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A Rectangular Ring Slot Microstrip Patch Antenna for Multiband Applications

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Abstract: A Rectangular Microstrip patch antenna (MPA) for multiband applications is designed using slotting technique. The proposed antenna supports different range of frequencies, the antenna can be operated at four different bands i.e., X, S, Ku, and C band. The antenna is designed using FR-4 epoxy substrate with dielectric constant of 4.4 and loss tangent of 0.02 The dimensions of the substrate are 36.27 X 30.03 X 1.5748 mm^3 designed antenna resonates at the following frequencies 3.2, 5.3, 6.6, 8.7, 9.4, 10.2, 10.8, 11.4, 12.4, 13.1, and 14.5 GHz with a gain of 11.11, 7.094, 4.40, 1.19, 6.65, 4.47, 2.69, 4.23, 3.24, 8.25, and 5.89dB respectively. The performance of the antenna is analyzed by various parameters like Return loss, Gain and VSWR etc. The design of antenna carried out using HFSS 13.0 version.

Keywords: MPA, Gain, VSWR, HFSS, Return loss, multi bands, slots

I. INTRODUCTION

In present days it is required that the antenna which will be operated at various frequencies for various applications. There are many advantages of using multiband antennas. One of them is prevents additional usage of bandwidth. There are many techniques for obtaining multiband antennas. Defected ground structure can be opted to obtain two and more bands with circular polarization abilities [1]. There are various other multiband antenna techniques. A rectangular micro strip antenna is used for various applications because of their attractive properties of light in weight, simple to fabrication, compact in size, economic in cost [2]. For these reasons patch antenna is used in this design. Micro strip line feeding technique is used in this design. In this paper rectangular slot is used on the patch to achieve multiband antenna characteristics. The resonating frequencies useful for wireless applications, military and satellite applications, and remote sensing applications.

There are various designs of Micro strip patch antenna with are proposed with diferrent slots for different wireless applications [7]. Performance of the antenna system can be improved using different sized slots in the antenna design [6]. Then structure of the antenna and shape of the patch can also influence the performance dramatically [8]. In this paper the length and width of the designed antenna was calculated by considering the following design procedure [2] employing the rectangular ring slot in the patch antenna to achieve multiple bands. The designed antenna covers 3.2 GHz to 14.5 GHz bands.

II. ANTENNA DESIGN CONSIDERATIONS

Rectangular microtrip patch antenna is modeled by using the following considerations. The simple rectangular patch antenna structure is given below in Fig 1. And the proposed design is shown in Fig 2.

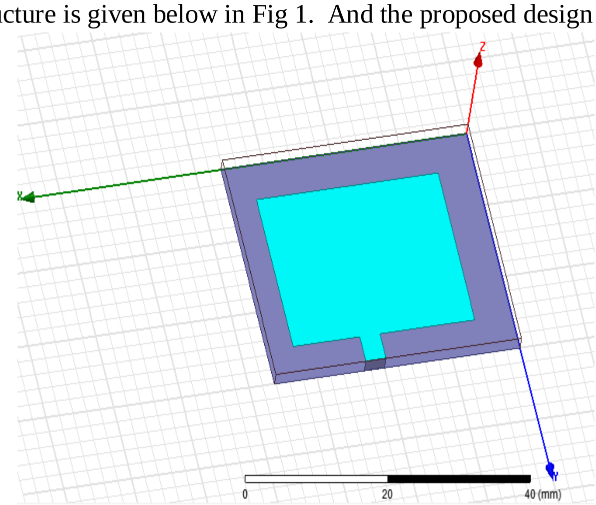

Fig. 1 Simple Rectangluar Patch Antenna

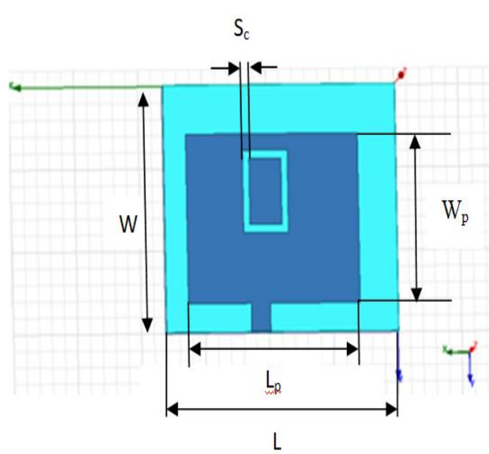

Fig. 2 Proposed Patch Antenna design

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A. Design Procedure

1) First choose the frequency of resonant f_r substrate thickness (h) and dielectric constant $\in_r$.
2) The width and length of patch is calculated as follows:
3) Patch width is taken as

