Fall 11-2011

Applications with a Radiation Pattern in the Horizontal Direction

Sudarshan Reddy Tippi Reddy

DESIGN OF A MICROSTRIP ANTENNA FOR 2.4 GHZ APPLICATIONS WITH A RADIATION PATTERN IN THE HORIZONTAL DIRECTION

by

SUDARSHAN REDDY TIPPI REDDY

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Electrical Engineering
Department of Electrical Engineering

Hector A. Ochoa, Ph.D., Committee Chair

College of Engineering and Computer Science

The University of Texas at Tyler
December 2011

The University of Texas at Tyler
Tyler, Texas

This is to certify that the Master's thesis of

SUDARSHAN REDDY TIPPI REDDY

has been approved for the thesis requirements on
July 22, 2011
for the Master of Science in Electrical Engineering degree

Approvals:

____
Thesis Chair: Hector A. Ochoa, Ph.D.

____
Member: Ron J. Pieper, Ph.D.

____
Member: Mukul V. Shirvaikar, Ph.D.

____
Chair and Graduate Coordinator: Mukul V. Shirvaikar, Ph.D.

____
Dr. James K. Nelson, Jr.,Ph.D, P.E,
Dean, College of Engineering and Computer Science

Acknowledgements

I am heartily thankful to my parents Tippi Reddy Venkata Krishna Reddy and Tippi Reddy Sudha Reddy for their love, support, patience and encouragement in facing this challenge. I would also like to thank my friend Ramya Sree Godala who has been constantly encouraging me, keeping me active and supporting me throughout the journey of Masters. I would like to express the deepest appreciation to my advisor Dr. Hector A. Ochoa for his encouragement, patience, supervision and constant support from preliminary to the concluding level. Without his guidance and persistent help this thesis would not have been possible. And I would also like to thank my brothers Yoga, Sarru, Ramu and Bharath and my uncle Rajashekar Reddy for constantly encouraging the completion of my degree.

I am grateful to Dr. Mukul Shirvaikar for guiding me, advising me and encouraging me throughout my Master’s. I would like to thank my committee member Dr. Ron J. Pieper for taking time and reviewing my work. I would like to thank the entire EE department, CS department and the University of Texas at Tyler for supporting me throughout my Master’s. I am grateful to my mentor, my boss and a wonderful person Ms. Kay Pleasant of computer science department for all her support in my Masters program. Finally, I would like to thank Rahul Mupasani and my friends in “803” and all those who supported me in any respect during the completion of the thesis.

Table of Contents

List of Figures

Abstract

DESIGN OF A MICROSTRIP ANTENNA FOR 2.4 GHZ APPLICATIONS WITH A RADIATION PATTER IN THE HORIZONTAL DIRECTION

Sudarshan Reddy Tippi Reddy

Thesis Chair: Hector A. Ochoa, Ph.D.

The University of Texas at Tyler
July 2011

Antennas play a vital role in communication systems by radiating and receiving signals of interest. There are various structural types of antennas differentiated by their individual properties such as: the directivity, the power transmitted and the gain. One of these types of antennas with special properties is the microstrip antenna. There are multiple applications for microstrip antennas in wireless communication, due to its small form factor and geometrical shape. These antennasare typically employed at frequencies above the Ultra High Frequency (UHF) range. The reason for this is that their dimensions are directly related to the wavelength of the operating frequency.The resonance frequency ofa microstrip antenna is controlled by the patch length and the permittivity of the substrate.Amicrostrip patch antenna has two radiating slots along the width and two radiating slots along the length of the patch. Each slot radiates the same amount of

energy. The radiations from the width and the length respectively are added in a direction normal to the patch.A single patch antenna provides a maximum gain of around 6-9 dB.Using lithography techniques microstrip patch antennas can be easily printed as an array of multiple rows and columns. Patch arrays can provide a much higher gain compare to a single patch at minimum additional cost. For that reason, patch arrays are widely used in military and aeronautical applications.

In this research, a design for a microstrip antenna in which the radiation is spread along the horizontal axis is proposed. Several antenna configurations were considered for the design, and their radiation patterns were studied while always considering the constraints related to the directivity andthe radiation patterns. Antenna directivity was one of the major concerns during the design process of a microstrip antenna. In order to control its directivity, reflectors and directors were included in the design.Due to software limitations, a wire structure was chosen in place of a metal patch. When a wire structure is used the antennaefficiency is also significantly affected. The thinner the wire in the design, the smaller is the loss generated by the antenna. The design of the microstrip antenna was created by modifying the location of the directors and reflectors with respect to the driven element. The 2-Dimensional and 3-Dimensional radiation patterns from each configuration were generated and analyzed in order to obtain the desired results. A 2.4 GHz operating frequency was chosen to design the microstrip antenna because most of the wireless standards like: WiFi, IEEE 802.15.4 ZigBee and LAN employ the same frequency band. The radiation pattern from these microstrip antennas can be controlled by carefully positioning the directors and the reflectors within the design. The simulation results show that the radiation of the main lobe is suppressed and the energy in the side lobes is increased, which corresponds to the desired radiation pattern.

Chapter One

Introduction

1.1 Microstrip antenna

The concept of microstrip antenna (MSA) was first proposed by Georges.A.Deschamps in 1953.However, it did not become practical until the 1970s when it was further developed by Robert E. Munson using low-loss soft substrate materials, which were just becoming available at that time [1]. One of the major advantages of a microstrip antenna is the low cost of fabrication. They are easy to feed and are light weight. A microstrip antenna consists of a metallic plate or patch on top of an electrically thin dielectric material which is connected to ground. Due to the ease of their design, it is easy to create large and complex array structures. Large microstrip array antennas with different types of feeding techniques are further discussed in section 2.1.1.

The length of a rectangular microstrip antenna is approximately half the wavelength of the operating frequency. The microstrip antenna is generally equipped with a dielectric or with air as the substrate. As the dielectric constant of the substrate is increased, it affects the length of the antenna for that specific operating frequency [2]. Even more, as the dielectric constant is increased, the bandwidth of the antenna decreases. The bandwidth of a standard microstrip antenna is small compared to other antennas. However, there are different techniques used to increase their bandwidth. One example of these techniques is increasing the width of the substrate. The rectangular microstrip antenna can be easily analyzed by using the transmission-line model. An equivalent circuit of the transmission model with loads on either ends is helpful to analyze the conductance of the wire antenna [3].

For the simulation of the microstrip antenna, it was decided to use the Numerical Electromagnetic Code (NEC) software. This software was used to create, view, optimize and check 2-dimensional and 3-dimensionalantenna structures. This software was also used to generate, display and compare near and far-field radiation patterns [4]. The design of microstrip antennas depends completely on the desired operating frequency. Microstrip antennas are not practical for frequencies below the microwave range (0.3 GHz to 300 GHz). This is due to the size required to construct them. For example, at the X-band (8.0 to 12 GHz) the dimensions of a microstrip antenna are in the order of 1 centimeter long. On the other hand, the dimensions of a microstrip antenna designed to operate for an FM radio would be in the order of 1 meter long and for AM radios working at 1000 KHz, the microstrip patch would be very large in size.

1.2 Rectangular microstrip antennas

In wireless communications different types of microstrip antennas are being used. Each antenna is efficient with respect to their specific application. The rectangular microstrip antenna is one of the most popular designs for this type of antennas. Figure 1 illustrates the geometry of the antenna including the dielectric substrate and with the arrows showing the electric field. The length of the antenna (rectangular patch) is inversely proportional to the dielectric constant of the substrate. In other words, as the length of the antenna decreases the dielectric constant of the substrate increases. The radiating part of the antenna is at the ends of the length dimension of the rectangle, which sets up single polarization. The radiation that occurs at the ends of the width dimension is far less than the other two radiating slots. The radiation from the length dimension is small compared to the other two sides on the width; therefore, these two are usually referred to as non-radiating slots. Figure 2 shows the schematic of the radiating and the non-radiating slots with the electric field and magnetic field perpendicular to each other.

