Design and Simulation of Microstrip Patch Array Antenna for Wireless Communication System

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Abstract—**This paper presents a microstrip patch antenna designed using computer simulation technology (CST) Microwave Studio at a resonant frequency of 2.4 GHz. The antenna consists of three layers, the upper layer called metallic patch, the bottom layer called ground and the dielectric layer in between the conduction layers called the substrate. The antenna has the advantage of minimal weight, low profile and can maintain high performance over a wide spectrum of frequencies. As such the study focused on the novel design of a rectangular microstrip patch antenna. The performance characteristics of the antenna patch arrays elements 1X2, 1X4 and 2X2 were compared. The aim of designing an antenna with improved gain, reduced losses and use for X band applications such as radar, satellite, communication, medical applications and other wireless systems was achieved. The performance of the designed antenna in terms of radiation efficiency, gain, reflection coefficients and radiation patterns were verified and found suitable for wireless local area network (WLAN) applications.**

Keywords: Patch antenna, Radar technology, Radiation efficiency, Microstrip

I. Introduction

Antenna is one of the most important components of any wireless system. An antenna is an electronic device that transmits and (or) receives electromagnetic waves. In most cases, it operates as a resonant device that efficiently operate in a relatively narrow frequency band [1]. For the antenna to work efficiently, its frequency must be tuned to the frequency band of the communication system to which it is connected, otherwise, the signal transmission will be impaired [2]. The receiving antenna is responsible for turning the electrical signal into its original form.

In recent years, the development in communication systems necessitates the requirement of low cost, minimal weight, low power, and low profile antennas that are capable of maintaining high efficiency over a wide band of frequencies [3]. A microstrip patch antenna is a single layer design that in most cases contains four main parts the patch, the ground plane, the substrate in between patch and ground, and the feeding port. The design and construction of the antenna are very simple using the conventional microstrip feed line method. The patch can be designed in any shape although in most cases rectangular and circular configurations shapes are more prominent] [7]. The ground plane can be finite or infinite depending on the model (transmission line model, cavity model, full-wave model or method of moments) used for the analysis of dimensions [1]–[8]. Relative permittivity (ϵ_r) and height (h) are the two most important characteristics considered for any antenna type. The substrate, as well as the feeding port, can be microstrip line, coaxial probe, aperture coupled or proximity coupled Feed [5]–[7]. Single microstrip patch antenna presents the advantages of low cost, light-weight, conformal and low profile [9]. The drawbacks are very little which are low gain, low directivity, low efficiency, and narrow bandwidth [10].

II. Antenna Design and Simulation

The antenna array was designed and simulated using computer simulation technology (CST) Studio Suit Software. CST is a 3D full-wave electromagnetic field simulator; it uses the finite element method together with adaptive meshing to solve the wave equation. If a 3D model has been made, CST sets up the mesh automatically. The CST computes S-parameters can be calculated and plot both the near and far-field radiation. It also computes important

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parameters such as gain and radiation efficiency. This software was used to vary the sizes of patches, microstrip feed line, and ground plane to come up with the desired results.

The dimension of any antenna type is design based on its area of application. The present antenna was designed based on WLAN application and the specification for WLAN antenna is given in the Table I.

TABLE I. DIMENSION OF WLAN ANTENNA

Frequency	2.4GHz
Substrate	FR4 (lossy)
Dielectric constant	4.7
Loss tangent	0.019
Substrate Height	1.6mm
Conductor thickness	0.035mm

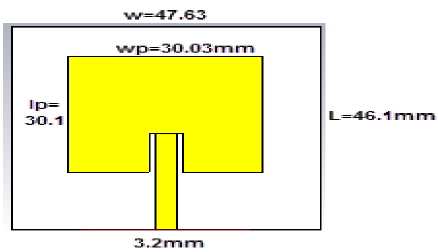
A. *Layout based Simulation*

The first step before designing the layouts, the dimensions of the desired antenna and feeds should be calculated. The layout design environment is brought out. The EM Structure on the PROJ tab is right-clicked. The New EM Structure option is selected. An empty design layout will appear in the main design window on the right.

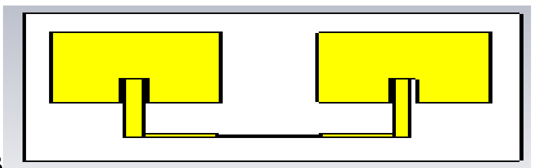
The parameters specification for the antenna used in this study is shown in Table II.

