



## Design, Analysis and Optimization of A Slotted Microstrip Patch Antenna Array at Frequency 5.25 GHz for WLAN-SDMA System

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**Abstract:** The design of array antenna is vital study for today's Wireless communication system to achieve higher gain, highly directional beam and also to counteract the effect of fading while signal propagates through various corrupted environments. In this study, the design and analysis of a (2x2) microstrip patch antenna array is introduced. It is designed to function in the 5.25 GHz which corresponds to IEEE 802.11a (VSWR<2, data rate 54Mbps/B.W 20 dB and S-parameters,  $S_{ij} < -20\text{dB}$  where  $i \neq j$ ) wireless LAN application. It achieves single band functionality through additional slots to rectangular patch of dimension 18.8 mm by 24.4mm. The proposed antenna array is a high gain, low-cost, low weight base station antenna. The characteristic analyses such as return loss (RL), bandwidth, VSWR and radiation pattern of the prototype antenna array have been investigated both numerically and experimentally. In this investigation, VSWR less than 1.45 and bandwidth of 180MHz (For  $RL > -9.5\text{dB}$ ) and antenna gain of 13.88 dBi have been achieved. Both numerical and experimental studies have been carried out to optimize the distance between the antenna elements. The measured results have a good agreement with that of simulated results. The numerical study has been done by using Zeland make IE3D electromagnetic simulator and measurements have been done with the help of Agilent make N5230A, network analyzer.

**Index Terms:** Antenna array, Antenna gain, Slotted microstrip patch, Fringing field, Wireless LAN, IE3D electromagnetic simulator, antenna feed point, Array optimization.

### 1. Introduction

Over the last two decades the wireless communication system has experienced a significant growth from first generation (1G) analog voice signal to forthcoming fourth generation (4G) mobile technology. The motto of 4G communication system is to provide Wi-Fi (Wireless Fidelity) communication network and high quality audio and video services. Today's technology requires high data rate and longer range to provide quality services to the users. For current mobile communication, the diversity scheme has already been implemented to mitigate the fading effects of multipath scenario [1], [2]. In a multipath rich wireless channel, deploying multiple antennas at both the transmitter and receiver achieves high data rate without increasing the total transmission power [3]. In this study, an antenna array has been design to improve the gain, antenna beam, bandwidth and reliability of the communication system. This is achieved as a result of the use of multiple antenna elements, excited through single feed point via the transmission line networks.

The array antenna structure is very interesting study and it is widely applicable to increase the range and reliability [4]-[6] of Wi-Fi LAN, Bluetooth, PDA (Personal Digital Assistants) DCS (Digital Communication System) and mostly in the field mobile communication. This article describes the design, analysis and simulation of single element and multi elements patch antenna array for recent wireless communication system which operates at 5.25 GHz band. The antenna is designed, optimized and analyzed with commercially available IE3D electromagnetic simulator. In this investigation, a simple rectangular patch with rectangular slots in there different positions has been taken to achieve good performances. We focused on

the antenna aspect of array system where four element microstrip patch configuration is proposed. Some good review articles are [7], [8], [9] and [10] where they did not optimized the distance between the antenna elements for reducing the effect of mutual coupling between the elements. But despite that they still give good introduction to the advantages and disadvantages of the system.

## 2. Design Principles

Initially the dimension of the single patch has been designed with three slots in three different positions with characteristic parameters of length (L), width (W) and thickness (t) as shown in Figure 1.

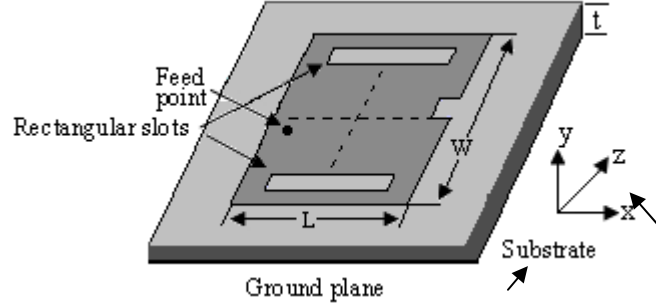


Figure 1. Geometry of a single element of the microstrip patch array.

To meet the actual design requirements i.e. operating frequency 5.25GHz, beam pattern, band width and the radiation efficiency, some approximations have been taken. The calculations are based on transmission line model. The width and length of the microstrip patch have been calculated by the following formula [11]

$$W = \frac{c}{2f_0 \sqrt{\frac{\epsilon_r + 1}{2}}} \quad (2)$$

Where the required frequency  $f_0=5.25$  GHz,  $c= 3e10$ cm/s and  $\epsilon_r= 2.2$ . Substituting above values, the width of the patch (W) becomes 22.58 mm. The effective length of the patch can be calculated with the help of equations (3) and (4).

$$L_{\text{eff}} = \frac{c}{2f_0 \sqrt{\epsilon_{\text{reff}}}} \quad (3)$$

$$\epsilon_{\text{reff}} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left( \frac{1}{\sqrt{1 + 12t/w}} \right) \quad (4)$$

In this design, RT/duroid substrate has been used with substrate parameters are  $\tan\delta=0.001$ , thickness of the substrate,  $t=1.588$  mm. Substituting  $W=22.58$  mm,  $\epsilon_r= 2.2$  in equation (4) we get  $\epsilon_{\text{reff}} = 1.925$ . Hence  $L_{\text{eff}} = 20.60$  mm. The length extension is to be calculated by (5)

$$\Delta L = 0.412t \frac{(\epsilon_{\text{reff}} + 0.3) \left( \frac{W}{t} + 0.264 \right)}{(\epsilon_{\text{reff}} - 0.258) \left( \frac{W}{t} + 0.8 \right)} \quad (5)$$