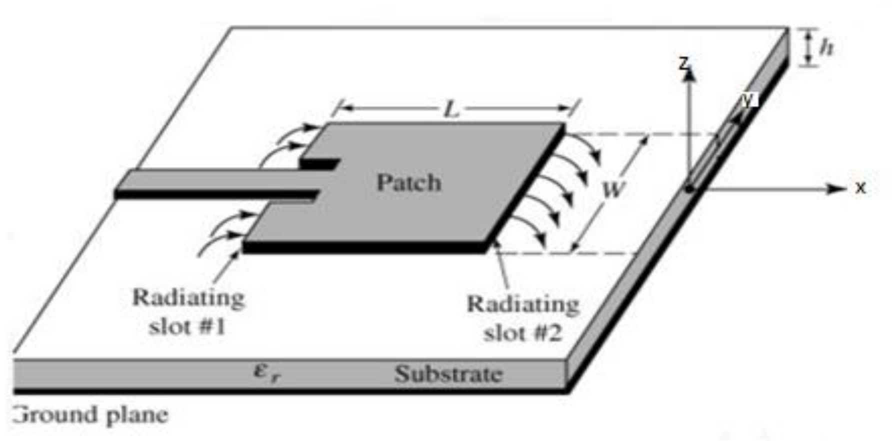


Figure 1.The geometry of a Microstrip antenna patch [3]

The gain of a rectangular microstrip patch antenna is measured by replacing the test antenna with a standard antenna and measuring the radiation patterns from both. The gain is calculated by comparing the difference in power between the design test antenna and a known standard antenna. Since the length of the patch is half a wavelength, a gain of 2dB is observed in the direction of the vertical axis. On the other hand, if the length and the width of the patch are the same, the radiation pattern has a larger directivity and a larger bandwidth. The radiation behind the antenna is reduced by the addition of a ground plane. Moreover, the addition of a ground plane also increases the gain by 3 dB and reduces the power averaged in all directions by a factor of two. In the case of a square patch antenna, the average gain is about 7-9 dB.

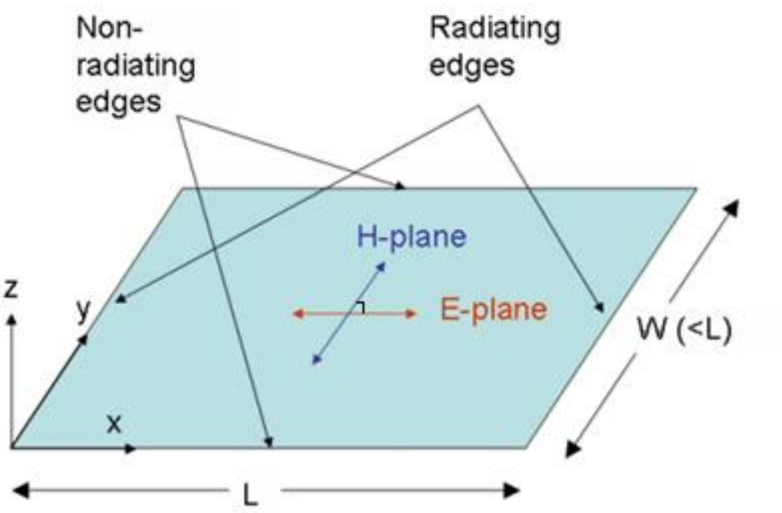


Figure 2.The radiating and non-radiating edges of a microstrip antenna.

1.3 Review of relevant work

In this section, the most relevant research and developments in the field of microstrip antennas are discussed. Some of this research work includes the one presented in the article "*Switchable Quad-Band Antennas for Cognitive Radio Base-station Applications"* by Rong Lin Li and Manos M. Tentzeris [5]. This document presents a cognitive radio which is designed to reduce the unused bandwidth spectrum in the existing communication standards. The proposed design has a typical structure to facilitate theantenna configuration for multiple frequency operation bands. The four frequency bands are B1 (800-900 MHz), B2 (1.7- 2.5 GHz), B3 (3.3-3.6 GHz), and B4 (5.1-5.9 GHz).Antennas were simulated for each frequency band and their results were discussed with their radiation patterns in the H plane. On the other hand, the research on "*Vertically Multilayer-Stacked Yagi Antenna With Single and Dual Polarizations*," by

Olivier Kramer, TarekDjerafi and Ke Wu [6] shows a classical Yagi-Uda antenna for high-directivity with single and dual polarizations. Two antenna designs were proposed, one based on single polarization and the other on circular polarization. Both designs were built with respect to various parameters such as the reflector dimensions, the director dimensions and the polarizations. The spacing between the driven element and the director elements has been important for the research.

1.4 Thesis outline

The outline of this thesis is as follows. Chapter 1discusses the technology used to design microstrip antennas and the most-recent research in microstrip antennas. Chapter 2 describes the theoretical background and the design of microstrip antennas. It also describes how the different parameters from a microstrip antenna affect the overall design. Chapter 3 present the results obtained from the proposed design. The 2-dimensional and 3-dimensional radiation patterns for the proposed microstrip antenna are presented. Finally, Chapter 4 presents the conclusions obtained from this research and the future work that can be performed in this area.

1.5 Research objective

The main goal of this thesis is the design of a microstrip antenna in which the energy will be radiated in the horizontal plane. Typically, a microstrip antenna radiates perpendicular to the surface. Several designs were constructed, and their radiation patterns were studied. The proposed design of the microstrip antenna consists of directors and reflectors to control the radiation. The results are achieved by properly placing the directors and the reflectors with respect to the driving element in order to achieve the desired results.

Chapter Two

Microstrip Antenna Design and Analysis

Microstrip antennas were designed as alternatives to metal waveguide slotted arrays. When compared to waveguide antennas these antennas have advantages in terms of weight, thickness and cost. These thin structure antennas are portable and can be easily mounted onto vehicles or missiles [7]. One of the limitations of these antennas is that the bandwidth decreases as the separation between the radiating element and the ground plane decrease. Moreover, typically microstrip antennas have a smaller bandwidth compared to regular wire antennas. During their manufacture, the amplitude and the phase distribution can be adjusted to the specific application. As their operating frequency increases, a small amount of power is injected into the substrate board which gives energy to the lobes. Typically, in every microstrip antenna, the radiating element is surrounded by the substrate and equipped with a feeding element. The energy given to the radiating element through the feeding element is observed in the form or electromagnetic waves, and this energy usually is measured as the radiation patterns. In Figure 3 the basic model of a microstrip antenna is presented. When a microstrip antenna is excited at the operating frequency, a strong field is set up within the substrate and a large current at the (bottom) surface of the patch is produced. As a result, a significant amount of radiating energy is produced.

2.1 Theoretical background of a microstrip antenna

There are many configuration parameters for the design of microstrip antennas depending on their respective applications. The rectangular patch is the most widely used configuration. This configuration is typically analyzed using transmission-line models and cavity models. However, the transmission line model is more common due to its simplicity compared to the cavity model.

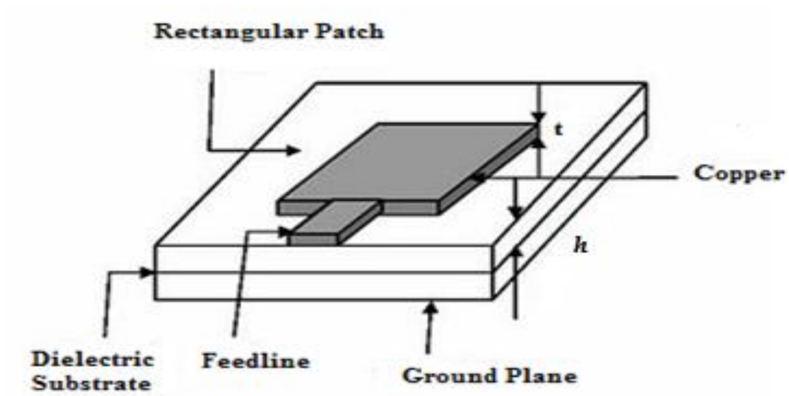


Figure 3.Rectangular patch microstrip antenna

In the transmission-line model the microstrip antenna is represented by two radiating narrow apertures (slots), each of width *w* separated by a low-impedance transmission line of length ℓ. Some of the basic properties of the microstrip antennas which prominently affect the radiation pattern are discussed in the following subsections.

2.1.1 Feeding methods

There are multiple techniques that can be used to feed energy into the microstrip antenna. The most popular feeding techniques are the microstrip line, the co-axial probe, the aperture coupling and the proximity coupling. The microstrip feed line is a conducting strip usually of a much smaller width compared to the patch. An example of a microstrip feed line is shown in Figure 4. The microstrip feed line is easy to fabricate and it is easy to control the width. However, if the thickness of the substrate is increased, the surface waves and the radiation also increase. As a result, the bandwidth of the microstrip antenna is limited compared to other types of antennas. The proximity coupling has the largest bandwidth, but it is also the most complex to fabricate. The microstrip line feed and co-axial feed are widely used in the design of microstrip antennas. The model of a co-axial feed is shown in Figure 5.

