Design and Result Analysis of 3.4 GHz Rectangular Microstrip Patch Antenna for Wireless Data Communication System

Article *in* International Journal on Communications Antenna and Propagation (IRECAP) · May 2017

DOI: 10.15866/irecap.v7i1.11423

3 authors:

Ahmed Al Amin
University of Michigan

Md. Shoriful Islam
Brigham Young University

Md.Noman Habib Khan
Thycon Industries PTY Ltd.

International Journal on Communications Antenna and Propagation (I.Re.C.A.P.), Vol. 7, N. 1
ISSN 2039 – 5086
February 2017

Design and Performance Analysis of 3.4 GHz Rectangular Microstrip Patch Antenna for Wireless Communication Systems

Ahmed Al Amin[1], Md. Shoriful Islam[2], M. A. Masud[3], N. H. Khan[4],
J. W. A. Zavala[5], M. M. U. Islam[6]

Abstract – *Wireless communication provides low-cost, high-speed and flexible communication in present days. Hence antenna plays a vital role in the wireless communication sector. The main concern of this paper is therefore to design a 3.4 GHz rectangular Microstrip patch antenna. Moreover, the feed probe based rectangular patch antenna will be designed. The performance of the designed rectangular patch antenna will be evaluated by analysing the major parameters of the simulation results. Hence the radiation pattern, gain, impedance matching and reflection coefficient or return loss calculation will be executed by the HFSS software to evaluate the performance of the antenna.*

Keywords: *High-Frequency Electromagnetic Field Simulation, Return Loss, Feed Probe, Radiation Pattern, Gain, Rectangular Patch Antenna, MATLAB*

Nomenclature

HFSS	High-Frequency Electromagnetic Field Simulation
dBi	Decibel compared to isotropic radiator
RF	Radio Frequency
RL	Return Loss
GHz	Giga Hertz
E-Plane	Electric Plane
H-Plane	Magnetic Plane
CGS	Centimeter-Gram-Second system of units

I. Introduction

Due to minimum cost and compact size, the patch antenna is the ultimate choice for wireless communication. Among different types of patch antenna, the feed probe based rectangular patch antenna designing is much more efficient and easy to design.

Moreover, the rectangular patch antenna can provide much more expected radiation patterns than others. Nowadays, many countries such as Hungary and others are trying to exploit the frequency band of 3.4 GHz to 3.8 GHz for different kinds of wireless communication services [1]-[2]. For this reason, a compact and flexible feed antenna should be necessary for 3.4 GHz frequency. The main focus of this paper is to design a rectangular patch antenna for 3.4 GHz wireless systems and analyze its performance.

Hence, different kinds of rectangular patch antenna designing methods for different frequency ranges and applications will be discussed in the research methodology segment.

Afterwards, in the antenna design sector the designing methods such as the position of the feed probe, length and width will be calculated by MATLAB code. Afterwards, based on those parameters the designing process will be done by using the HFSS. Finally, the reflection coefficients and radiation pattern will be analyzed in the results analysis section to evaluate the performance of the designed antenna for 3.4 GHz frequency.

II. Research Background

The main target of this paper is to design a rectangular patch antenna for 3.4 GHz frequency. Some remarkable works on rectangular patch antenna are discussed here for various applications. In 2011 Indrasen Singh *et Al.* proposed a 3.4 GHz rectangular patch antenna which provides moderate return loss (-14.19 dB) and a moderate gain of 2.08dBi [3]. Moreover, in the same year, Pratibha Serra *et Al.* placed a narrow cross-slit in a rectangular patch antenna, which provides bandwidth improvements for 3.3 GHz range [4]. In 2014, Monika Kiroriwal *et Al.* proposed a new geometry of rectangular patch antenna to enhance performance in case of gain, radiation pattern and impedance [5]. However, in 2014, Aliel Alami *et Al.* designed an efficient Microstrip rectangular patch antenna for RFID (Radio Frequency Identification) applications [6]. Furthermore, in 2015, Ankur Kaushal *et Al.* illustrated merits, demerits and different principles such as polarization, bandwidth, frequency agility and so on [7]. Additionally, in 2015 Muhammad Noman *et Al.* developed some antennas for 2.7 GHz and 5.6 GHz frequencies for China Multimedia Mobile Broadcast (CMMB). In addition, the bandwidth

