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DEVELOPMENT OF RECTANGULAR MICROSTRIP PATCH ANTENNA PARAMETERS USING CORNER ROUNDING TECHNIQUE

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ABSTRACT

In this paper, a simple and small in size rectangular microstrip patch antenna has been designed and its parameters are compared with rectangular microstrip patch antenna (RMPA) with round corners. Simulation of the antenna has been operated at 2.45 GHz wireless radio band using High Frequency Structure Simulator (HFSS) Software (14.0). The performance characteristics antenna parameters for RMPA with round corners such as return loss of -21.9022 dB, Voltage Standing Wave Ratio (VSWR) of 1.2, gain 7.8578 dB and bandwidth 36 MHz at 2.45 GHz. The results showed satisfactory performance.

***Keywords*— Ansoft HFSS (14.0), Corner Round Effect, Rectangular Microstrip Patch Antenna (RMPA).**

I. INTRODUCTION

Nowadays, use of Microstrip patch antennas has been extensively increased in wireless devices like communication systems etc. Due to its various advantages such as low volume, its compatibility with integrated circuits(IC's), light weight, easy installation on the rigid surfaces, easy integration with the feed networks and low cost [1].The Microstrip patch Antenna does consist of a dielectric substrate having the dielectric constant in the range of 2 to 12. Radiating metallic patch of different geometrical shapes like rectangular, triangular, circular, helical, ring, elliptical etc. is on the one of the sides of the dielectric substrate. The geometrical shape of the patch can be taken according to the requirement. Other side of the substrate constitutes the ground plane. The metallic patch can take any geometrical shapes like rectangular, etc according to the requirement. The patch dimensions correspond to the resonant frequency of the antenna [2].Effects of various design dimensions have been simulated for the operational frequency of 2.45 GHz

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[3].Voltage Standing Wave Ratio (VSWR) to nearly 1 and Reflection coefficient of -21.9022 dB have been achieved. Radiation gain has also been improved to 8.0051 dB.

II. CORNER ROUNDING EFFECT

Rounding of corners which has been done here has an important role in maintaining the balance between the resistive part and the reactive (inductive and capacitive) part as these have the effect on the antenna's impedance matching [3-4].By rounding the corners of the rectangular patch, radiaton modes are excited and the unwanted modes are supressed to give more sight of directed radiation patterns in

different planes. By modifying the rounded corners, the upper frequency edge of the operating band also increases significantly [5]. Rounding of corners has been optimized from 0.5mm to 3 mm with the step size of 0.1 mm. After simulation, best optimized results can be seen at rounded corners of 1.2 mm. So the corner rounding of 1.2 mm has been optimized for the proposed antenna for the better antenna performance results.

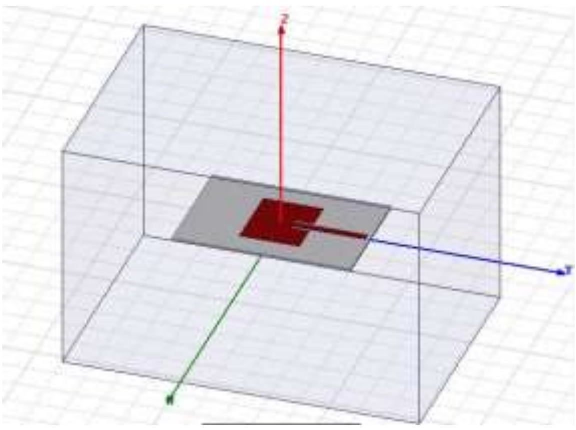

Fig. 1. Model of the designed antenna in HFSS

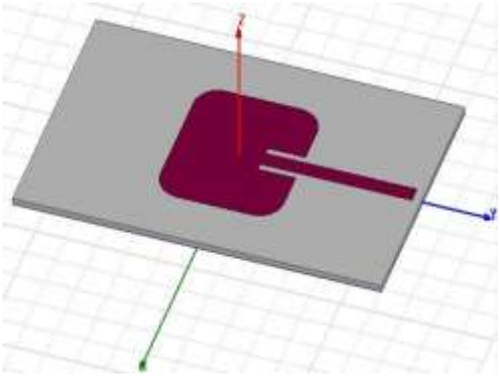

Fig. 2. Geometry of the proposed antenna with rounded corners

III. ANTENNA DESIGN

Fig.1 shows the basic model of the designed antenna consisting of three layers. The ground plane with the size of 78.1 mm and 100.85 mm covers the rectangular shaped substrate on the lower side. The middle layer i.e. dielectric substrate is placed above the lower layer i.e. ground plane. RT/Duroid 5880 (tm) is used here as the antenna substrate having dielectric constant of 2.2, loss tangent of 0.0009 and thickness of the substrate is 2 mm. The upper one layer being the patch covers the dielectric substrate's top surface. The patch used here is rectangular which has sides of 45.4 mm and 38.5 mm that covers the upper middle portion of the dielectric substrate. For proper impedance matching of the antenna, inset fed technique is used. Using this technique, slots are cut down from the patch near the microstrip feed line. Then this patch is fed by the line having 50 Ω input impedance. Initially slots were symmetrically positioned at the centre of the patch, but in order to get proper impedance matching, adjustment of slot position and dimensions need to be done accordingly. A number of simulations have been performed for different slot position and dimensions using HFSS to obtain the better results in the frequency range ranging from 2 to 3 GHz. Convergence was tested for a number of times. Various analysis methods have been proposed for the design of antenna which include transmission line, free space, co-axial probe and cavity techniques. From these, transmission line analysis method has been used here for the proposed antenna. The design dimensions of antenna depend on the operational frequency [4].The designing equations are given below:

A. *Calculation of the Width (W)*

To design a RMPA, all the dimensional parameters for simple patch antenna are initially calculated using the conventional formulae [2]. Width of patch can be calculated as

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$$W_p = V_f/(2 * \frac{f*\sqrt{\in+1}}{\sqrt{2}}) \quad (1)$$

Where V_f is velocity of light, f is resonant frequency and $\in$ is dielectric constant

B. *Calculation of Effective dielectric constant* $(\in_{reff})$

Due to the air-dielectric interface, effective dielectric constant can be calculated as the combination of dielectric constant of substrate and dielectric constant of air above it at the edges of the patch given by

$$\in_e = \frac{\in+1}{2} + \frac{\in-1}{2}/\sqrt{[1 + 12 * \frac{h}{W_p}]} \quad (2)$$

where $\in$ is dielectric constant of antenna substrate, h is the substrate height, W is the patch width.

C. *Calculation of the Effective length* (L_{eff})

The effective length is given by:

$$L_{eff} = \frac{c}{2f_r\sqrt{\in}_{eff}} \quad (3)$$

D. *Calculation of the length extension (ΔL)* Due to the effect of fringing, electrical length of microstrip antenna seems to be lengthier than its actual physical dimensions (length). For the principal E-plane the dimensions of the path along its length are extended on each side by a distance ΔL, which is a function of effective dielectric constant and width to height ratio (W/h).The length extension is:

$$\Delta L = 0.412h \frac{(\in_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\in_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (4)$$

E. *Calculation of patch actual length (L)* As the resonant element is having the narrow bandwidth; the patch length becomes a very critical parameter. The actual length is obtained by:

$$L = L_{eff} - 2\,\Delta L \quad (5)$$

F. *Feed point location*

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Feed point (x, y) location is determined to obtain a good impedance match between the generators impedance and input impedance of the patch. With the change in the feed point location, input impedance gets changed. At the resonant frequency, the input resistance can be obtained by

$$R_{in} = R_r \cos^2\left(\frac{\pi x_f}{L}\right) \quad ; R_r \geq R_{in} \qquad (6)$$

Where x_f the inset length from the radiating edge is, R_r is the radiation resistance at resonant frequency, R_{in} is the input impedance of feed line generally taken 50 Ω. After calculating all parameters a three layer simple patch antenna can be designed with lowermost layer as ground plane of PEC material with thickness approximately equal to thickness of patch. Above the ground plane there is substrate of material RT/Duroid 5880 (tm) and the uppermost layer is patch. All other parameters used to design simple patch antenna are shown in Table. I.

IV. DESIGN DIMENSIONS

Dimensions for the design of antenna with rounded corners are given in Table I.

TABLE I. DESIGN PARAMETERS FOR RMPA WITH ROUNDED CORNERS

Sr. No.	Parameters	Dimensions
1	Substrate dimension along X	78.1mm
2	Substrate dimension along Y	100.85 mm
3	Substrate thickness	2mm
4	Dielectric Constant	2.2
5	Substrate Dielectric Material	RT/Duroid 5880 (tm)
6	Loss Tangent	0.0009

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7	Patch dimension along X	45.4 mm
8	Patch dimension along Y	38.5 mm
9	Inset distance	11.369mm
10	Feed width	4.52mm
11	Feed length	35.298mm
12	Solution frequency	2.4 GHz
13	Corner rounding in modified antenna	1.2mm

V. SIMULATIONS AND RESULTS

Considering design parameters of Table 1 without round corners and operating frequency as 2.45 GHz, following simulation results are obtained using HFSS Software (14.0).

A. Return loss

Simulation results of RMPA with round corners structure are obtained using HFSS software. Fig.4 shows graph of reflection coefficient in dB verses frequency of RMPA with rounded corners. At 2.45 GHz, frequency simulated RMPA with round corners structure exhibits the reflection coefficient of -21.9022 dB.

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Fig 3. Return Loss of Microstrip Patch Antenna with rounded corners

B. VOLTAGE STANDING WAVE RATIO (VSWR)

Simulation results of VSWR are obtained using HFSS software. Fig. 3 shows graph of VSWR verses frequency of RMPA. At 2.45 GHz frequency simulated RMPA exhibits the VSWR of 1.2.