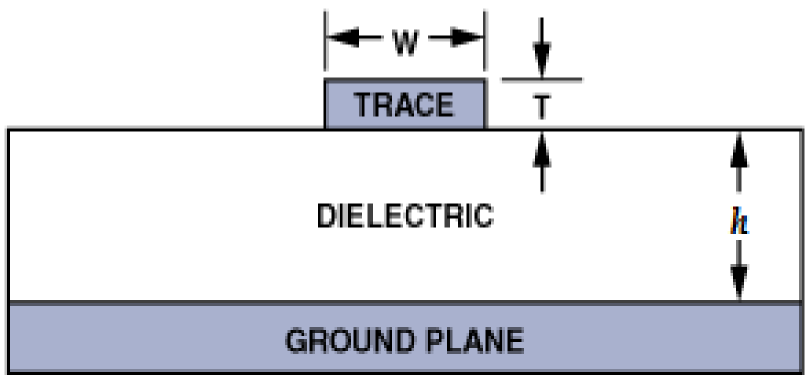


Figure 4. Microstrip line feed

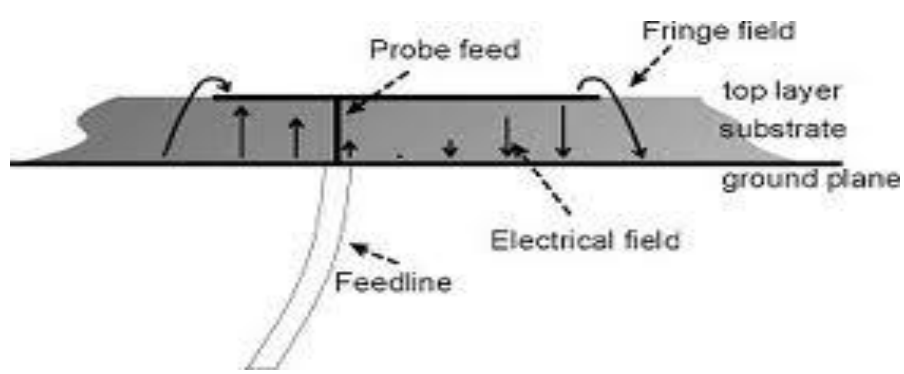


Figure 5. Co-axial microstrip feed antenna

2.1.2 Fringing effects

In a rectangular patch antenna, the dimensions of the patch are finite along the length and the width; the fields at the edges of the patch which are considered the radiating elements typically undergo fringing. This effect is depicted in Figure 6. The amount of fringing is proportional to the dimensions of the patch and the height of the substrate. For the principal *E*-plane (*xy*-plane) fringing is proportional to the patch length ℓ and to the height *h* of the substrate. A similar relation is applied to the width of the patch. For that reason, a length correction factor is introduced (fringing length extension "ℓe"), as fringing makes the patch looks electrically larger. Fringing is smaller for microstrip antennas which poses a length to height ratio greater than one ($\ell / h >> 1$). Even more, the length to height ratio must be seriously considered, because it directly influences the resonant frequency of the antenna.

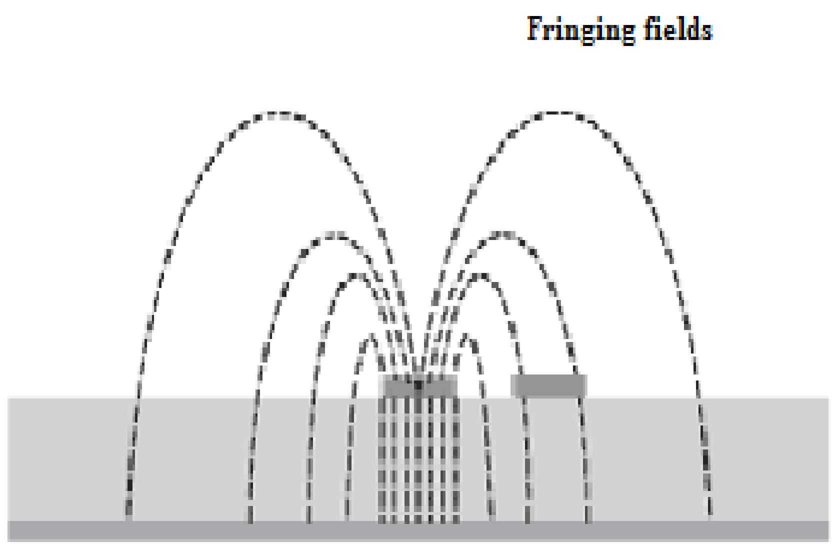


Figure 6.Fringing fields of a microstrip antenna.

2.1.3 Resonance frequency

Resonance is the tendency of any system to oscillate at a particular frequency with larger amplitude. The frequencies that oscillate at larger amplitude are named "Antenna resonant frequencies." Since for a typical microstrip antenna the substrate height is very small ($h < 0.05\lambda$), the resonance frequency is controlled by the patch length ℓ and the substrate permittivity. A higher substrate permittivity allows for a smaller antenna structure and a smaller bandwidth. The correction factor of length can be calculated using equation (2.1). It is equivalent to say that the length ℓ of the patch is one half of the wavelength in a dielectric (2.2).The resonance frequency is defined as

$$\mathrm{f} = \frac{\mathrm{c}}{\sqrt{\epsilon_{\mathrm{r}}}}\left(\frac{1}{2\ell}\right) \tag{2.1}$$

$$\mathrm{f} = \frac{\mathrm{c}}{\sqrt{\epsilon_{\mathrm{r}}}}\left(\frac{1}{2\ell_{\mathrm{e}}}\right) \tag{2.2}$$

2.1.4 Bandwidth

Bandwidth plays a vital role in every wireless communication system. Typically, the bandwidth depends on the volume of the substrate and the permittivity of the microstrip antenna. The antenna bandwidth is directly proportional to the width *w* and is inversely proportional to the substrate permittivity. To achieve better bandwidth, special feeding techniques like proximity coupling and stacked patches are used. With these techniques, the bandwidth can be increased over a 50% [8]. Even more, by increasing the thickness of the substrate an increment of 10% in the bandwidth can be achieved.

2.1.5 Radiation efficiency

Radiation efficiency is defined as the ratio of power radiated by the antenna into the free space to the total power accepted by the antenna at its input terminals. In real applications, a radiation efficiency of 100% can never be achieved. This is due to the losses in the conductor, in the dielectric and the surface wave power. Typically, the conductor losses increase with the operating frequency and thinner substrates. By using a foam substrate, higher radiation efficiencies can be obtained, which has the effect of making the substrate thicker. In terms of efficiency the conductor loss is more important than the dielectric loss. The radiation efficiency is also dependent on the gain and the directivity of the antenna.The directivity is the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over-all directions [3]. For the antenna to have good radiation efficiency it should have a large gain. This can be clearly seen in the following relation

$$\text{Radiation efficiency} = \frac{\text{gain}}{\text{directivity}} \qquad (2.3)$$

2.1.6 Radiation patterns and directivity

The radiation pattern and the directivity are some of the most important parameters of every microstrip antenna. In a microstrip antenna, the electric and magnetic fields are perpendicular to each other. This can be clearly seen in Figure 7. The radiation patterns of the field can be considered as four slots of radiating elements in the patch, two along the length and two along the width. However, only two slots contribute to the radiation while the other two radiating elements which are separated by the width cancel along the principal plane [9]. The direction and intensity of the energy radiated is defined by the following equation

$$D_0 = \frac{4\pi U_{\max}}{P_{rad}} \tag{2.4}$$

where D_0 is the maximum directivity, $U_{\max}$ is the maximum radiation intensity, P_{rad} is the total radiated power.

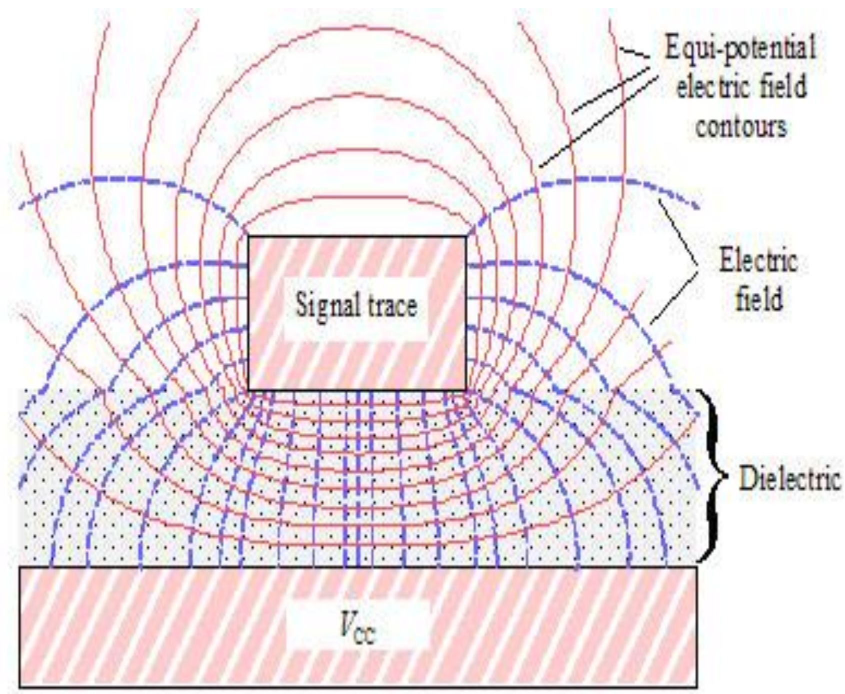


Figure 7. Electric field contours of a microstrip antenna

2.2 Construction of a regular microstrip antenna

The simulation of a microstrip antenna is performed using Numerical Electromagnetic Code (NEC) software. The microstrip antenna is simulated using thin copper wires, fed by a current source and the RLC loading is defined within the simulation. The NEC software also provides the possibility of placing the driven, directing and reflecting elements so that radiation patterns for different configurations can be analyzed. The spacing between the ground plane, the directors, and the reflectors with respect to the driving element is taken from previous research on microstrip antennas and Yagi-Uda antennas. The use of air as the substrate between the ground plane and the director will improve the bandwidth of the microstrip antenna [10]. The article "*ModifiedRectangular Patch Antenna with Air-Gap for Improved Bandwidth*"[10] shows improvements in the bandwidth up to a 33.5% for a modified rectangular patch antenna with an air gap corresponding to its resonant frequency. The radiation pattern of a regular microstrip antenna is compared to the radiation pattern of the antenna with air as substrate.