DOI: 10.15866/irecap.v7i1.11423

for 2.7 GHz is 300 MHz, on the other hand for 5.6 GHz the bandwidth increases up to 600 MHz [8]. Recently, in 2016, Ikram Tabakh *et Al.* designed and developed a slotted patch antenna for RFID applications in the microwave band. The design is focused on gain, directivity and return loss [9]. Moreover, in 2016 Braden P. Smyth *et Al.* designed a rectangular patch antenna for dual operating frequencies. However, the meta-material based electronic band gap has been implemented on the radiating edges to support two different frequencies [10]. Additionally, in 2016, Hassan M. Elkamchouchi *et Al.* designed a microstrip patch antenna with double I slot for wideband applications such as radar, remote sensing and satellite communication. The designed antenna works between 7.2 – 12 GHz frequency bands [11]. Moreover, in 2016, Appoorva Jain designed a rectangular microstrip patch antenna for GPS systems. It is suitable for navigation system at 1.7 GHz range [12].

III. Antenna Design

The main concern of this paper is to design a rectangular Microstrip patch antenna of 3.4 GHz, to analyze the result of the antenna as well as to evaluate the performance of the antenna. The basic steps are shown in Fig. 1.

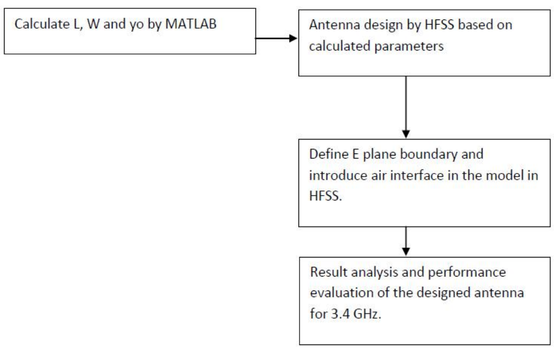


Fig. 1. Block diagram of proposed antenna designing

Figure 1 shows that at first the length (L), width (W) and the position of feed probe (y_o) are calculated by MATLAB code for 3.4 GHz frequency using some equations for the rectangular patch antenna.

In the second part, the parameters provided by MATLAB will be used to design the rectangular patch antenna by HFSS and set the air interface around the designed antenna. Finally, the results will be analyzed and the performance of the antenna will be evaluated using the HFSS simulation. Moreover, the radiation patterns, matching impedance and reflection parameters will also be illustrated and examined by the HFSS. The following Microstrip substrate specifications are used to design the expected antenna [11]:

- Height of the substrate, H=0.8 mm
- Dielectric constant of substrate, ε_r=2.54
- Relative permeability of the substrate, μ_r=1
- Conductivity of the conductor, *Cond*=1×10^{50} Ω^{-1}
- Height of the metal box (if the model is covered), *Hu*=1×10^{33} mm
- Conductor Thickness, T=35 µm
- Dielectric loss tangent, tanδ=0.0003
- RMS surface Roughness of the substrate, R=0 mm

These parameters are considered to design the appropriate rectangular patch antenna for 3.4 GHz. Afterwards, the main concern is to calculate the length, width of the patch and the appropriate position of the feed probe on the rectangular patch. Hence the length and width of the patch will be calculated by equations (2), (4). However, for this reason, the effective dielectric constant (ε_{reff}) and normalized extension length ($\Delta L/h$) should be calculated by equations (1), (3) significantly. Moreover, equation (2) has been used to measure the width (W), which will be used in equation (3) consequently [12]-[13]:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + \frac{12h}{w}\right]^{-\frac{1}{2}} \quad (1)$$

$$w = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r + 1}} = \frac{v_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad (2)$$

$$\frac{\Delta L}{h} = 0.412\frac{\varepsilon_{reff} + 0.3\left(\frac{w}{h} + 0.264\right)}{\varepsilon_{reff} - 0.258\left(\frac{w}{h} + 0.8\right)} \quad (3)$$

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\mu_0\varepsilon_0}} - 2\Delta L \quad (4)$$

However, equation (4) has been used to calculate the length (L) of the rectangular patch antenna. From the MATLAB code based on the above equations, the patch length (L=2.7375 cm) and width (W=3.31 cm) are calculated. Moreover, the input resistance (R_{in}) is another vital factor in determining the position of the feed probe on the patch. So by using equation (5), the input resistance can be calculated. However, the slot conductance (G_1) and I_1 are the two major parameters to determine R_{in}. Therefore G_1 and I_1 can be calculated by equation (6) and (7). Furthermore, the constant K_o and width (W) of the patch has been used as well to calculate I_1, which is mentioned in equation (7) [12]-[14]:

$$R_{in} = \frac{1}{2(G_1 + G_{12})} \quad (5)$$

$$G_1 = \frac{I_1}{120\pi^2} \quad (6)$$

$$I_1 = \int_0^{\pi}\left(\frac{\sin\left(\frac{KoW\cos\theta}{2}\right)}{\cos\theta}\right)^2 \sin^3\theta d\theta = \quad (7)$$

$$= -2 + \cos(x) + xS_i(x) + \sin(x)/x$$

where, $x = K_o W$.