$$W = \frac{c}{2 f_r}\sqrt{\frac{2}{\in_r + 1}} \quad \text{...} (1)$$

Where c=3x10^8 m/s

4) The patch length is taken as

$$L = L_{eff} - 2\Delta L \quad \text{…………………………………..} (2)$$

$$L_{eff} = \frac{c}{2 f_r \sqrt{\in_{reff}}} \quad \text{……………………….………} (3)$$

Where effective dielectric constant is

$$\in_{reff} = \frac{\in_r + 1}{2} + \frac{\in_r - 1}{2}[1 + 12\frac{h}{w}]^{-1/2} \quad \text{…………} (4)$$

Where Normalized extension length is

$$\Delta L = 0.412h \frac{(\in_{reff} + 0.3)(\frac{w}{h} + 0.264)}{(\in_{reff} - 0.258)(\frac{w}{h} + 0.8)} \quad \text{………} (5)$$

5) The length of the substrate is taken as $L_s = L + 6h$ and the width of the patch is taken as $Ws = W + 6h$

TABLE I Antenna Design Parameters

S.No	Parameter	Notation	Value
1.	Relative Permittivity	ε_r	4.4
2.	Operating Frequency(GHz)	f_r	3.4
3.	Height of Substrate(mm)	H	1.5748
4.	Substrate width(mm)	W	36.27
5.	Length of Substrate(mm)	L	30.03
6.	feed line width(mm)	w_{feed}	3
7.	Length of feed line(mm)	l_{feed}	12
8.	Length of the patch(mm)	L_P	20.59
9.	Width of the patch(mm)	W_p	26.83
10.	Ring slot width (mm)	S_c	1
11.	Length of the slot(mm)	L_{slot}	7

Where

c is free space velocity.

$\in_r$ is dielectric constant

L is patch length.

W is patch width.

h is thickness of the substrate

L_s is substrate length.

W_s is substrate width

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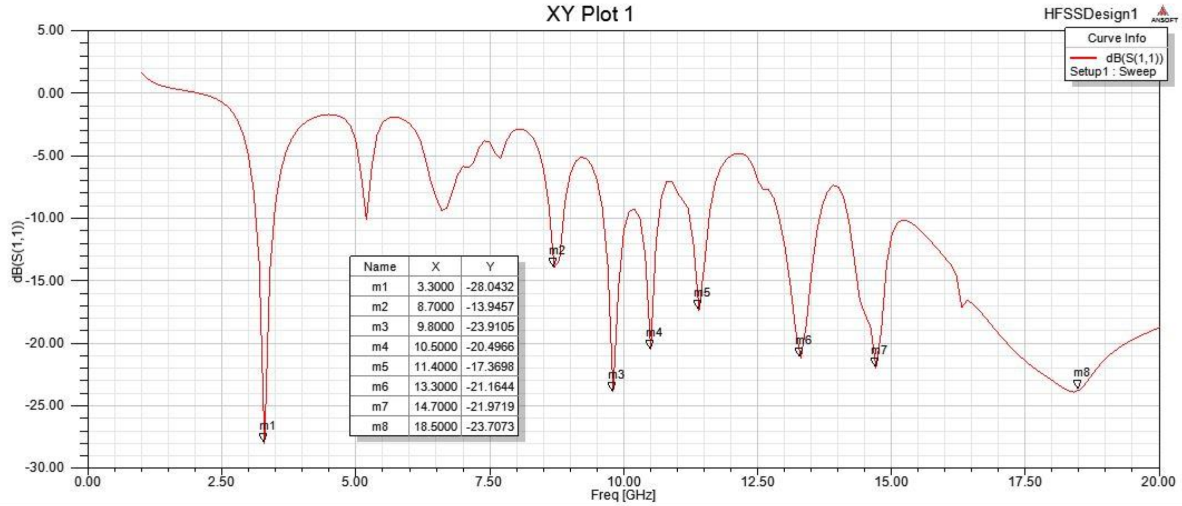
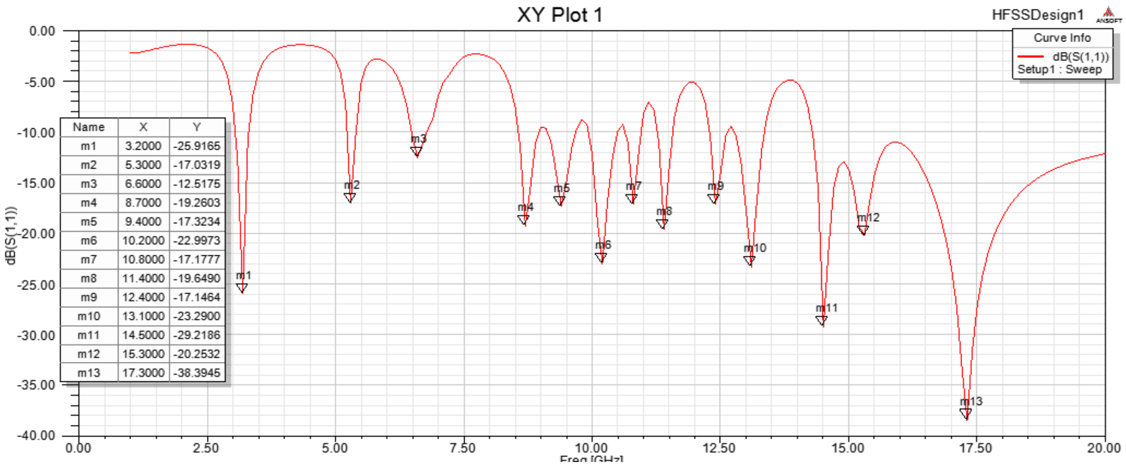
III. SIMULATION RESULTS