The dimensions of a microstrip antenna are calculated as follows. The width and the length of the antennas are given by the following expression $w = \ell = \lambda/2$ where λ is proportional to the operating frequency. The height of the metal patch is taken as 0.25λ from the perfect ground plane. The 3-D structure of the antenna created in NEC software can be seen in Figure 8. This metal patch design is developed using a rectangular grid [3, 11]. The diameter of the wire used to create the antenna is kept as low as possible in order to meet the required specifications for the metal patch and the operating frequency. Figure 9 shows the top view of the constructed microstrip antenna.

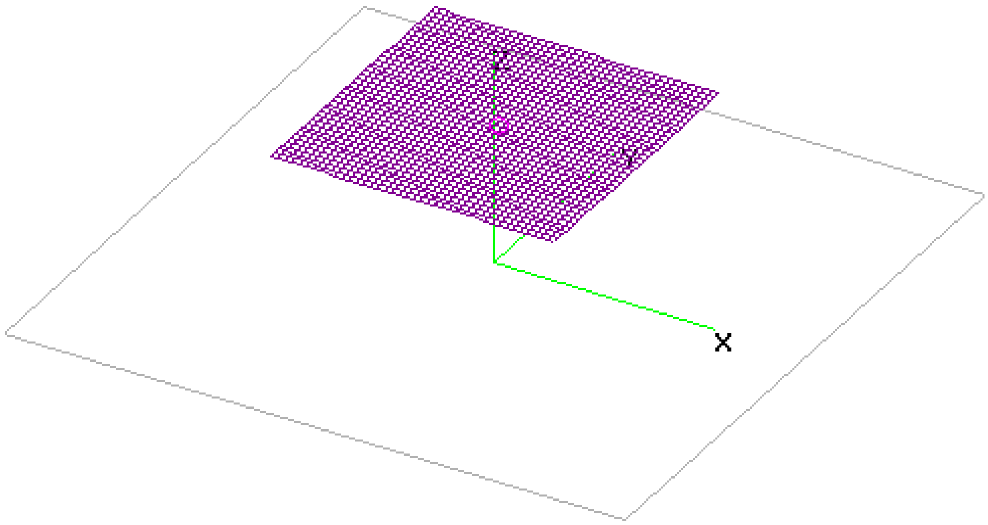


Figure 8. 3- D view of the designed microstrip antenna.

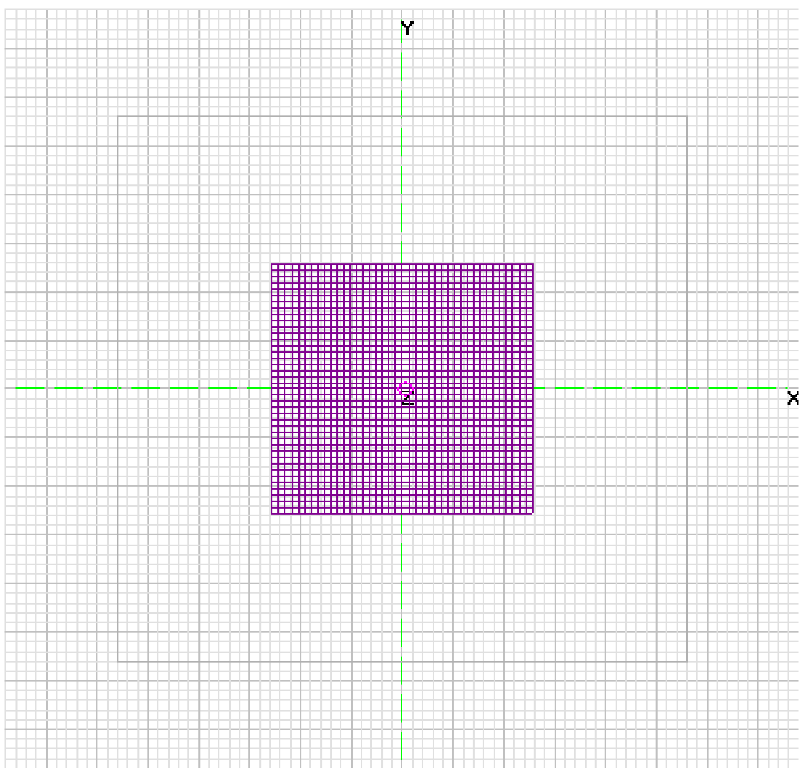


Figure 9. Top view of the microstip antenna

2.3 Simulation of a regular microstrip antenna

In this section, the radiation patterns obtained from simulating the rectangular patch antenna are observed. These radiation patterns were compared with patterns obtained from regular microstrip antennas. The goal was to observe that the design was in agreement with a regular microstrip antenna and proceed to more complex structures. The radiation patterns from the microstrip antenna are shown in Figures 10 through 14. Figures 10 and 11 shows the total gain of the antenna in a 3-dimensional view and in the vertical plane respectively. The radiation pattern of the horizontal gain in the horizontal plane is shown in Figure 14, and the 3-dimensional pattern is shown in Figure 13. The vertical gain of the radiation pattern is shown in Figure 12, which gives us a clear idea of the antenna gain. These figures show that the radiation patterns are in agreement with those from a conventional microstrip antenna.

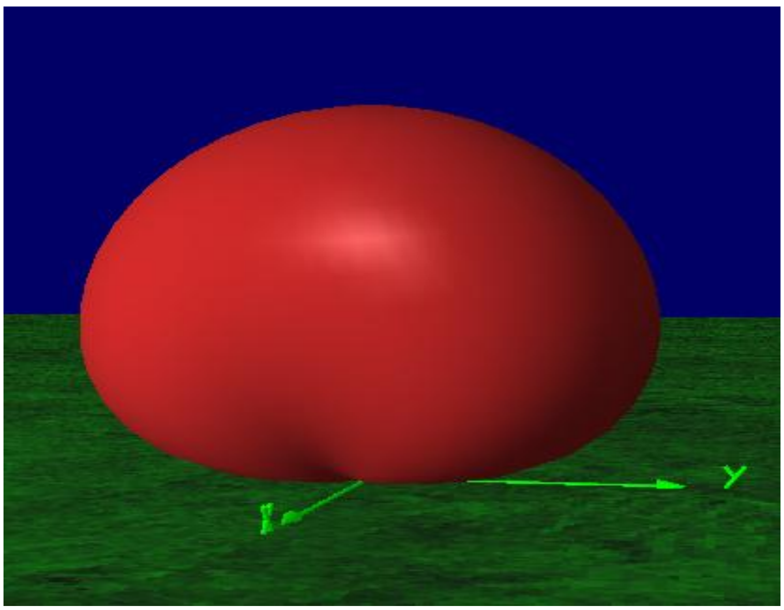


Figure 10. 3-D view of the total gain

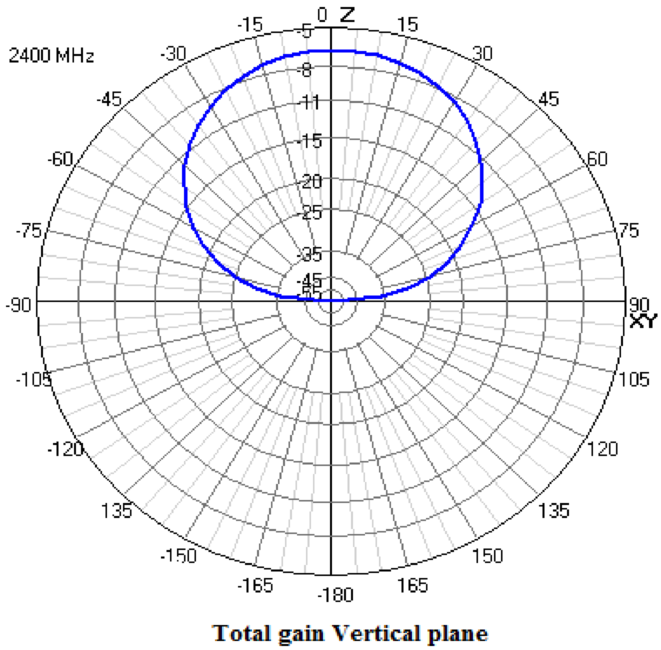


Figure 11. Radiation pattern showing total gain in the vertical plane.