Subsequently to calculate the position of the feed probe, the values of G_{12}, R_{in} and I_1 are required. The values of G_{12} = 5.2473×10^{-4} Ω^{-1}, I_1=1.6930 and input resistance, R_{in}= 255.920Ω have been consequently calculated by the MATLAB code. This code also calculated the necessary values based on the equations (5)-(7) [12], [15]. Moreover, the feed probe position for rectangular patch antenna has been accurately calculated by equation (8):

$$R_{in}(y = y_o) = \frac{1}{2(G1 \pm G12)} cos^2 \frac{\pi}{L} y_o = R_{in}(y = 0) cos^2 \left(\frac{\pi}{L} y_o\right) \quad (8)$$

Finally, the position of the feed probe (y_o =0.9698 cm) on the rectangular patch has been calculated by the MATLAB script based on the equation (8) and other necessary parameters which have been mentioned earlier [16]-[18].

These design parameters will be used to design the rectangular patch antenna for 3.4GHz frequency. All the design parameters such as length, width and the feed probe position are in CGS unit for antenna design, since HFSS usually uses CGS unit for designing purposes.

By using all the calculated parameters, a proper rectangular patch antenna for 3.4GHz has been designed by Ansoft HFSS which is showed in Figs. 2.

In designing the section, first a perfect E boundary has been provided to the patch. Moreover, a perfect feed probe has been designed and placed according to the calculated position (y_o=0.9698 cm) by MATLAB code, which is showed in Fig. 2(a). The antenna has been designed with a characteristics impedance of 50Ω, like most of the present communication systems. In addition, to give the simulation a more practical view, an air interface has been used as material around the rectangular patch antenna. Moreover, a radiation boundary has been also placed around the antenna (Fig. 2(b)).

Finally, the following simulation parameters are provided in HFSS to give the simulation a more realistic view:

i. Far field parameters:

-Infinite Sphere option with azimuth plane {Phi (Start: 0, Stop: 90, Step size: 90)}

-Tilt plane {Theta (Start: -180, Stop: 180, Step size: 2)}

ii. Solution Frequency:

-Solution setup option with solution frequency 3.4 GHz

iii. Pass Setup:

-Maximum number of passes 20, Maximum delta S per passes 0.02.

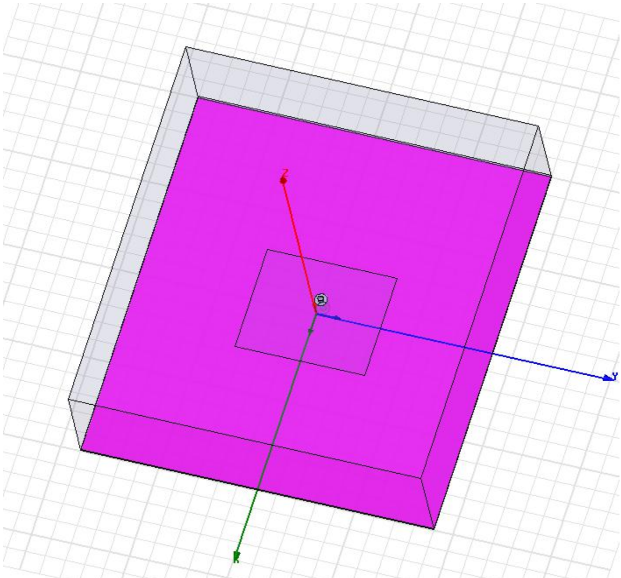
iv. Sweep type: -Sweep type: Fast

v. Frequency Setup:

