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Design of a Slotted Rectangular Microstrip Patch Antenna Operated in ISM Band Using RT-Duroid Substrate

Merbin John[1], Manoj B[2], Jagadish Chandran G[3]

PG Student [VLSI], Dept. of ECE, College of Engineering Munnar, Kerala, India [1]

Assistant Professor, Dept. of ECE, College of Engineering Munnar, Kerala, India [2]

Assistant Professor, Dept. of ECE, College of Engineering Munnar, Kerala, India [3]

ABSTRACT: This paper give the modified design of a rectangular microstrip patch antenna operated in ISM band with enhanced directivity and gain along with a reduction in size. The antenna designed in RT-DUROID substrate with inset feeding technique. The dimension of the feed line is 21.06 x 6.16 mm.The designed antenna has 80MHz of band width and -34 dB of return loss for ISM 2.48 GHz frequency band. Since we designed antenna using RT-DUROID substrate which has low loss tangent, it has minimum power loss. It is able to achieve a gain and directivity above 7dB.

KEYWORDS: Microstrip Patch Antenna; Slotted patch antenna; Inset Feeding

I. INTRODUCTION

We can see a fast growth in the field of wireless and mobile communication. Now a day's most of the embedded systems are relies on mobility. Embedded system can be classified in basically to Stand Alone Embedded Systems and Mobile Embedded Systems. Some of the major mobile wireless embedded applications such as wireless local area network (WLAN) identified as IEEE 802.11b and IEEE 802.11g which is operated in the ISM 2.4 GHz band necessitate an antenna that operated in 2.4 GHz frequency. In such cases, due to some better physical properties like reliability, reproducibility, light weight, low profile, low production cost, and ease of fabrication, microstrip antenna is popular with all types of wireless equipments. A slotted microstrip patch antenna has better characteristics including wider bandwidth, high gain, less return loss and less conductor loss. Such antennas are must be capable of exchanging high data rate streams with a low return loss, high directivity and bandwidth.

In this paper design of a slotted rectangular microstrip patch antenna having minimum height, high gain, low return loss and high directivity is explained. Our design analysis was gone through different antenna models and the final antenna is build on RT-Duroid substrate having minimum height of 2 mm that satisfy all design equations. Since RT-Duroid has a dielectric constant of εr=2.2, it has the low loss tangent and hence the least dielectric losses associate with an antenna. Since most of the wireless embedded systems are operated in ISM band, the preferred antenna is designed at 2.4 GHZ ISM band frequency. The proposed antenna model is designed with inset feeding technique and with a characteristic impedance of 50 ohm. The basic rectangular microstrip patch antenna layout is adapted from a paper published by Angana Sarma, Kumaresh Sarmah and Kandarpa Kumar Sarma then we modified its dimensions and slot cuts for RT-Duroid substrate using several design equations. The height is optimized to its minimum which will make the antenna compactable and reduce power losses associate with it.

Since microstrip patch antenna consume low power and also be designed to meet application requirements it is preferred for such mobile applications. Several works of similar nature have been reported as outlined below. In paper [1], the authors report the design of a 4 x 4 microstrip square patch antenna array operating at 2.4 GHz with a return loss of -8 dB and 16 \% bandwidth for wireless video using point to point communication system. It uses inset feeding technique .A novel dual broadband rectangular slot antenna for 2.4 and 5 GHz wireless local area network (WLAN) with the use of a U-shaped strip inset at the centre of the rectangular slot antenna were reported in [2].All these works

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designed antennas with gain and directivity less than 5dB.But here, the proposed antenna has gain and directivity greater than 7 dB and better returnloss while we scarifies the bandwidth.

II. PROPOSED MODEL

In this paper, the modified design of a rectangular microstrip patch antenna that reported in [3] is given. This design is based on transmission line model. This model represents the microstrip antenna with a width W and height h, separated by a transmission line of length L. The microstrip transmission line consists of three layers namely metal strip, ground plane and dielectric substrate. Fig. 1 shows the layout of the proposed inset feed microstrip patch antenna.

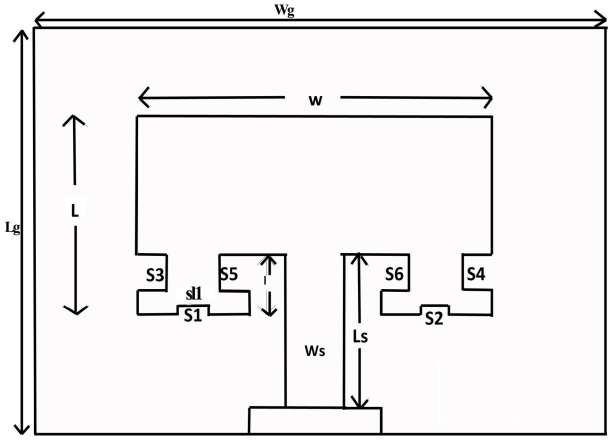

Fig. 1: Proposed Antenna Model

The antenna design was done in different steps. First step was the calculation of antenna dimensions according with specific mathematical equations available in different reference papers. Then we designed antenna using a software tool and cut proper slots in order to achieve the require characteristics.
The mathematical calculations in our design include,