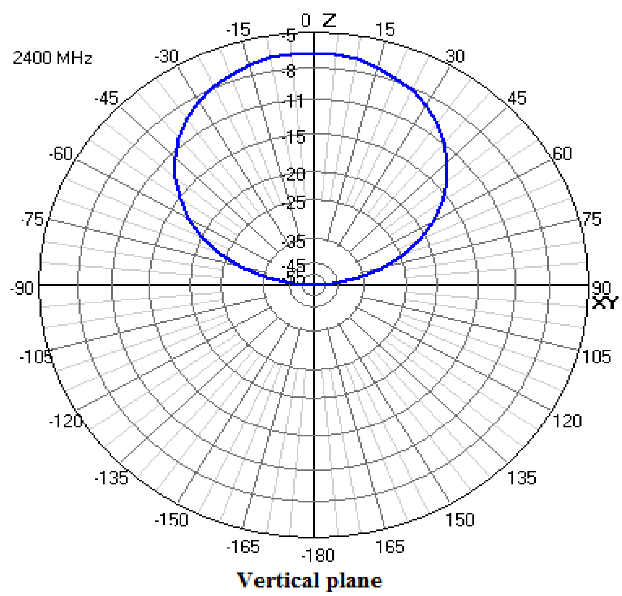


Figure 12. Radiation pattern showing vertical gain in the vertical plane.

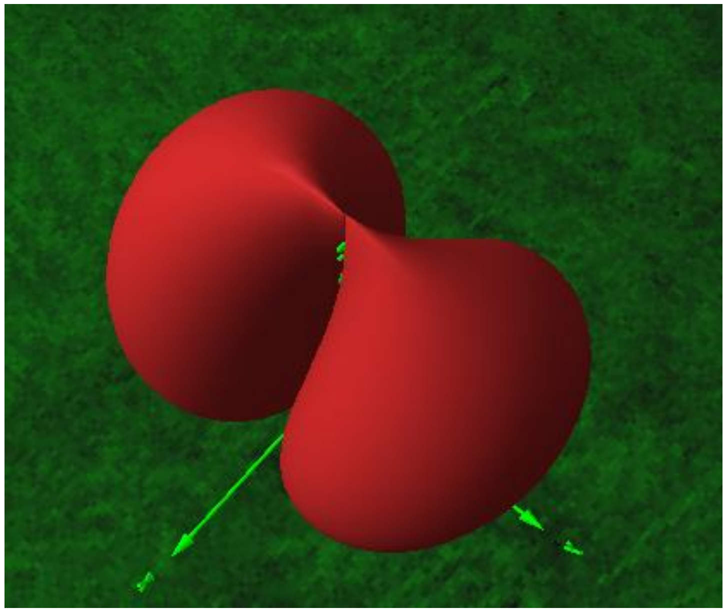
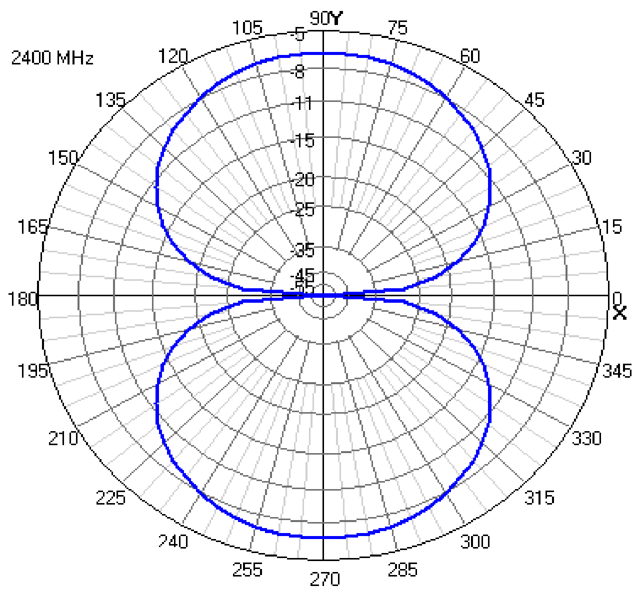


Figure 13. 3-D view of the Horizontal gain on horizontal plane.



Horizontal gain Horizontal plane

Figure14. Radiation pattern showing horizontal gain in the horizontal plane.

Chapter Three

Analysis and Design of Antenna Geometry

In this section, details regarding the design of the proposed microstrip antenna are discussed. In the previous section the proposed antenna structure was presented in Figure 8. The design of this microstrip antenna is based on the theory of microstrip antenna and the principles of Yagi-Uda antennas. The proposed system consists of a driver patch, a reflector and four directors. The placementof the directors and reflectors was based on the theory of the Yagi-Uda dipole antenna [6]. On the other hand, the analysis of the radiation patterns from thin-wire microstrip antennas was been provided by Rana and Alexopoulos [3, 11].In general, in every antenna system, the reflector is placed behind the driven element to suppress the back lobe and the directors are placed in front of the driven element to increase the gain in that specific direction. The distance between the driven element and the reflector should be smaller than the distance from the driven element and the nearest director [3]. Figure 15 shows a schematic of a Yagi-Uda antenna with directors and reflectors arranged with a specific distance for maximum gain. It is clear that the length of the directors and reflectors are not equal and the distance they are placed with the driven element varies respectively.

In the case of a microstrip antenna, a metal patch is used as the driving element. For this research work, it was decided to use a rectangular grid of wires to simulate the patch antenna [3, 11]. The patch antenna was designed to work at a center frequency of 2.4 GHz.

The distance from the ground plane and driven element is given by

$$h = 0.25\lambda \tag{3.1}$$

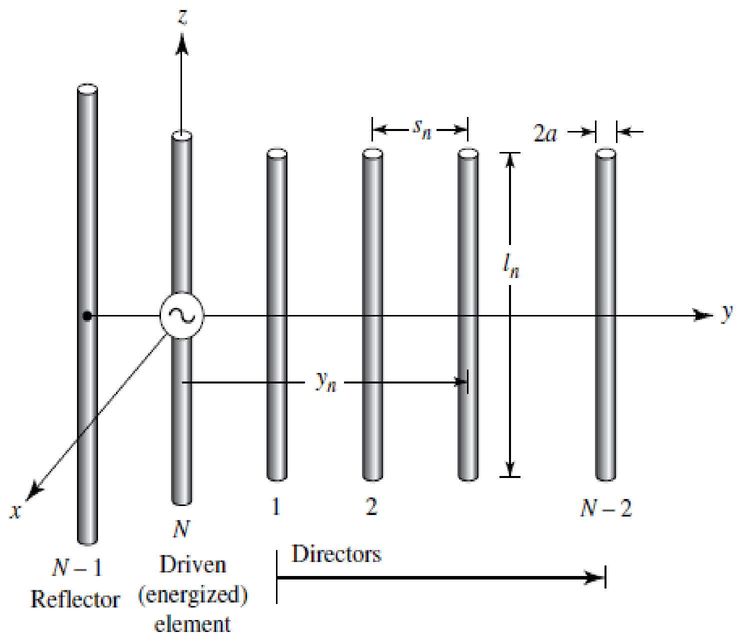


Figure 15.Yagi-Uda antenna with directors and reflector elements [3].

The length (ℓ) and the width (W) of the patch is calculated using the following expression:

$$\ell = w = \frac{\lambda}{2} \tag{3.2}$$

The radius of the wire used to build the micro strip antenna should be between

$$0.96\lambda < r < 1.44\lambda \tag{3.3}$$

The length of the directors is given by 0.4λ. The separation between the driven element and the nearest director is optimum at 0.3 λ. Also, it is well known that the optimum spacing between the reflector and the director for the maximum directivity is between 0.15λ and 0.25λ. This is the same as in the standard Yagi-Uda structure [6]. For that reason it was decided to place the reflector at a distance of 0.25λ from the driven element. Antenna characteristics such as gain, beam width and center frequency can be modified by changing the length of the driven element, the length of the parasitic elements, the spacing between reflector and driven element [8]. The design is developed on a perfect ground as the microstrip antenna design theory suggests the same. The total height of the design is 68 mm from ground plane as shown in the Figure 18.The Top view and a 3-dimensional view of the designed antenna are shown in the Figure 17 and Figure 16 respectively.