TABLE II. DIMENSION OF RECTANGULAR PATCH ANTENNA ARRAY

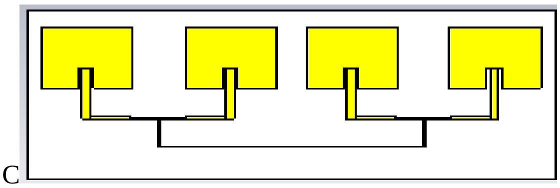
Patch	
Width, w (mm)	30.03
Length, L (mm)	30.10
50 Ω feedline	
Width, w (mm)	3.20
Length, L (mm)	17.00
100 Ω feedline	
Width, w (mm)	0.70
Length, L (mm)	14.00
75 Ω feedline (λ/4 transformer)	
Width, w (mm)	1.60
Length, L (mm)	15.00



A



B



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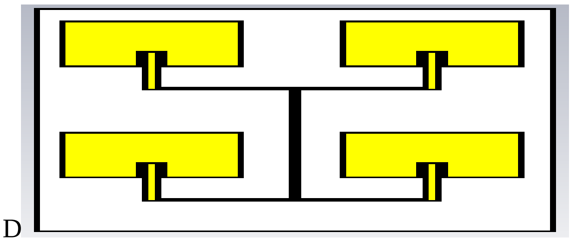

D

Design Layout of (A) Single patch antenna (B) Array Antenna 1x2 (C) Layout of Array Antenna 1x4 (D) Layout of Array Antenna 2x2

Before starting to draw the conductors on the enclosure, the correct size and dimensions should be defined for the enclosure. This can be done by clicking on the Enclosure button. A substrate information option window will appear before the user, as brought in the CST. The desired size on x and y position (length and width) enough for the antenna and feed to be printed on the entered. Cell sizes are the distance of the point to the next point in the layout and it is determined by the value of X and Y divisions. Once again, a refined cell size will give greater accuracy, however, at the expense of simulation resources.

III. SIMULATION RESULTS AND ANALYSES

A. *Graphs and Charts*

The antenna responses were plotted using sigma plot and the following results are obtained.

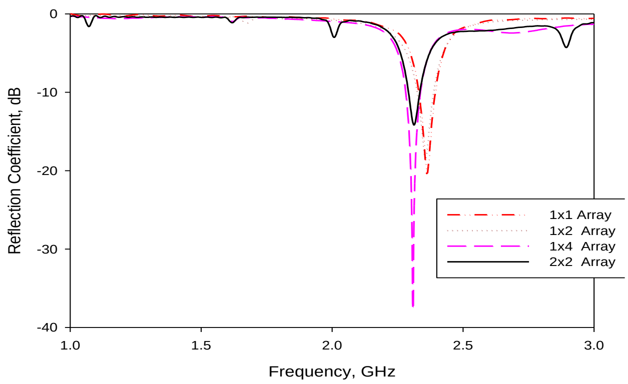

Figure 1: S_{11} Result

Figure 1 shows the S_{11} parametric response of the configured antenna of different array designs which is the frequency response of the antenna at the giving frequency of 2.4GHz.

In Figure 2 the antenna array radiation efficiency is shown. It indicated that antenna 1x1 has the highest radiation efficiency than the other.

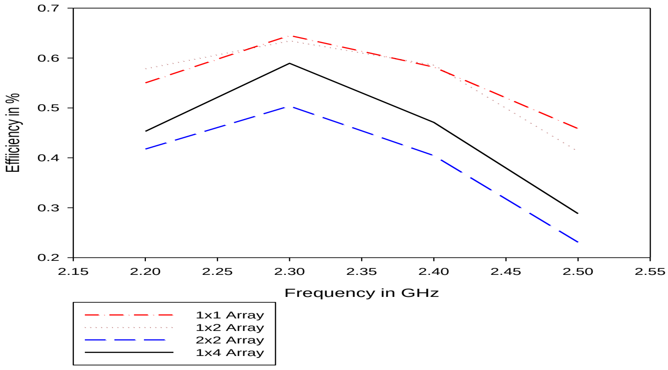

Figure 2: Radiated Efficiency

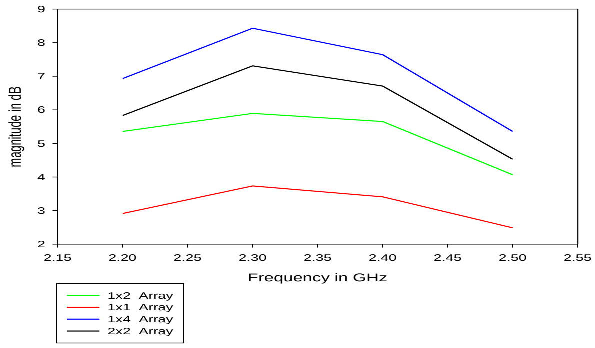

Figure 3: Maximum Gain

The result in Figure 3 shows the maximum gain of the antenna, which indicate that the antenna 1x4 has a maximum gain. This implies that it will cover a higher distance of receiving and transmitting signals followed by 2x2 then 1x2 and lastly 1x1.