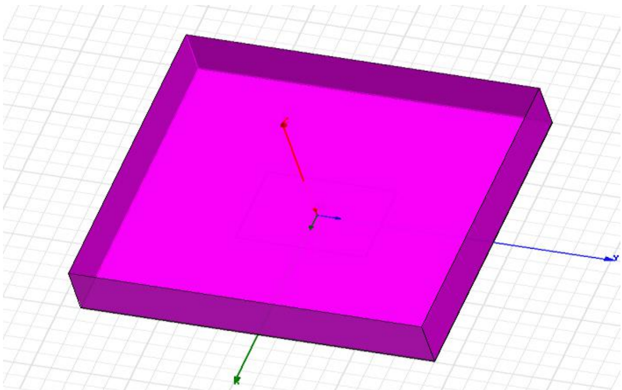
-Frequency setup type: Linear Count -Start: 1 GHz

-Stop: 5.0 GHz -Count: 201

The above-provided parameters in HFSS are used to give the simulation a more realistic view. The perfect electric field (E-field) boundary and infinite ground have been also introduced in the model. The tilt and azimuth angles provide the desired lobe and gain which will be illustrated in the radiation pattern in section IV. Since the desired frequency is 3.4 GHz, the solution frequency is set to 3.4 GHz as well. However, a maximum of 20 passes are used and fast sweep is also introduced to get precise results. In addition, a linear type frequency setup from 1 to 5 GHz has also been selected to examine the performance of the antenna within this band such as return loss and characteristics impedance [19].



(a)



(b)

Figs. 2. (a) placement of probe into the patch in HFSS simulation, (b) Create radiation boundary in HFSS simulation

First the return loss, which is represented by S_{11}, will be evaluated by HFSS. Second, the impedance calculation will be performed. This will illustrate the characteristics impedance of the antenna based on the real and imaginary part. However, the antenna has been designed for around 50Ω, hence most of the devices in communication fields are designed based on 50Ω characteristics impedance. Moreover, if there is any impedance mismatching between the two components, it could cause a mismatching which may lead to an enormous return loss and it could cause the degradation of gain which is a vital factor of an antenna. Finally, the radiation pattern will be examined to evaluate the gain of the designed antenna in case of E and H planes.

The main lobe and back of the designed antenna will also be illustrated. In case of mobile wireless communication, the back lobe is the most unexpected lobe, since it may cause interferences in different cells. Afterwards, the model of the designed 3.4 GHz rectangular patch antenna will be simulated. All the results will be illustrated by using the Ansoft HFSS software to evaluate the performance of the designed antenna.

IV. Results and Discussion

Based on the MATLAB code results, the length, width of the rectangular patch and the position of the feed probe on the probe have been calculated with the MATLAB code showed in Table I. However, all design parameters are calculated in CGS unit since HFSS only supports the design parameters in centimeters (cm).

TABLE I
CALCULATED DESIGN PARAMETERS FOR RECTANGULAR PATCH ANTENNA BY MATLAB CODE

Design Parameters	Values (cm)
Length	2.7375
Width	3.31
Feed probe position on the patch	0.9698

After far field and other parameters in HFSS, the proper antenna model has been designed (Fig. 3). Moreover, the radiation boundary has been provided as well to extensively evaluate the performance of the antenna. Finally, the antenna has been designed along with all the calculated parameters in an adequate simulation environment. Therefore, to evaluate the performance of the antenna some major analysis should be performed. Hence the return loss, characteristics impedance radiation pattern and gain will be analyzed in result analysis [20]-[21].

Therefore, the rectangular patch antenna for 3.4 GHz frequency has been designed by the calculated design parameters. The parameters have been calculated in the previous segment. In addition, the radiation boundary and air interface have been also integrated to the antenna model to give the model a more practical view. Moreover, the appropriate far field parameters along with azimuth and tilts angles are also provided for a proper practical environment. After the validation and simulation, some major parameters are observed to analyze the performance of the rectangular patch antenna for 3.4 GHz frequency range. At first, the return loss usually mentioned by S_{11} has been investigated. The results of RL parameter have been illustrated by HFSS (Fig. 4).

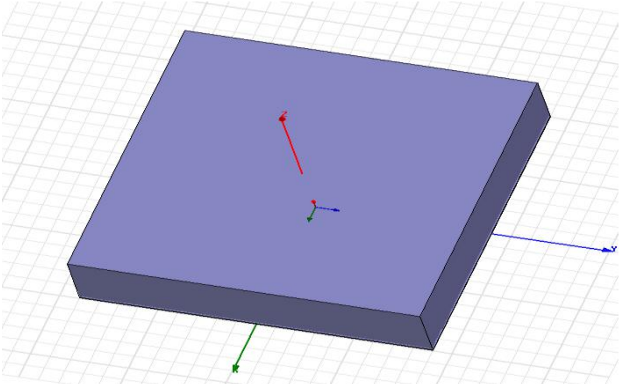


Fig. 3. The Fully designed rectangular patch antenna for 3.4 GHz with feed probe in HFSS