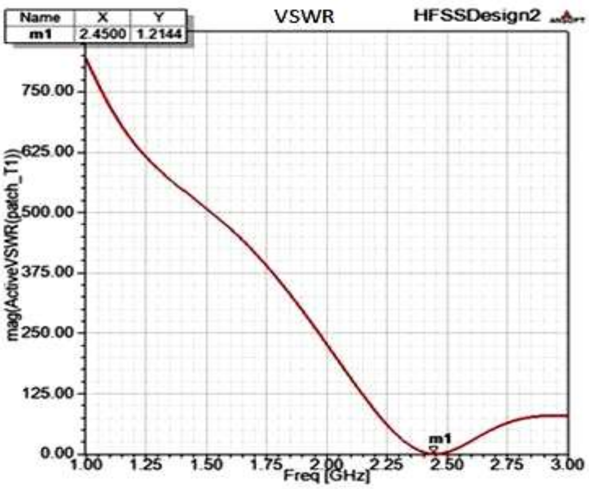

Fig 4. VSWR of Microstrip Patch Antenna with rounded corners

C. Radiation pattern

Fig. 6 shows radiation pattern of RMPA having maximum gain of 7.8578 dB . Fig. 7 and Fig. 8 depicts Radiation pattern of phi = 0 and 90.

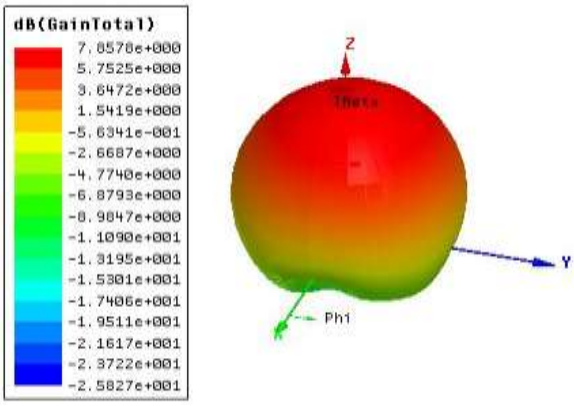

Fig 5. Radiation gain of rectangular microstrip patch antenna with rounded corners

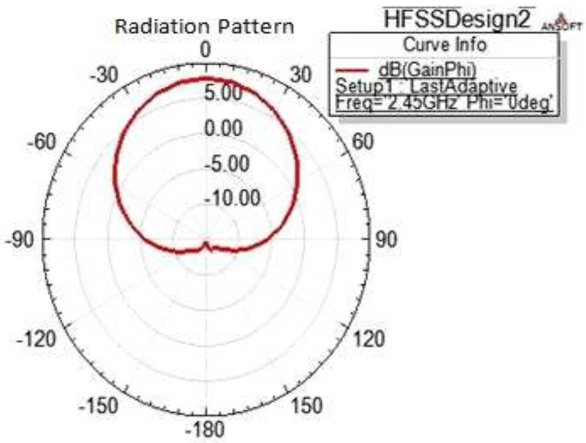

Fig 6. Radiation pattern of phi = 0 degree of rectangular microstrip patch antenna with rounded corners

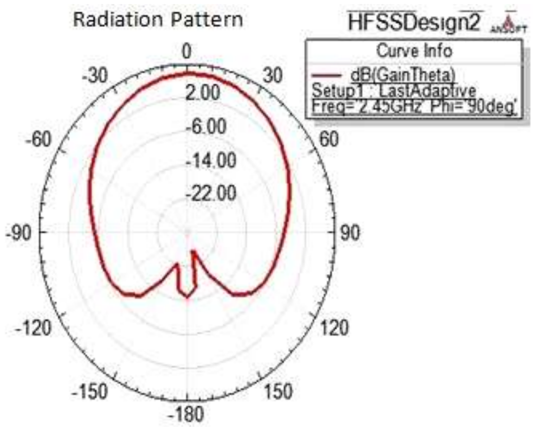

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Fig 7. Radiation pattern of phi = 90 degree of rectangular microstrip patch antenna with rounded corners

VI. RESULTS AND DISCUSSION

A same RMPA with round corners is proposed and the simulated results have been compared with the conventional antenna (without round corners) at resonant frequency of 2.45 GHz. This shows that when corner rounding is introduced in the antenna, then performance parameters of antenna like bandwidth, reflection coefficient, radiation gain, VSWR are improved. Simulated results are summarized in Table II.

TABLE II. RESULT TABLE

Parameter	RMPA with Rounded Corners
Reflection coefficient	-21.9022 dB
VSWR	1.2
Gain	7.8578 dB
Bandwidth	36 MHz
Resonant Frequency	2.45 GHz

VII. CONCLUSION

It is observed that, by introducing the corner rounding of 1.2 mm, drawbacks of RMPA can be overcome. Increased radiation gain of 8.0051 dB indicates that now most of the power would be radiated from the patch and only a small amount of reflection waves would be returned back to the source. VSWR has also come nearly to 1.There is improvement in Reflection coefficient although -21.9022 dB. Bandwidth is increased 36 MHz which is very useful for wireless communications. Further improvement in performance parameters can be increased by taking different radii or location of Round Corners.

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