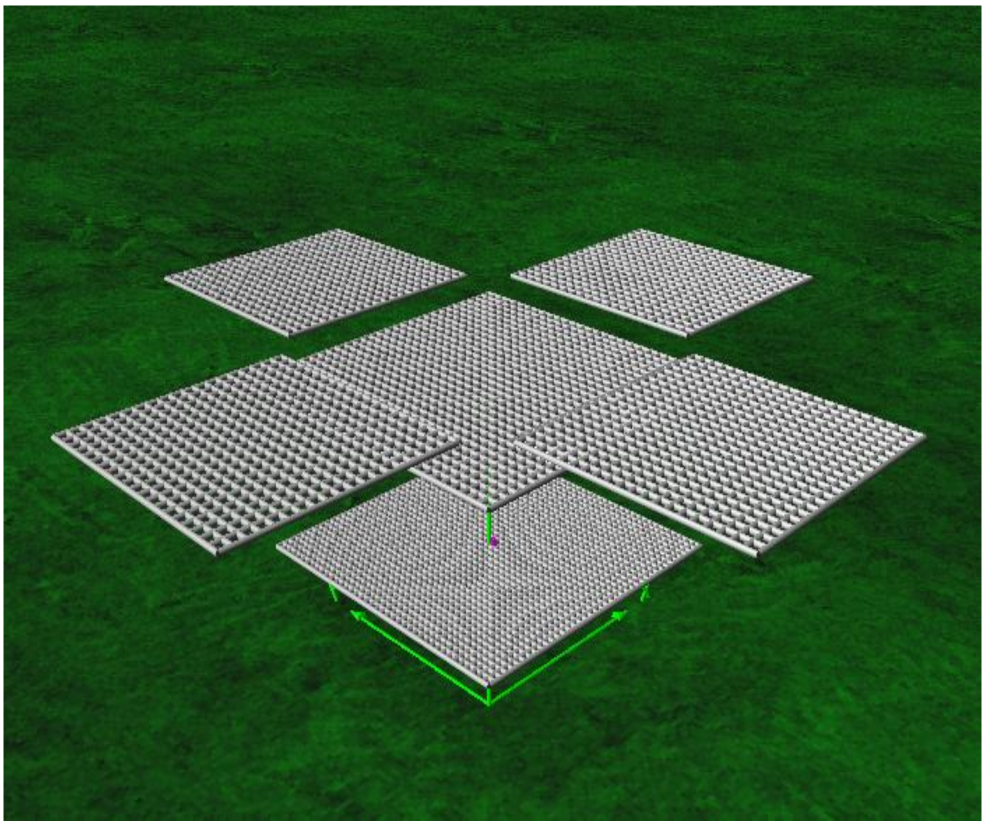


Figure 16. 3-D view of the antenna design

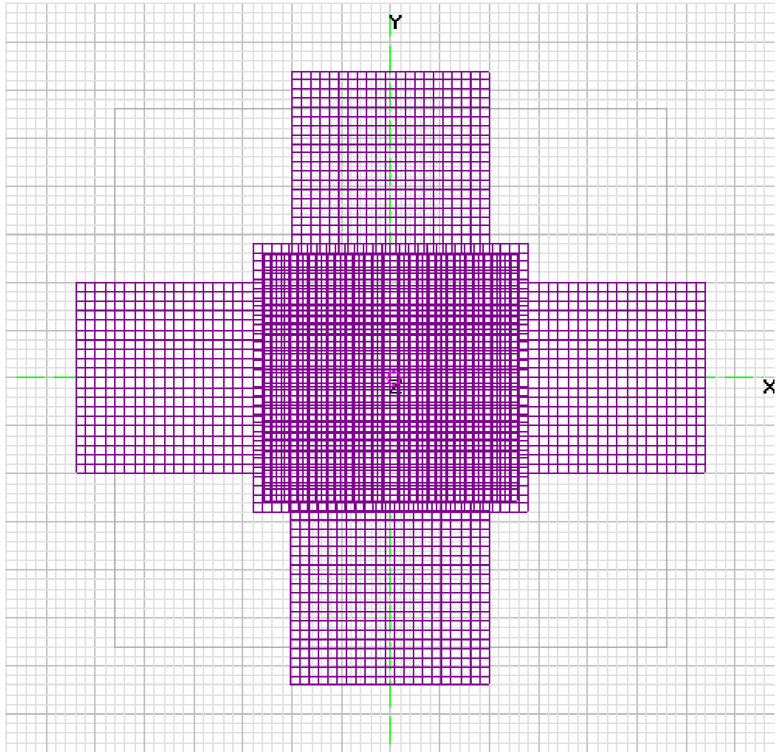


Figure 17. The top view of the antenna.

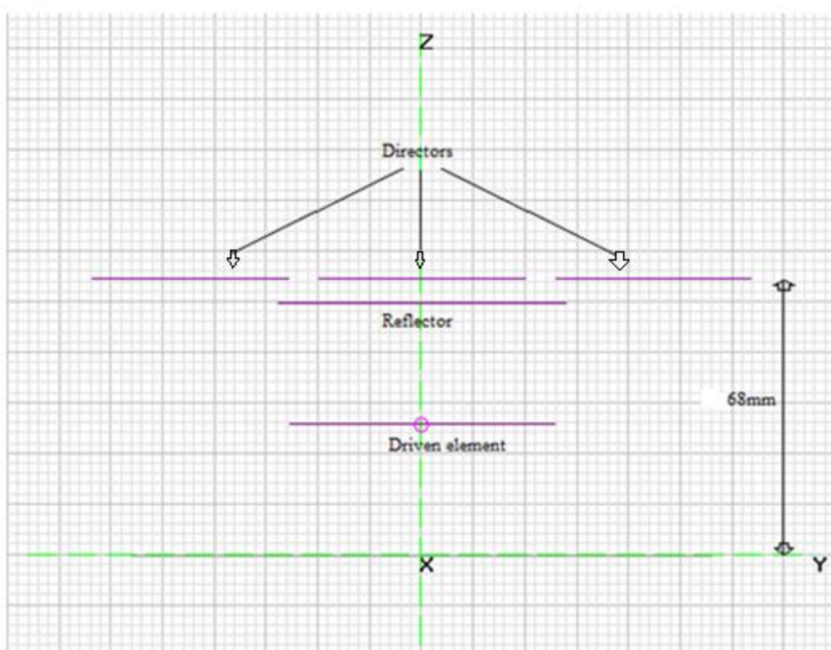


Figure 18. The zy - plane view of the antenna.

3.1 Results

This section describes the results obtained from the simulations performed for the proposed microstrip antenna at 2.4 GHz. The simulation was performed with a sufficient number of linear wire segments and under the limitation with respect to the desired wavelength. These numerical simulations considered an infinite perfect conducting ground plane and perfect conducting wire (copper).

The plots of the radiation patterns obtained from the simulations can be observed in Figures 19-25. Figure 22 shows the 3-D view of the horizontal gain. This is the gain obtained when a horizontal polarization is considered. It is clear by looking at this figure that the main lobe has been reduced and the energy at the sidelobes has been increased compared to Figure 13. Even more, Figure 25 shows the radiation pattern for the total gain of the antenna. It is clear by comparing Figure 25 to Figure 10 that the inclusion of the reflectors and directors has affected the shape of the radiation pattern. In this case the energy at the reflector has been reduced and the energy at the sidelobes has increased. Allowing the energy at the sidelobes to increase results in better antenna performance in the horizontal plane.

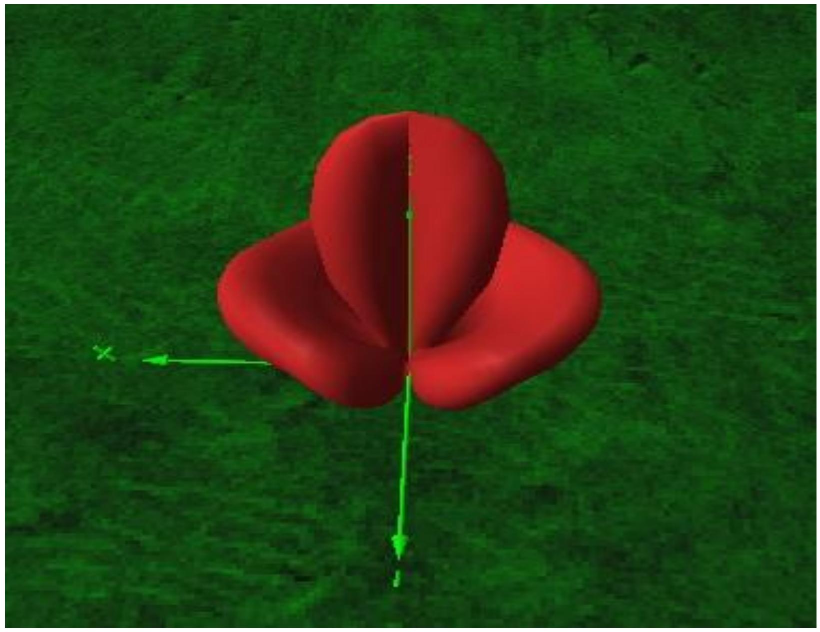


Figure 19. 3-D view of the vertical gain

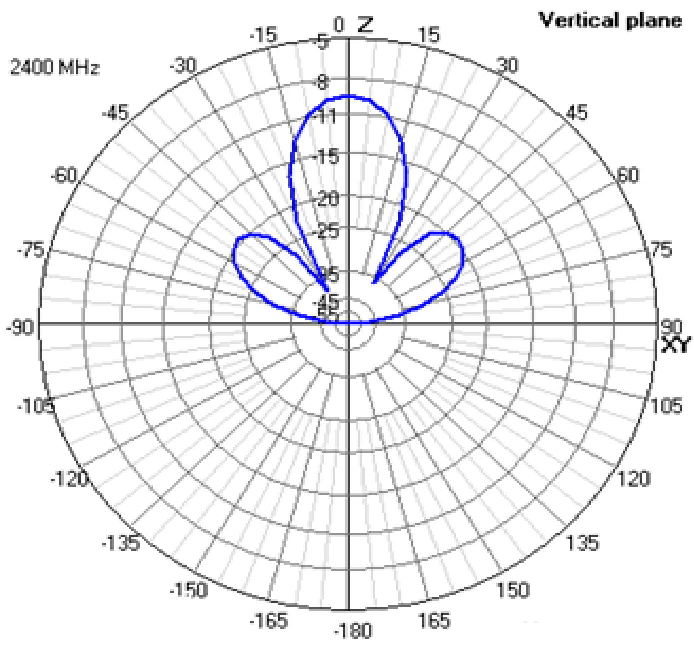


Figure 20. Radiation pattern showing the vertical gain in the vertical plane.