1) *Return loss:* The phenomenon of propagation of signal reflected back when impedance mismatch occurs. The return loss is calculated as $RL = -20\log_{10}^{|\Gamma|}(dB)$ ……………………………………………………(6)



Name	X	Y
m1	3.3000	-28.0432
m2	8.7000	-13.9457
m3	9.8000	-23.9105
m4	10.5000	-20.4966
m5	11.4000	-17.3698
m6	13.3000	-21.1644
m7	14.7000	-21.9719
m8	18.5000	-23.7073

Fig. 3 Return loss plot for simple MPA

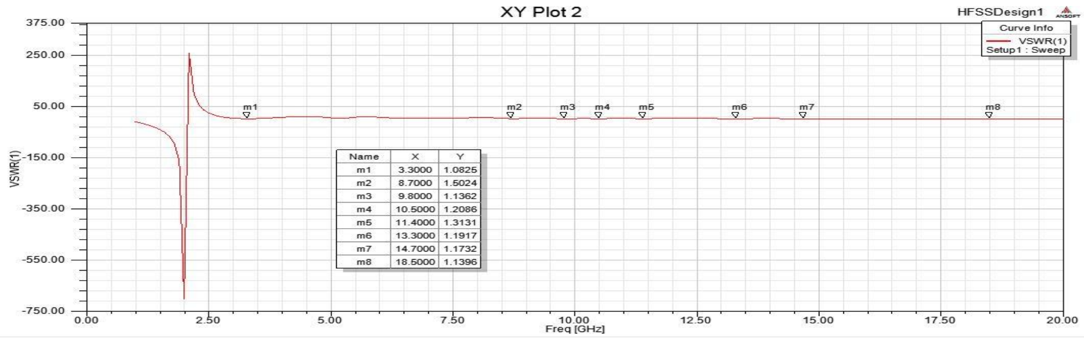


Name	X	Y
m1	3.2000	-25.9165
m2	5.3000	-17.0319
m3	6.6000	-12.5175
m4	8.7000	-19.2603
m5	9.4000	-17.3234
m6	10.2000	-22.9973
m7	10.8000	-17.1777
m8	11.4000	-19.6490
m9	12.4000	-17.1464
m10	13.1000	-23.2900
m11	14.5000	-29.2186
m12	15.3000	-20.2532
m13	17.3000	-38.3945

Fig. 4 Return loss for Slotted MPA

2) *VSWR: It shows how much power is reflected back from the antenna. It is Expressed as*

$$VSWR = \frac{1+\Gamma}{1-\Gamma} \quad \text{……………………………………………… (7)}$$



Name	X	Y
m1	3.3000	1.0825
m2	8.7000	1.5024
m3	9.8000	1.1362
m4	10.5000	1.2086
m5	11.4000	1.3131
m6	13.3000	1.1917
m7	14.7000	1.1732
m8	18.5000	1.1396