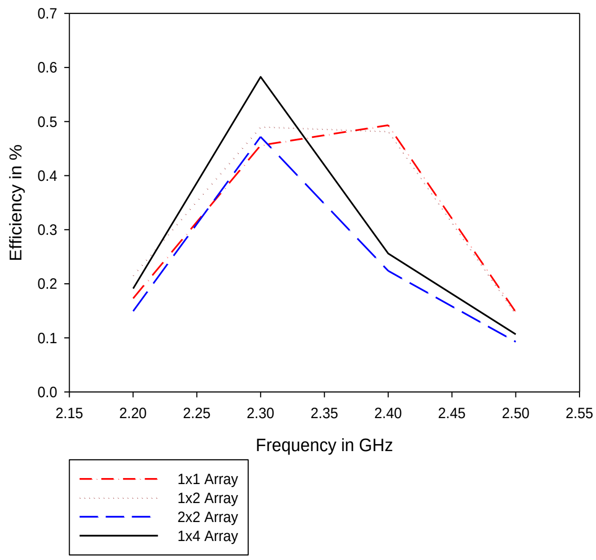

Figure 4: Total Efficiency

Figure 4 shows the total efficiency, it can be seen that the antenna 1x4 have a highest efficiency than the other antennas.

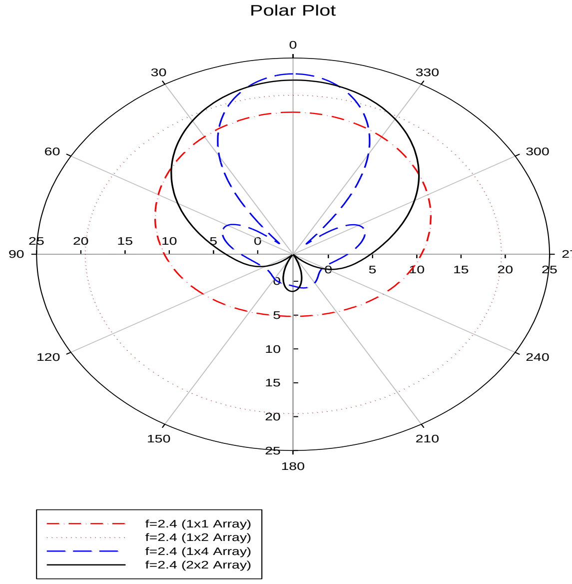

Figure 5: E-plane

The result in Figure 5 shows the E-plane result of the antenna and the antenna radiate only in one direction towards the main lobes (uni-directional radiation pattern).

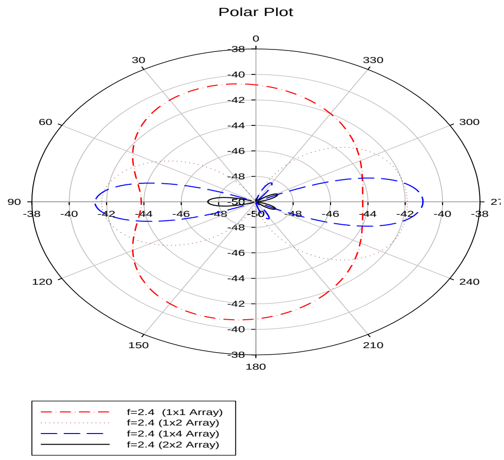

Figure 6: H-plane

In Figure 6, the H-plane result of the anenna is shown and the antenna radiates in two direction (in both two main lobes that is bi-directional).

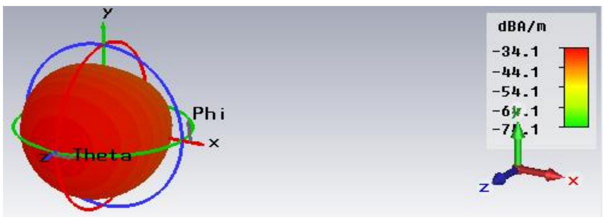

Figure 7: D Polar plot of 1X1 array

Figure 7 shows the polar plot of the 1x1 antenna and it shows 3D plot of the radiation pattern of that 1x1 antenna.