A. Selection of Dielectric substrate:
To select a substrate for design a microstrip patch antenna, its dielectric constant usually in the range of $2.2 \leq \varepsilon_r \leq 12$. Dielectric substrate used for this design is RT-DUROID with a relative permittivity (ε_r) value of 2.2 .since it has less dielectric constant and loss tangent, antenna designed using this particular substrate has minimum dielectric loss. Hence we can use it for mobile embedded applications with minimum power losses.

B. Selection of Patch dimension:
The performance of the microstrip antenna depends on patch dimensions. To design the proposed antenna we calculated the following dimensions using the reference equations [4][5]given below

1. *Calculation of Width (W) of patch.*

$$W=\frac{1}{fr\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} = \frac{C}{2fr}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (1)$$

Where
c = free space velocity of light
f_r = resonating frequency
ε_r = Dielectric constant of substrate

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2. *The effective dielectric constant of the rectangular micros trip patch Antenna.*

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(\frac{1}{\sqrt{1+\frac{12h}{w}}}\right) \quad (2)$$

3. *The actual length of the Patch (L).*

$$L = L_{eff} - 2\Delta L \quad (3)$$

Where

$$L_{eff} = \frac{c}{2fr\sqrt{\varepsilon_{eff}}} \quad (4)$$

ΔL=*Length Extension.*

4. Calculation of Length Extension.

$$\frac{\Delta L}{h} = 0.412\,\frac{(\varepsilon_{ef}+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{w}{h}+0.8\right)} \quad (5)$$

Here, for the calculations take h=2mm

5. *Length of ground*
$$L_g = 6h+L \quad (6)$$

6. Width of ground
$$W_g = 6h+w \quad (7)$$

C. Design of strip line

For a given characteristics impedance and dielectric constant, the relation between width (W) of strip line and thickness (h) (in our design h= 4 mm) of the dielectric layer is given by [6][7][8]

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$$\frac{W_s}{h} = \begin{cases} \dfrac{8 \times e^A}{e^{2\times A} - 2}, & for\ \dfrac{W_s}{h} \le 2 \\ \dfrac{2}{\pi}\left[B - 1 - \ln(2B-1) + \dfrac{\varepsilon_r - 1}{2 \times \varepsilon_r} \times \left\{\ln(B-1) + 0.39 - \dfrac{0.61}{\varepsilon_r}\right\}\right], & for\ \dfrac{W_s}{h} > 2 \end{cases}$$

Where $A = \frac{Z_o}{60} \times \sqrt{\frac{\varepsilon_r + 1}{2}} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1} \times \left(0.23 + \frac{0.11}{\varepsilon_r}\right)$,

$B = \frac{377 \times \pi}{2 \times Z_o \times \sqrt{\varepsilon_r}}$

For the present design, the characteristics impedance =50. Therefore, the width of port 1 is 6.16mm. Again the length of strip is $\frac{\lambda_g}{4}$, where $\lambda_g = \frac{\lambda_0}{\sqrt{\varepsilon_r}}$. In our design ε_r=2.2. Therefore, the length of strip is 21.06 mm. The base model is modified with further improvements to gain and band width by cutting 2 additional slots.

D. Feeding Techniques:

Patch feeding can broadly be classified as either contacting or non-contacting. In the contacting method, either a micro strip line or coaxial cable is used to directly excite the radiating patch. This makes these techniques easy to fabricate and simple to model. The main advantage of these techniques is that impedance matching is relatively easy since the probe or micro strip line can be placed at any desired position [6] [8] [4].

In this geometry, inset feed is used to feed the antenna. Inset length of micro-strip patch antenna is given by[9][10]

$$l = 10^4(0.001699\varepsilon_r^{\ 7} + 0.13671\varepsilon_r^{\ 6} - 6.1783\varepsilon_r^{\ 5} + 93.187\varepsilon_r^{\ 4} - 682.69\varepsilon_r^{\ 3} + 2561.9\varepsilon_r^{\ 2} - 4031\varepsilon_r + 6697)\frac{L}{2}$$

E.Lumped port

A lumped port is inserted as excitation and it would be selected in a way that that impedance matching with the characteristic impedance should be satisfied. The dimensions of lumped port is 18.48mmx4mm

F.Slots

In order to get the better characteristics we modified the number of slots and slot dimensions from the reference paper. These modifications are done through different trials and fixed slot dimensions as given in the table.