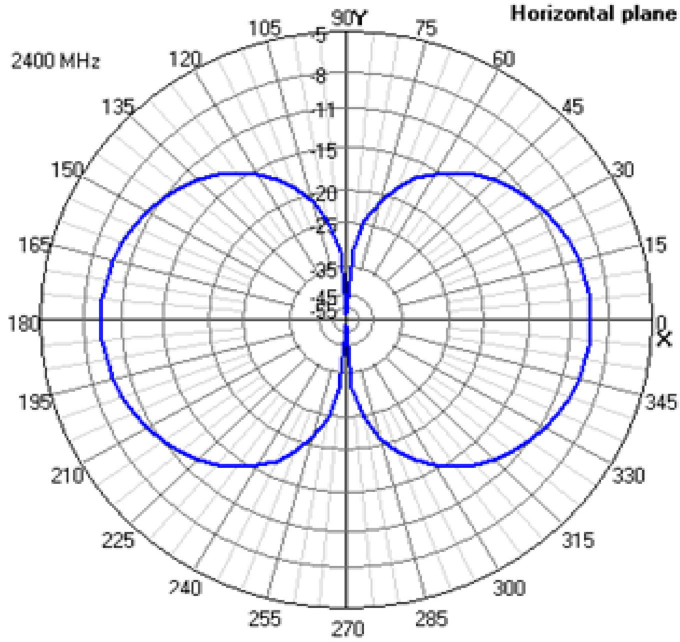


Figure 21. Radiation pattern showing vertical gain in the horizontal plane.

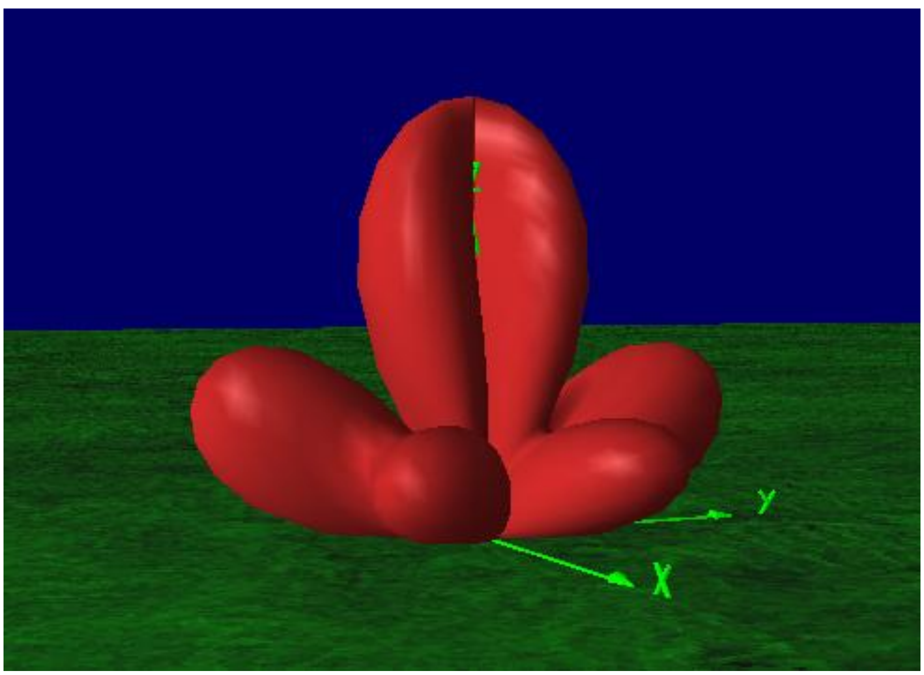


Figure 22. 3-D view of the horizontal gain.

