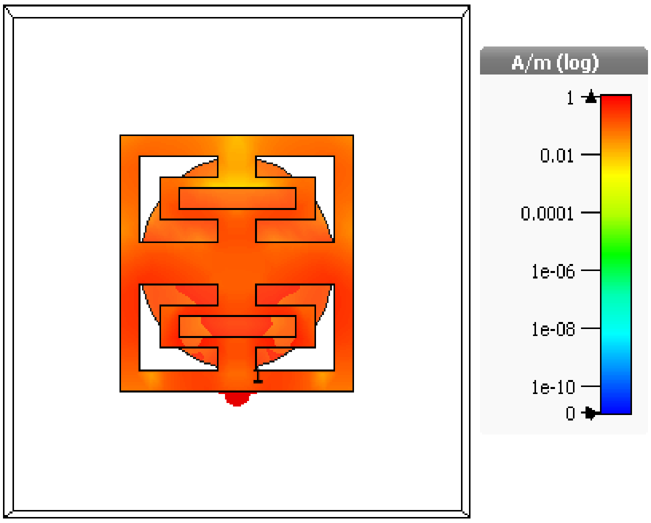

Fig.20 Surface current a distribution Back View

The Overall Results have been presented in Table 3.

TABLE 3

OVERALL RESULTS

Parameter	Value
Operating Frequencies	5.3 , 7 ,7.7 GHz
Return Loss	-15.4 ,-30 ,-17.85 dB
VSWR	1.42,1.07,1.29
Bandwidth	120,250,210 MHz
Efficiency	40 %
Gain	4.54,5.65,6.47 dBi
Front to Back Ratio	4.2,1.5,2.5

IV. CONCLUSION

The proposed metamaterial antenna achieved multiband resonant frequencies such as 5.3 GHz, 7 GHz and 7.7 GHz in compact dimension of 24*24 mm and gain of 4.54, 5.65, 6.47 dBi, and return loss of -15.14, -30, -17.85 dB and the bandwidth of 120, 250, 210 MHz. The proposed antenna is suitable for operating in WLAN and RADAR in C and X band frequency regions.

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