Using these equations we calculated the dimensions of antenna which is given in table 1

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TABLE 1: Antenna dimensions

Dimension Parameters	Value(in mm)
L_g	53.12
W_g	61.4
L	41.12
W	49.40
W_s	6.16
L_s	21.06
I	9.89
$S1_l$ &S1w	4.5 &1.5
$S2_1$ &$S2_W$	4.5 &1.5
$S3_l$ &S3w	4.5 &1.5
$S4_l$ &S4w	4.5 &1.5

Simulation Setup

The ANSOFT HFSS software is utilized here for execution of current proposal of coaxial feed rectangular microstrip antenna. And results of return loss, gain and band width are presented.

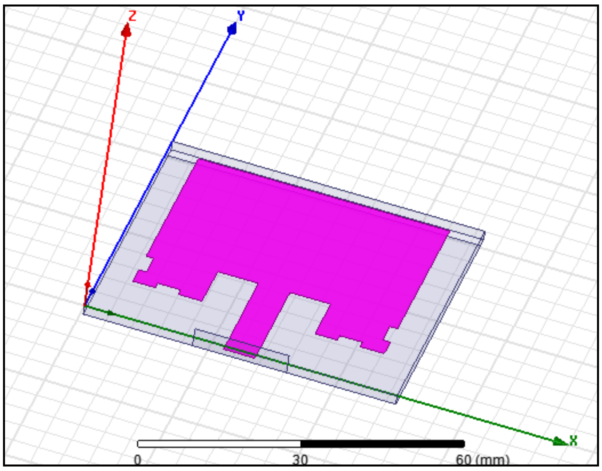

Fig. 2: Simulated model

III. RESULTS

The proposed rectangular patch antenna is designed according to the dimensions mentioned in Table 1. The simulation is done in HFSS. The S parameters of the simulated result are given in Fig 3. The results show an efficient approximation. The antenna dimensions were modified effectively. The height taken for the calculations was 2mm but when we modified the antenna design by cutting different slots. From the modified antenna design, we got a bands at 2.48 GHz. The plots for return loss, radiation pattern,3D plot for gain and directivity that obtained from simulation were drawn in fig 3, 4, 5, 6and 7 respectively. From the simulation observed that the proposed antenna has almost 80MHz bandwidth at 2.4GHz.Its return loss is -34 db along with a VSWR =1.In addition the proposed antenna has gain around 7dB and directivity of 7.1 dB. So this antenna is efficient enough for use in mobile embedded applications operated in ISM band.

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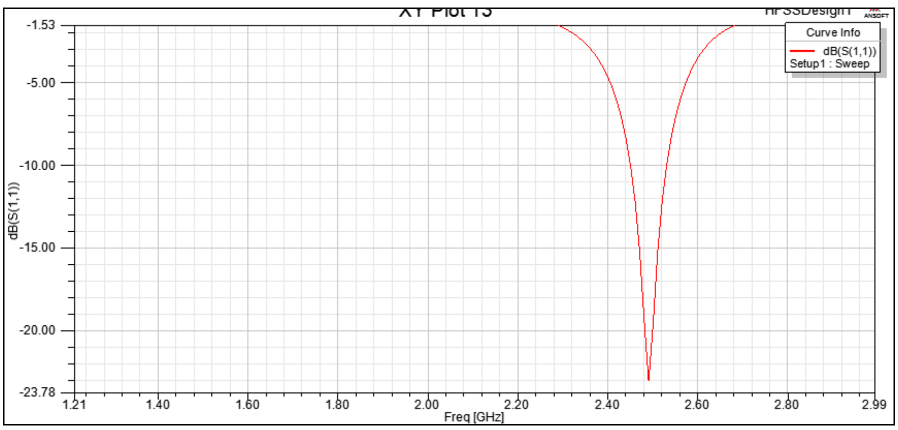