Fig. 5 VSWR plot for Simple MPA

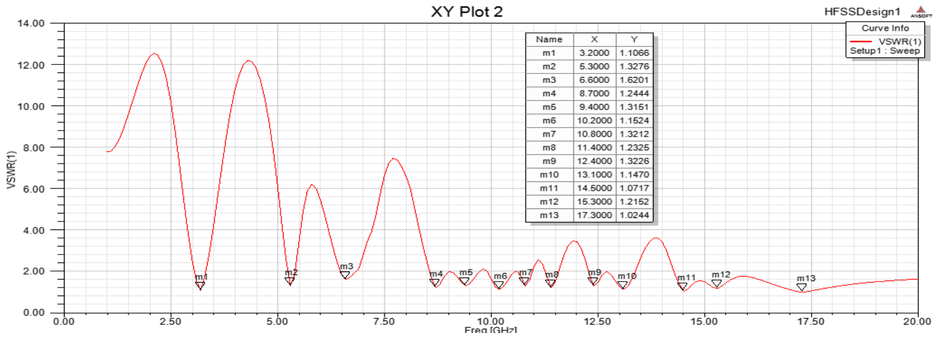


Fig. 6 VSWR plot for Slotted MPA

3) *Gain:* It is the amount of power transferred in that direction.