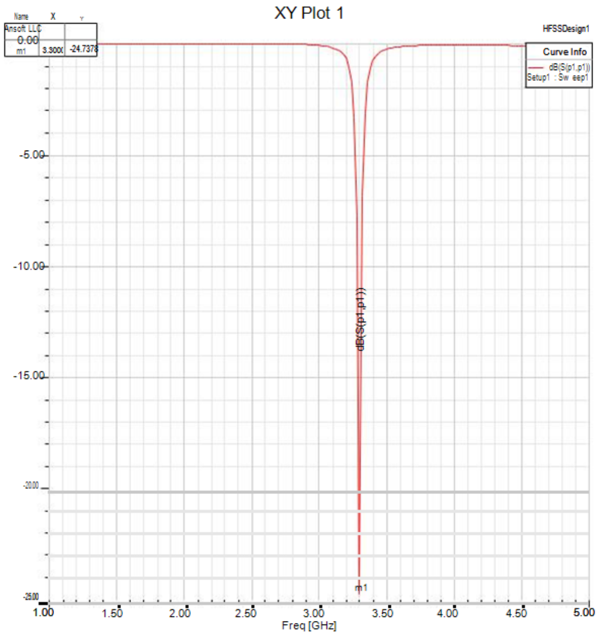


Fig. 4. S_{11} parameter (return loss) for 3.4 GHz Rectangular patch antenna

Figure 4 shows that the return loss (RL) is very low for 3.4 GHz which is almost -25dB. RL plays a vital role in antenna designing, since a high return loss may degrade the efficiency of the designed antenna.

Moreover, the gain could be drastically degraded due to high return loss as well. However, Fig. 4 illustrates the response of the antenna return loss from 1 to 5 GHz due to the provided frequency setup parameters of HFSS. Moreover, the return loss is considerably low (around -25 dB) at 3.4 GHz frequency. This result also verifies the accurate position of the feed probe on the patch for the desired frequency.

Furthermore, another important factor is the characteristics impedance. Due to the displacement of the feed probe position the characteristics impedance could vary. Moreover, most communication systems are designed for 50Ω characteristics impedance. The impedance mismatching could therefore degrade the performance of the antenna as well as of the system. On the other hand, the probe position is very much accurate to keep the Z_o as close as 50Ω to keep the return loss as low as possible.

Figure 5 plots the real and imaginary impedance of the antenna. However it shows that both real and imaginary parts (marked by m1 and m2 respectively) have the same amount of impedance (52Ω). So the antenna perfectly matches the antenna with 52Ω system hence the reflection has been successfully minimized. Since 52Ω is much closer to 50Ω, the designed antenna is much more suitable for 50Ω communication systems. However, the antenna has been designed for 50Ω characteristics impedance for 3.4 GHz frequency. So 52Ω characteristics impedance of the designed rectangular patch antenna provides low return loss for 3.4 GHz frequency.

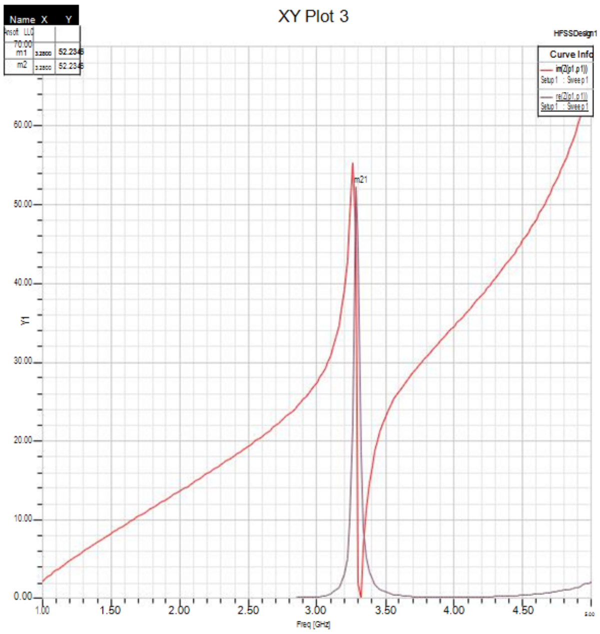


Fig. 5. Plot of real and imaginary part of impedance for 3.4 GHz rectangular patch antenna

The most vital part is the radiation pattern of any antenna. The radiation pattern illustrated the direction and gain of the designed antenna. Moreover, the radiation pattern can be achieved for predefined tilt and azimuth angles along with far field parameters as well.