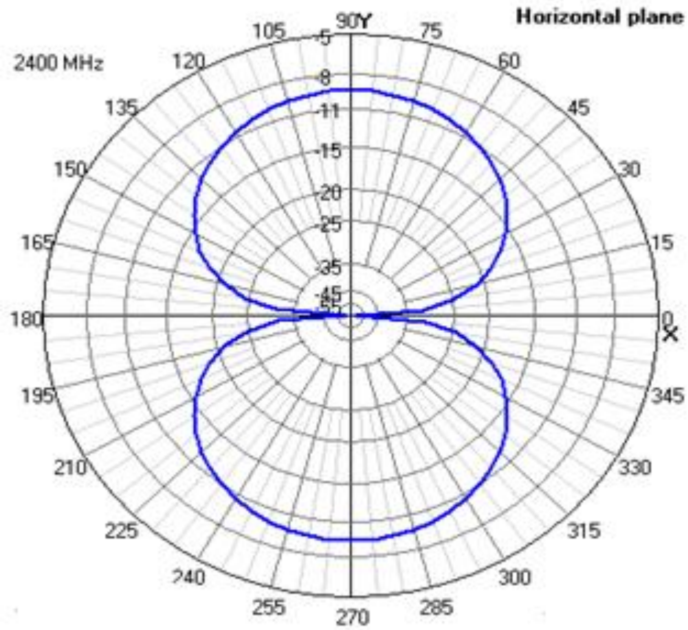


Figure 23. Radiation pattern showing horizontal gain in the horizontal plane

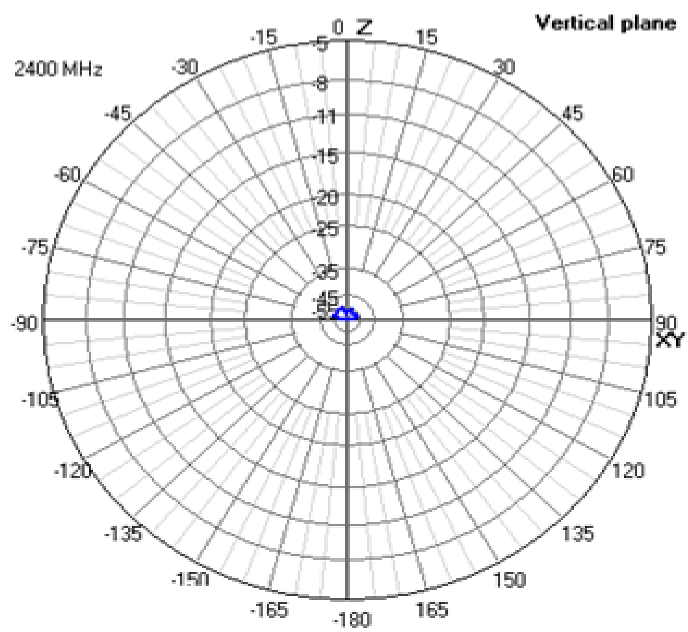


Figure 24. Radiation pattern showing horizontal gain in the vertical plane

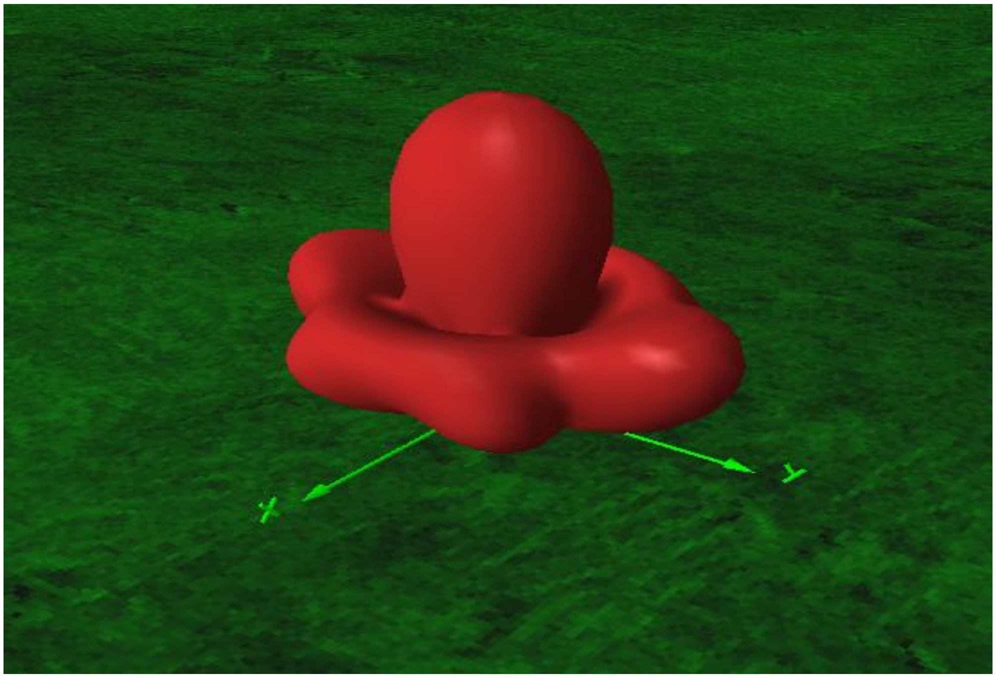


Figure 25. 3-D view of the total gain

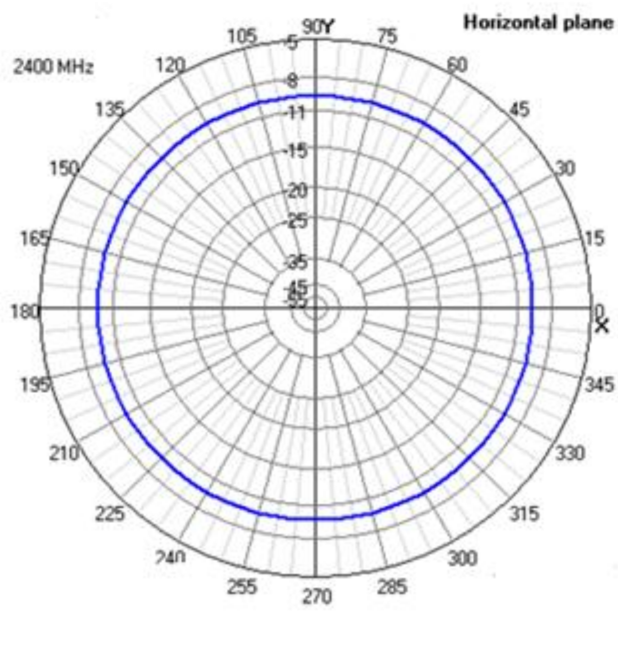


Figure 26. Radiation pattern showing total gain in the horizontal plane

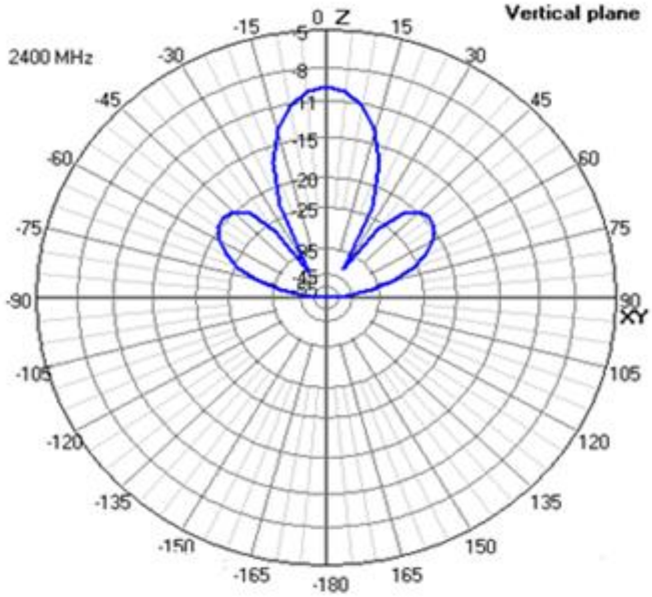


Figure 27. Radiation pattern showing total gain in the vertical plane

Chapter Four

Conclusion

In this research work, the design of a microstrip antenna to obtain a radiation pattern in the horizontal direction was studied. In order to compare the results, a regular rectangular microstrip antenna was built using air as the substrate. By looking at the radiation patterns of the regular microstrip antenna it was evident that the power at the sidelobes is insignificant and most of the radiated energy is concentrated in the vertical direction. The proposed design uses rectangular microstrip patches as reflectors and directors. The specifications of these elements were decided based on the concept of Yagi-Uda antennas. After testing multiple designs, a system composed of 4 directors and 1 reflector demonstrated the highest directivity in the horizontal direction. The results obtained from the simulations were in the form of three-dimensional and two-dimensional plots of the radiation patterns. These results showed that by using reflectors and directors the power at the main lobe is reduced from 7 dBi to 10 dBi. On the other hand, the power at the sidelobes went from 0 dBi up to 19 dBi. This clearly shows that some of the power from the main lobe was transferred to the sidelobes. As a result, the proposed design provides better performance in the horizontal plane.

4.1 Future work

The design work and the simulation of the antenna can be improved by using a circular director or array of directors and multilevel geometries. The use of innovative structures with interesting properties can enhance the performance of the design. This work suggests the proposed concept is low-cost and can be utilized for wireless sensor systems in various antenna applications. Directivity of radiation has a positive effect on device connectivity using the proposed antenna design. It can be expected that the new antenna designs will provide an alternative for a wide range of microwave applications. Practically this can be achieved more accurately with the directors used in a circle configuration.

References

[1] Constantine A. Balanis, *Advanced Engineering Electromagnetics,* New York: John Wiley & Sons, 1989.

[2] Tecpoyotl-Torres, M. Vera-Dimas, and J.G. Torre Cisneros, "Patch antenna for 2.4 GHz," in *IEEE/LEOS Summer Topical Meetings, 2008 Digest of the Center for Res. of Eng,* pp.33-34, August 2008.

[3] Constantine A. Balanis, *Antenna theory: Analysis and Design*, New York: John Wiley& Sons, Third Edition, 2005.

[4] NEC software official site http://home.ict.nl/~arivoors/.

[5] Rong Lin Li, and Manos M. Tentzeris, "Switchable Quad-Band Antennas for Cognitive Radio Base station Applications," in *IEEE Transactions on Antennas And Propagation*, Vol. 58, no.5, pp. 1468-1476, May 2010.

[6] Olivier Kramer, TarekDjerafi, and Ke Wu, "Vertically Multilayer-Stacked Yagi Antenna With Single and Dual Polarizations," in *IEEE Transactions on antennas and propagation*, vol .58, no.4, pp. 1022-1030, April 2010.

[7] J.R. James, Peter S. Hall, and Colin Wood,*Microstrip antenna theory and design.* United Kingdom: Peter Peregrines Ltd, 1986.

[8] L.C. Shen, and G.W. Raffoul, "Optimum design of Yagi array of loops," in *IEEE Transactions on Antennas Propagation*, vol 22, no. 11, pp. 829-830, Nov. 1974.

[9] Raul R. Ramirez, Franco De Flaviis, and Nicolaos G. Alexopoulos, "Single-Feed circularly polarized microstrip ring antenna and arrays," *in IEEE Transactions on antennas and propagation*, vol.3, pp.1364-1367, August 2002.

[10] Vijay Sharma, Brajraj Sharma, V. K. Saxena, K. B. Sharma, and D. Bhatnagar, "Modified rectangular Patch Antenna with Air-Gap for Improved Bandwidth," in *Recent Advances in Microwave Theory and Applications, MICROWAVE 2008* (Dept. of Phys., Govt. Women Eng. Coll., Ajmer), pp. 227-229, January 2009.

[11] Keith R. Carver and James W. Mink, "Microstrip Antenna Technology" in *IEEE Transactions on Antennas and Propagation,* vol.29, Issue:1, pp. 2-24, January 2003.

[12] Tomohiro seki, Kenjironishikawa, and Kazuyasu Okada, "60-GHz Multi-Layer Parasitic Microstrip Array Antenna with Stacked Rings using Multi-Layer LTCC substrate," *in IEEE conference 2008.* (Nippon Telegraph & Telephone Corp., Tokyo), pp. 679-682, March 2008.

[13] David R. Jackson, Introduction to microstrip antenna, www.egr.uh.edu/courses/ece/Ece6345

[14] MajaSekelja, ZoranBlazevic, Marino Maslac, “Helical antenna performance in wideband Communications,” in *Telecommunications and Computer Networks, SoftCOM 2008*. 16th International Conference (Mech. Eng. & Naval Archit., Univ. of Split, Split), pp. 21-26, November 2008.

[15] C.Chandan,Ghosh, S. K. Ghosh, S. Chattopadhyay, “Radiation Characteristics of Rectangular Patch using Air Substrates,” in *International Conference on Emerging Trends in Electronic and Photonic Devices & Systems*, ELECTRO-2009 (Dept. of ECE, Siliguri Inst. of Technol., Darjeeling, India),pp. 346-348, April 2010.