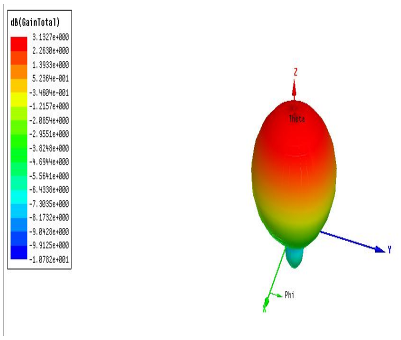


Fig. 7 Total gain of the Simple MPA

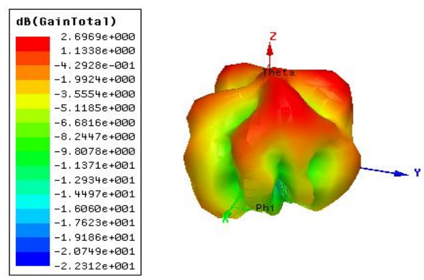


Fig. 8 Total gain of the Slotted MPA

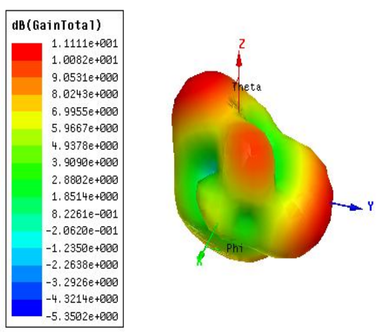


Fig. 9 Gain at 3.2 GHz

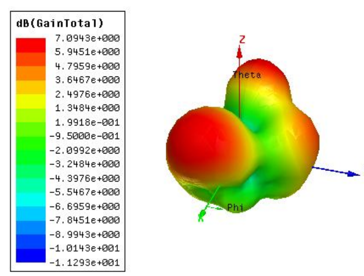


Fig. 10 Gain at 5.3 GHz

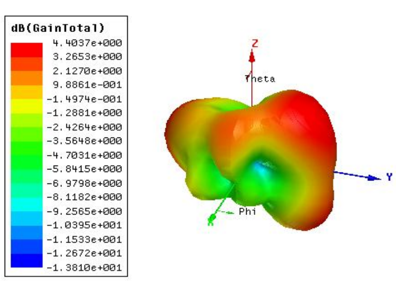


Fig. 11 Gain at 6.6 GHz

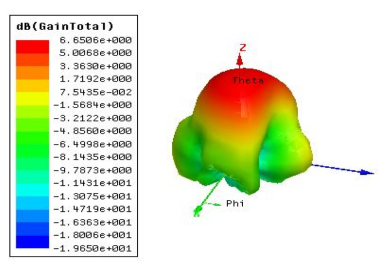


Fig. 12 Gain at 9.4 GHz

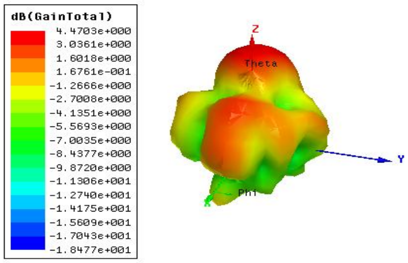


Fig. 13 Gain at 10.2 GHz

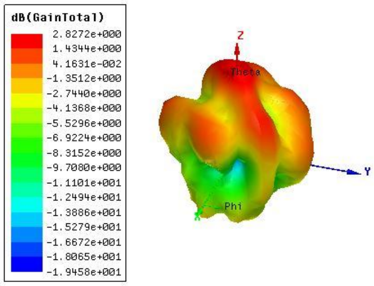


Fig. 14 Gain at 10.8 GHz

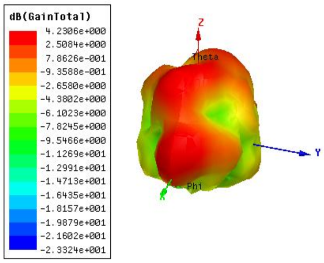


Fig. 15 Gain at 11.4 GHz

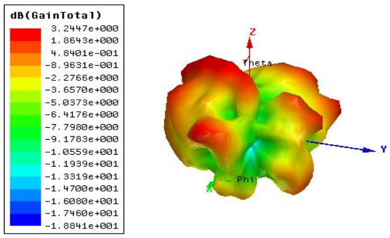


Fig. 16 12.4 GHz gain

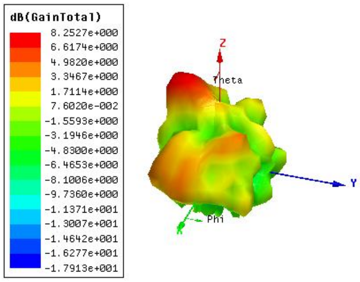


Fig. 17 Gain at 13.1 GHz

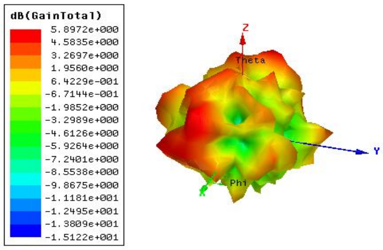


Fig. 18 Gain at 14.5 GHz

4) *Current distribution:* Slotted MPA current distribution at E-field and at H-field are bellow in following figures.

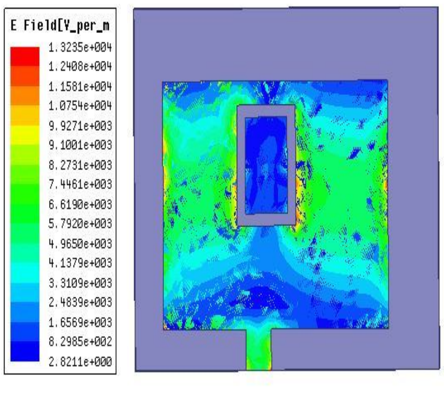


Fig. 19 Current distributuion at 3.4 GHz (E-plane)

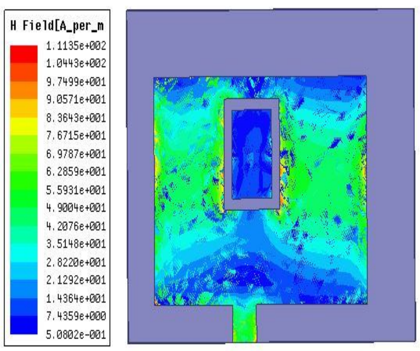


Fig. 20 Current distributuion at 3.4 GHz (H-plane)

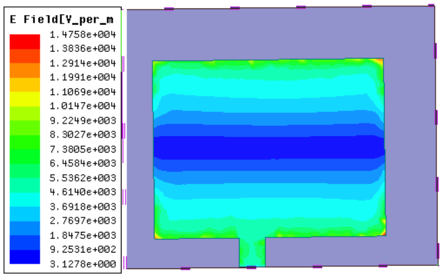


Fig. 21 E plane Current distributuion at 3.4 GHz

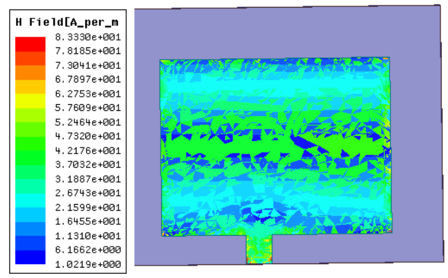


Fig. 22 Current distributuion at 3.4 GHz (H-plane)