Furthermore, HFSS showed the electric and magnetic field radiation simultaneously. Figure 6 demonstrates the radiation pattern of the designed antenna. The antenna gain at zero degrees is more than 7 dBi for electric (E) and magnetic planes (H). The electric plane is marked by red and the magnetic plane is marked by blue in Fig. 6.

However, back lobes are omitted to discard the interference issues. Hence this issue can reduce co-channel and adjacent channel interferences also in case of cellular based wireless communication.

However, the angles are illustrating the direction of the lobes and gain for electric and magnetic fields. Gain is an important factor for antenna designing.

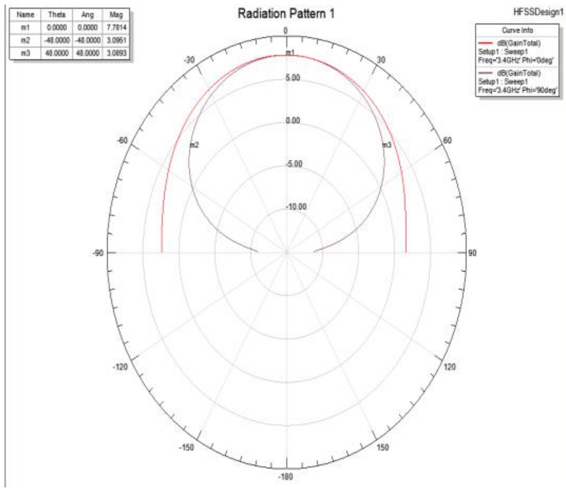


Fig. 6. Radiation pattern for 3.4 GHz Rectangular patch antenna

Therefore, to analyze the performance of the rectangular patch antenna, gain is another key issue to consider. According to the previous observation, it is clearly visualized that RL and impedance are reasonable for 3.4 GHz frequency. Hence the moderate level of gain can justify the performance of the designed rectangular patch antenna for 3.4 GHz. The gain of electric and magnetic fields are illustrated in Table II.

TABLE II
GAIN OF THE ELECTRIC AND MAGNETIC PLANE WITH CORRESPONDING ANGLES

H-plane			
Angle (Degree)	**Gain (dBi)**	**Angle (Degree)**	**Gain (dBi)**
90°	<-10.00	-90°	<-10.00
60°	0	-60°	0
48°	3.0893	-48°	3.0951
30°	5.045	-30°	5.035
0 °	7.7814	0°	7.7814
E-plane			
Angle (Degree)	**Gain (dBi)**	**Angle (Degree)**	**Gain (dBi)**
90°	<-10.00	-90°	<-10.00
60°	0	-60°	0
48°	4.813	-48°	4.825
30°	5.121	-30°	5.135
0 °	7.7814	0°	7.7814

At 0°, the moderate gain of 7.7 dBi for both electric and magnetic plane has been achieved. Moreover, by observing the radiation pattern, it is clearly visible that at 30° direction from the main lobe the gain is around 5dBi for H-plane. For the electric plane, the gain is more than 5dBi at the same direction. Consequently, for 48° angle, the gain decreases to around 3dBi in the magnetic plane. In contrast, for the electric plane for 48°, the gain is much higher than H-plane gain. Subsequently, in the electric plane, for 60°, the gain remains 0 dBi which is the same as the magnetic plane. In case of negative angles, such as for -30°, the gain is around 5 dBi for the magnetic plane whereas it is 5.135 dBi in case of electric plane. Besides in case of the electric plane, for -48° from the main lobe the gain is greater than 4.8 dBi, which is much higher than the gain of the magnetic plane at the same direction.

For -60^o and -90^o, the gain remains the same for the electric and magnetic plane. For -60^o the gain remains 0 dBi in case of electric and magnetic planes. Moreover, the gain is less than -10 dBi for -90^o angles from the main lobe in both planes. It is clearly visible that the gain is uppermost at the main lobe. However, it decreases in different directions of the main lobe. Furthermore, the gain remains moderate at different directions of the lobe. On the other hand, there is no unexpected backward lobe of the designed antenna. Since this issue may cause huge co-channel and adjacent channel interference in a cellular based wireless communication system, it may cause different kinds of interferences in cellular based wireless communication. Hence there is no back lobe visible at 90^o, -180^o or -90^o from the main lobe of the designed rectangular patch antenna and there are not electric (E) or magnetic planes (H) at those angles, which is desirable for antenna designing in case of a cellular based wireless communication system.