Fig. 3: return loss plot

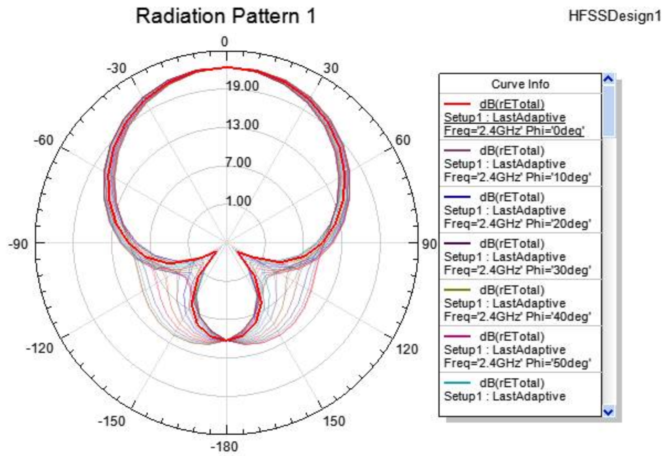

Fig. 4: Radiation plot

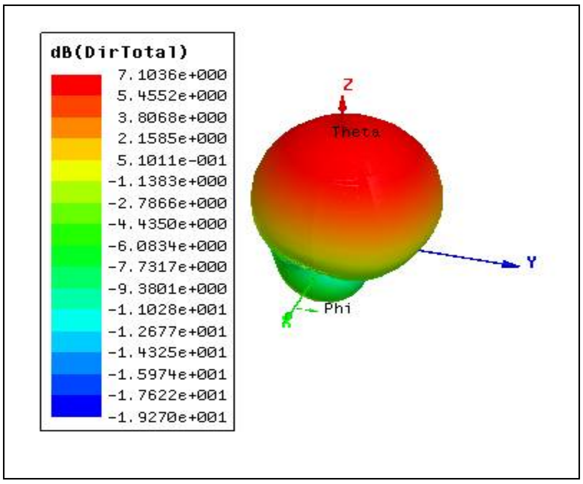

Fig. 5: Gain Plot

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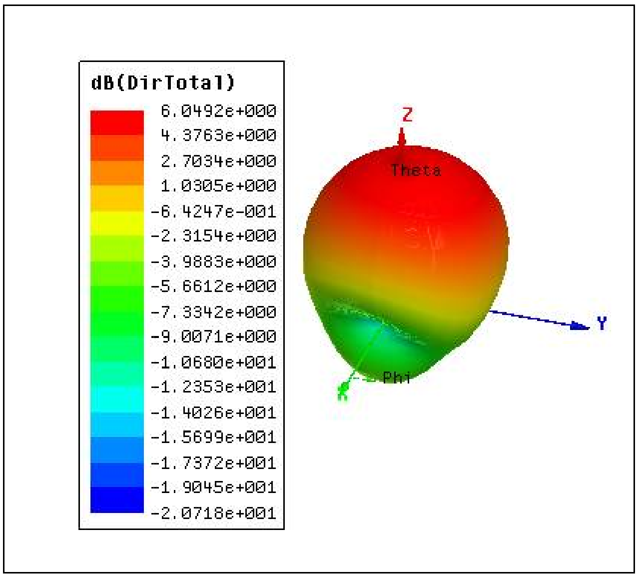

Fig. 6: Directivity Plot

IV. CONCLUSION

In this paper, we have proposed a modified design of slotted rectangular micro strip patch antenna working at 2.48 GHz. The design is proposed with its low return loss and high gain and directivity. Since it made using RT-DUROID substrate which has low loss tangent and dielectric constant, we can reduce the dielectric loss . Its physical implementations as a prototype integrated to a relevant system will enable exploring of its application areas and further refinement.

REFERENCES

[1] A. Alhaddad, R. Abd-Alhameed, D. Zhou, C. See, I. Elfergani, and P. Excell, "Low profile dual-band-balanced handset antenna with dual- arm structure for wlan application," Microwaves, Antennas & Propagation, IET, vol. 5, no. 9, pp. 1045–1053, 2011.

[2] J.-W. Wu, H.-M. Hsiao, J.-H. Lu and S.-H. Chang, "Dual broadband design of rectangular slot antenna for 2.4 and 5 GHz wireless communication," Electronics Letters, vol. 40, no. 23, pp. 1461–1463, 2004

[3]] K. K. S. Angana Sarma, Kumaresh Sarmah, "Low return loss slotted rectangular microstrip patch antenna at 2.4 GHz," in Proceedings of second international Conference on Signal Processing and integrated Networks (SPIN 2015), 2015.

[4] A. A. D. Al-Sajee and K. A. Hamad, "Improving bandwidth rectangular patch antenna using different thickness of dielectric substrate," 2006.

[5] A. H. Ahmad and B. K. Jaralla, "Design and simulation of broadband rectangular microstrip antenna," Eng. Tech. V0l, vol. 26, 2008.

[6] Y. Singh, S. Ghosh, K. Prathyush, S. Ranjan, S. Suthram, A. Chakrabarty, and S. Sanyal, "Design of a microstrip patch antenna array using ie3d software," in Proceedings of National Conference on Communication (NCC 2003), pp. 611–615, 2003.

[7] D. M. Pozar, Microwave engineering. John Wiley & Sons, 2009

[8] C. A. Balanis, Antenna theory: analysis and design, vol. 1. John Wiley& Sons, 2005

[9] M. Ramesh and K. Yip, "Design formula for inset fed microstrip patch antenna," Journal of Microwaves and Optoelectronics, vol. 3, no. 3, pp. 5–10, 2003.

[10] A. Kumar, J. Kaur, and R. Singh, "Performance analysis of different feeding techniques," International Journal of Emerging technology and Advanced Engineering, vol. 3, no. 3, pp. 884–890, 2013.