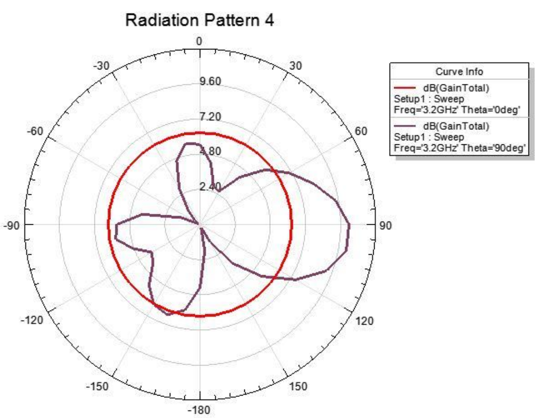


Fig. 23 H plane radiation pattern at 3.2 GHz

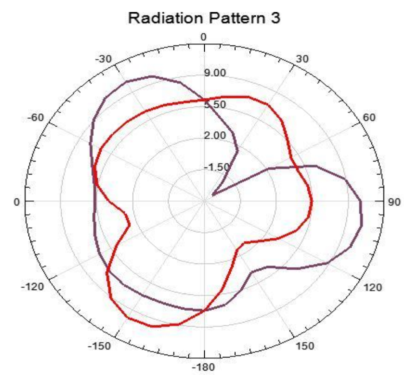


Fig.24 E plane radiation pattern at 3.2 GHz

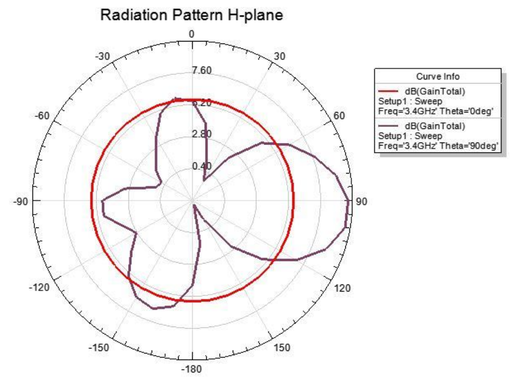


Fig. 25 Radiation pattern at 3.4 GHz (H-plane)

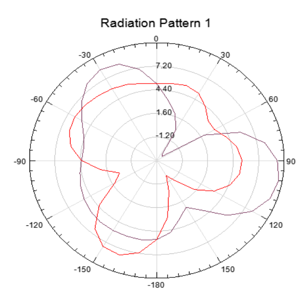


Fig. 26 Radiation pattern at 3.4 GHz (E-palne)

TABLE III
SIMULATED RESULTS OF SIMPLE ANTENNA

S.No	Frequency (GHz)	S11 (dB)	VSWR	Gain (dB)	Band width (MHz)
1.	3.3	-28.04	1.08	3.87	---
2.	8.7	-13.94	1.50	1.62	240
3.	9.8	-23.91	1.13	8.8	430
4.	10.5	-20.49	1.20	2.82	430
5.	11.4	-17.16	1.31	3.41	350
6.	13.3	-21.16	1.19	4.56	740

TABLE IIII

SIMULATED RESULTS OF SLOTTED MPA

S.No	Frequency (GHz)	S11 (dB)	VSWR	Gain (dB)	Band width (MHz)
1.	3.2	-25.91	1.10	11.11	270
2.	5.3	-17.03	1.32	7.09	170
3.	6.6	-12.51	1.62	4.4	300
4.	8.7	-19.26	1.24	1.19	210
5.	9.4	-17.32	1.43	6.65	430
6.	10.2	-22.99	1.15	4.47	500
7.	10.8	-17.17	1.32	2.69	500
8.	11.4	-19.64	1.23	4.23	310
9.	12.4	-17.14	1.32	3.24	310
10.	13.1	-23.29	1.14	8.25	350
11.	14.5	-29.21	1.03	5.89	580

The designed slotted antenna compared with the simple rectangle patch antenna design the over all the designed antenna gain is increased to 11.11 dB and the number of resonating frequencies also increased from 6 to 11 . The design antenna supports high gain applications.