The result analysis showed that the designed antenna has the perfect matching impedance of 52Ω the perfect component for a 50Ω system. Moreover, the accurate position of the feed probe and impedance matching keeps the return loss as low as possible to make the antenna much more efficient. Moreover, the radiation pattern illustrates that the gain is much more moderate for the main lobe. On the other hand, the other lobes provided moderate gain as well. In contrast, the back lobe has been discarded to avoid unexpected interferences in a cellular network. As a result, all the key factors are achieved by analyzing the performance of the designed rectangular patch antenna. Moreover, the antenna provides convincing results for 3.4 GHz operating frequency as well.

V. Conclusion

The main objective of this paper is to design a 3.4 GHz rectangular microstrip patch antenna. Moreover, the feed probe in the accurate position provides a low return loss and desired gain in case of rectangular feed probe antenna. As a result, the designed rectangular Microstrip patch antenna provided convincing results for the low amount of return loss (around -25 dB) and much higher gain value (around 7.7 dBi) without unexpected back lobes at 3.4 GHz frequency, which fulfilled the requirements of the antenna design. These results also represent a substantial performance of the rectangular patch antenna for 3.4 GHz wireless communication systems.

References

[1] *National media and info communications authority Hungary*. Introducing the 3400-3800 MHz frequency band; characteristics of current and future use, *white paper*.2011.

[2] Md. Mahabub Alam, Rifat Ahmmed Aoni, Md. Toufikul Islam. Gain Improvement of Micro Strip Antenna Using Dual Patch Array Micro Strip Antenna. *Journal of Emerging Trends in Computing and Information Sciences*, 2012, vol. 3, issues 12, page 1642-1647.

[3] Indrasen Singh, Dr. V.S. Tripathi. Microstrip Patch Antenna and its Applications: a Survey**.** *International Journal of Computer Technology and Applications, 2011, vol.* 2, issues.5, ,page 1595-1599,.

[4] PratibhaSekra, Manoj Dube, SumitaShekhawat, D. Bhatnagar, V.K. Saxena and J.S. Saini. Broadband Rectangular Patch Antenna with Orthogonal Crossed Slits. *International Journal of Microwave and Optical Technology, 2011,* vol.6, issues 4, page 179-184.

[5] Monika Kiroriwal and Sanyog Rawat. Improvement in Radiation Parameters of Rectangular Microstrip Patch Antenna. *International Journal of Engineering Research and General Scientific*, 2014, vol.2, issues. 6, page 393-397.

[6] Aliel Alami, Saad Dosse Bennani, Moulhime El Bekkali Benbassou, Design Analysis and Optimization of a New Structure of Microstrip Patch Antenna for RFID Applications. *Journal of Theoretical and Applied Information Technology*, 2014, vol. 63, issue 3, page 748-753.

[7] Ankur Kaushal, Sachin Tyagi. Micro strip Patch Antenna its Types, Merits Demerits and Its Applications. *International Journal of Engineering Sciences & Research Technology*, 2015, vol. 4, issue 7, page 619-622.

[8] Muhammad Noman, Muhammad Usman and Muhammad Zeeshan. Patch Antenna for 2.7GHz & 5.6GHz for CMMB. International Journal of Signal Processing, *Image Processing and Pattern Recognition*, 2015, vol. 3, issues 1, page 99-104.

[9] Tabakh, I., Jorio, M., El Amrani El Idrissi, N., Mazri, T., Design and Optimization of a New Slotted Patch Antenna for RFID Applications, (2016) *International Journal on Communications Antenna and Propagation (IRECAP)*, 6 (1), pp. 33-38.

[10]. Braden P. Smyth, Stuart Barth and Ashwin K. Iyer, Dual- Band Microstrip Patch Antenna Using Integrated Uniplanar Metamaterial-Based EBGs. *IEEE Transactions on Antennas and Propagation*, 2016, vol. 64, issue 12, page 5046-5053.

[11] Hassan M. Elkamchouchi, Rateba A. Salem, Microstrip patch antenna with double I slot for wide band applications, *SSRG International Journal of Electronics and Communication Engineering*, 2016, vol. 3, issue 3, pages 26-29.

[12] Apporva Jain, Rectangular Microstrip Patch Antenna for Global Position System, *International Journal of Engineering Trends and Technology,* 2016, vol. 37, issue 1, pages 28-32.