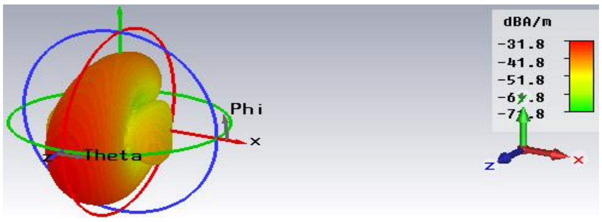

Figure 8: D Polar plot of microstrip 1X2 array

Figure 8 shows the polar plot of the 1x2 antenna. It shows 3D plot of the radiation pattern of 1x2 antenna.

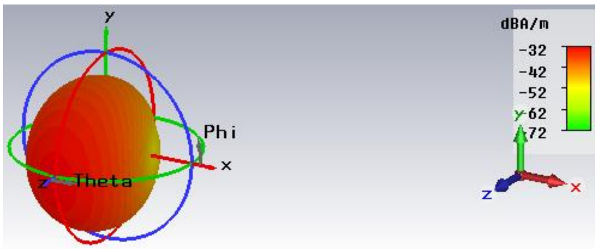

Figure 9: D Polar plot of 1X4 array

The result in Figure 9 shows the polar plot of the 1x24 antenna and depicted the 3D plot of the radiation pattern of the 1x4 antenna.

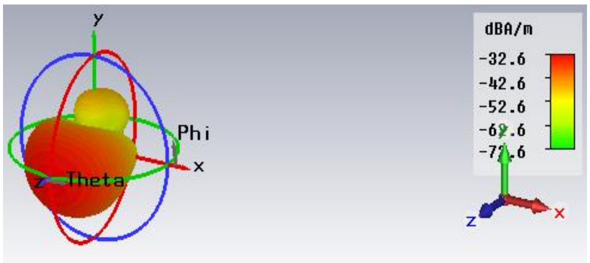

Figure 10: D Polar plot of 2X2 array

Figure shows the polar plot of the 1x24 antenna and it shows the 3D plot of the radiation pattern of the 1x4 antenna.

TABLE III. REFLECTION COEFFICIENT ANALYSES RESULTS

Element	Gain (dB)	Band width (%)	Radiated Efficiency (%)	Total Efficiency (%)
1x1	3.8	2.75	65	49
1x2	5.9	2.77	63	48
1x4	8.5	2.55	51	47
2x2	7.2	1.89	58	58

IV. CONCLUSIONS

A microstrip patch array antenna of a rectangular shaped radiating element was successfully designed and simulated using CST-STUDIO SUIT software and FR4 substrate.

During the simulation we observed that, the array antenna work in the 2.4GHZ ISM band by having a resonant frequency of 2.4GHz and has a fraction bandwidth of 4.12%. Based on the results obtained, it was also observed that the gain and directivity increase with the increase in spacing of the antenna.

V. REFERENCES

[1] B. Ramya, C. Supratha and S. Robinson, “Design and Analysis of microstrip patch array antenna for WLAN applications,” ICTACT Journal of microelectronics, vol. 3, Issued on 4 Jan., 2018.

[2] J. Vijayalakhmi, V. Dinesh and S. Rubasri, “Design and Analysis of high gain circular patch antenna arrays for 2.4GHz,” IJSTR vol. 9, ISSN 2277-8616, Issued on 4 April, 2020.

[3] M. T. I. Huque, et al., “Design and Performance analysis of microstrip array antennas with optimum parameters for X band applications”, International Journal of Advanced Computer Science and Applications, vol. 2, no. 4, 2011.

[4] A. Balanis, “Antenna theory: Analysis and Design/Constantine,” third edition, Hoboken. NJ. Wiley, 2005, ISBN 047166782X (hbk).

[5] J. L. Volakis, “Antenna engineering handbook,” 4th Edition, McGraw-Hill 207 ISBN 0071475745/1475747.

[6] M. A. Douglas (B. Ed.(Sci)), “Design and Analysis of microstrip antenna for 2.4GHz applications,” Master’s thesis, School of pure and applied science of Kenyatta University. (August, 2019).

[7] O. Barrou, A. El Amri, A. Reha, “Microstrip patch antenna array and its application: a Survey,” (IOSR-JEEE), e-ISSN: 2278-1676, p-ISSN:2320-3331, vol-15, Issued on Jan-Feb, 2020, pp 26-38, University of Casablanca, Morocco.

[8] Dr. A. K. Gautam, “Antenna and wave propagation,” Dept. of electronics and communication engineering, G.B. Pant, Engineering College, Daryaganj New-Delhi.

[9] H. Singh, “Electromagnetics and Antennas,” College of Engineering and Technology Tangori, Mohali (Punjab), New-Delhi.

[10] R. Garg, P. Bhartia, I Bahl and A. Ittipiboon, “Microstrip Antenna Design Hand Book” New Edition, Artech House, 2010.