IV. CONCLUSIONS

The proposed multi Band antenna is resonating at eleven frequencies and has better gain and return loss. These are in the operating range of X band, S band, Ku band C band. The antenna proposed particularly radiates at 3.2, 5.3, 6.6, 8.7, 9.4, 10.2, 10.8, 11.4, 12.4, 13.1, and 14.5 GHz with gains of 11.11, 7.09, 4.4, 1.19, 6.65, 4.47, 2.69, 4.23, 3.24, 8.25, and 5.89 dB respectively. It is observed that antenna has high gain of 11.11 dB at 3.2 GHz. The proposed antenna is mostly preferred for wireless, military and satellite and remote sensing applications etc. The designed micro strip patch antenna is analyzed and simulated using HFFS 13.0 version software.

V. ACKNOWLEDGMENT

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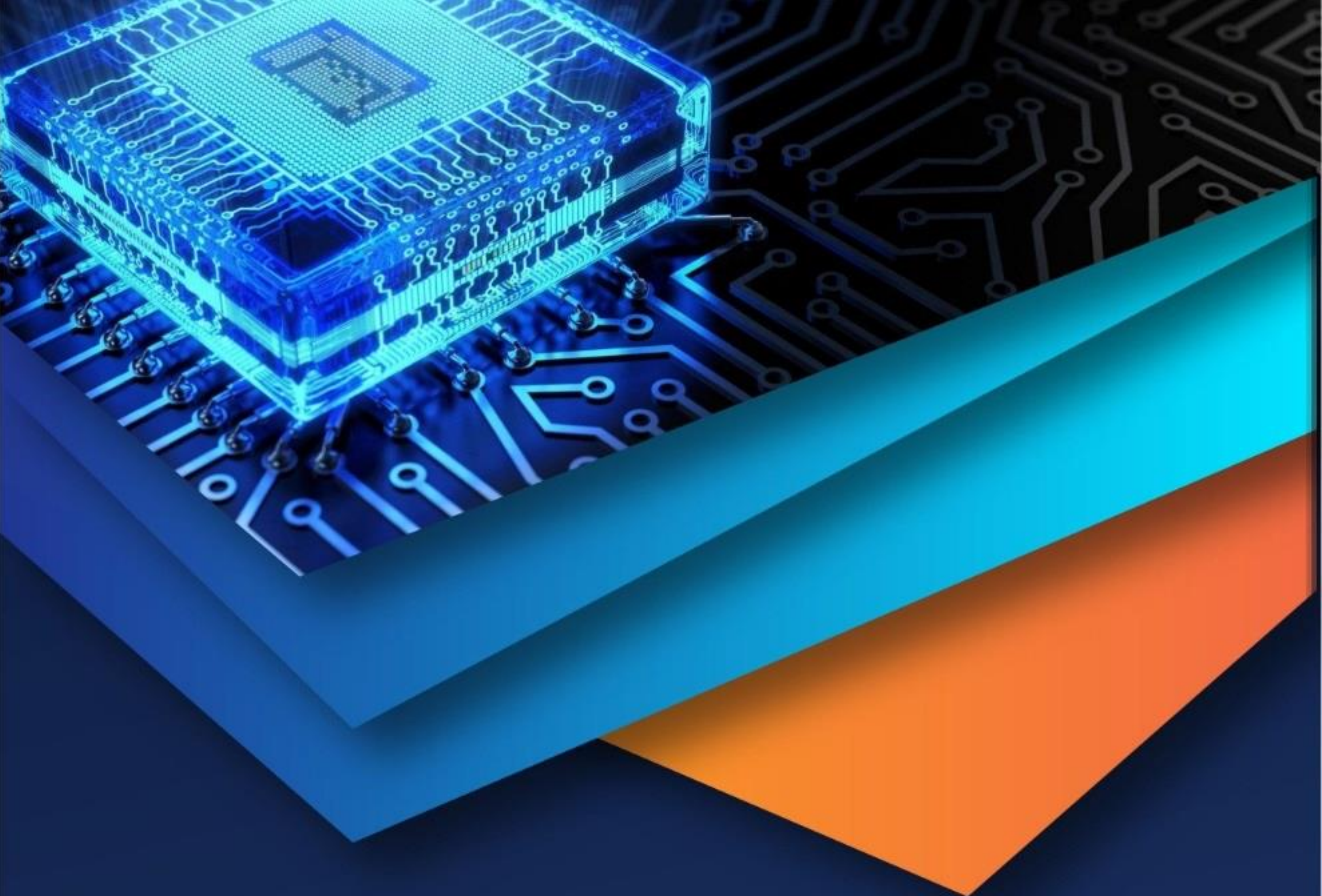

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