[13] Technical Training Manual, "Antenna Pattern Measurements," *Microwave Training System. Model MT-1, ARRA Inc. Antenna & Random Research Associates*, Accessed: 2016, page 14-1 to 14-6.

[14] Constantine A. Balanis, Antenna Theory Analysis and Design, 2nd edition, Chapter-14, *14.2 Rectangular Patch*, page 727-736.

[15] Kansheng Yang; Xiulong Bao; Patrick McEvoy; Max J. Ammann. Pattern reconfigurable back-to-back microstrip patch antenna. *The Institution of Engineering and Technology Journals & Magazines*, 2016, vol.10, issues 13, pages 1390-1394.

[16] Hayat Errifi, Abdennaceur Baghdad, AbdelmajidBadri, Aicha Sahel, Radiation Characteristics Enhancement of Microstrip Triangular Patch Antenna using Several Array Structures. *International Journal of Wireless and Microwave Technologies*, 2015, vol. 5, issue 3, page 1-17.

[17] Rahul Dev, Mishraand Pramod, Kumar Singhal, Gain Enhancement of Rectangular Microstrip Patch Antenna Designed for Exposure System Using Microstrip Array. *International Journal of Signal Processing, Image Processing and Pattern Recognition*, 2016, vol. 9, issue 5, page 417-430.

[18] Prof. Vivek, R. Urvi Dhandha, Design and Simulation of 4x1 Probe Feed Rectangular Patch Array Antenna for ISM Band Applications, 2014, *International Journal of Engineering Research & Technology*, vol. 3, issue 3, page 1537-1539.

[19] Vaishali Kirar and Sonam Ratohre, Design of Rectangular Microstrip Patch Antenna with I-shaped DGS for Satellite Communication, 2016, *International Journal of Engineering Research and General Science*, vol. 4, issue 1, page 403-408.

[20] Gurpreet Kaur and Er. Sonia Goyal, Effect of Height on Edge Tapered Rectangular Patch Antenna using Parasitic Stubs and Slots, 2016, *International Journal of Engineering Trends and Technology (IJETT)*, vol. 34, issue 5, page 368-372.

[21] Amit Kumar Jain and Monika Surana, Modified Rectangular Patch Antenna Loaded With Multiple C Slots for Multiple Applications, 2016, *Journal of Applied and Computational Mechanics*, vol. 2, issue 3, page 192-199.

Authors' information

[1]Assistant Professor, Department of EEE, Uttara University, Dhaka, Bangladesh.

[2,3]Senior Lecturer, Department of EEE, Uttara University, Dhaka, Bangladesh.

[4]Lecturer, Department of EEE, Uttara University, Dhaka, Bangladesh.

[5]Characterization Engineer, Radio Semiconductor Corporation, Netherlands.

[6]Department of Electronic and Telecommunication Engineering, University of Gavle, Sweden.

Juan Wilfaro A. Javala received his Masters in Electronics & Telecommunication from the University of Gavle. He is now working as Characterization Engineer at Radio Semiconductor Corporation, Netherlands. His research interests are Radio Frequency/Microwave Engineering, Antenna & Propagation and Signal Processing.

Md. Minhaz Ul Islam is now pursuing his Masters in Electronics &Telecommunication at University of Gavle, Sweden. His research interests are Antenna Engineering, Wireless, and Radio Engineering.

Ahmed Al Amin (corresponding author) was born in 1985. He received his Masters in Electronics & Telecommunications from University of Gavle, Sweden. in 2012. He is now involved with Uttara University, Bangladesh as Assistant Professor since 2013. His research interests include Antenna Engineering. Signal Processing, Wireless Communication.

Md. Shoriful Islam completed his B.Sc. in Electrical and Electronic Engineering. He is currently working as Senior lecturer at Uttara University from last two and half years. M.S. Islam has published some IEEE sponsored research papers and journals on different modulation techniques, Wireless communication and optical Communication.

Md. Noman Habib Khan received his M.Sc. from University of Gavle, Sweden. in 2016. He is now involved with Uttara University, Bangladesh as Senior Lecturer since 2016. His research interests include Electronics, Antenna/Microwave, Wireless Communication, Power Systems and Optical Communications.

Md. Atique Masud completed his B.Sc. in Electrical and Electronic Engineering. He is currently working as a lecturer at Uttara University since 2015. His research interests include Electronics, Antenna Engineering, Wireless Communication, Power Systems and Communication Systems.