Substituting  $\epsilon_{\text{reff}} = 1.925$  and the values of W and t, we get  $\Delta L= 0.823$ mm. Now the actual length (L) of the patch is given by  $L= L_{\text{eff}} - 2\Delta L = 20.60$  mm- 1.686 mm =18.91 mm. Apart from this approximate calculation, the dimension has been slightly adjusted in order to achieve



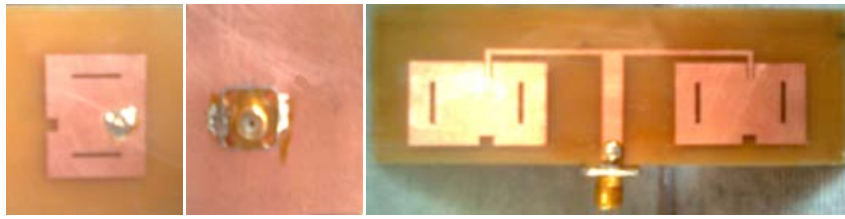


Figure 4. Fabrication of single element and two elements of the array

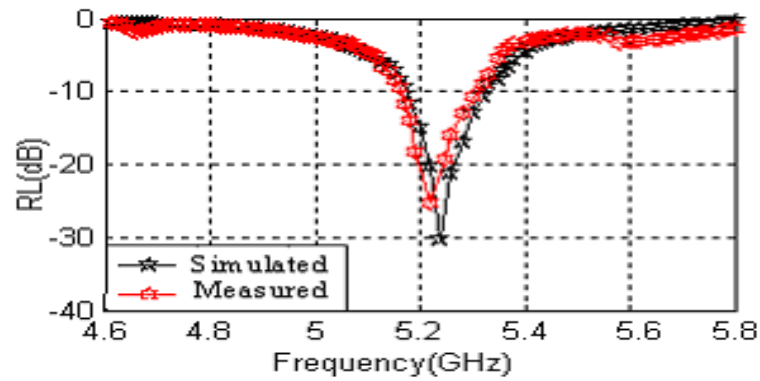


Figure 5. RL for single element of the array

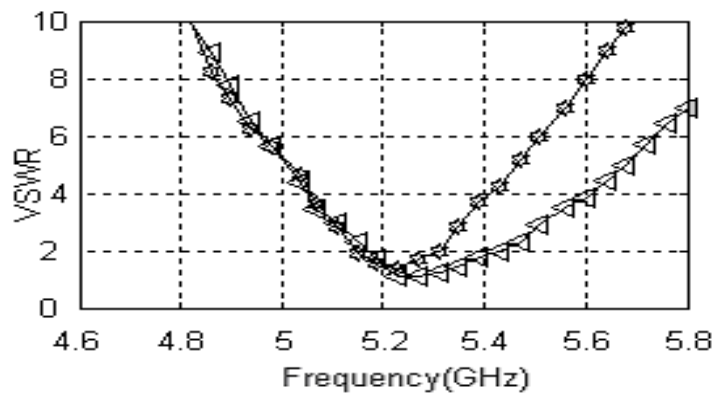


Figure 6. VSWR for single element of the array

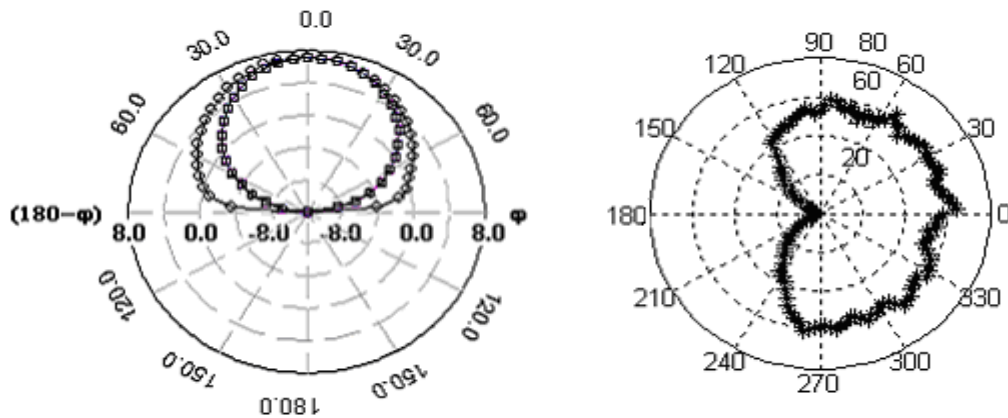


Figure 7. Elevation pattern gain simulated (left) for  $\phi=0\text{deg.}$ ,  $\phi=90\text{deg.}$  and measured radiation pattern (right) at frequency 5.25 GHz



The distance between the antenna elements has been optimized and fixed at  $x_1 = 3\text{ cm}$ . The isolation test has been carried out by placing the antenna elements at three different positions such as 2.2 cm, 2.5 cm and 3.0 cm respectively. From simulation results it is observed that to achieve better isolation the adjacent elements should be separated by the distance of at least  $\lambda/2$ . In this design  $\lambda/2 = 2.857\text{ cm}$  and the element distance ( $x_1$ ) has been fixed at 3.0 cm. Figure 8 and Figure 9 show the geometry and the prototype of the proposed array.

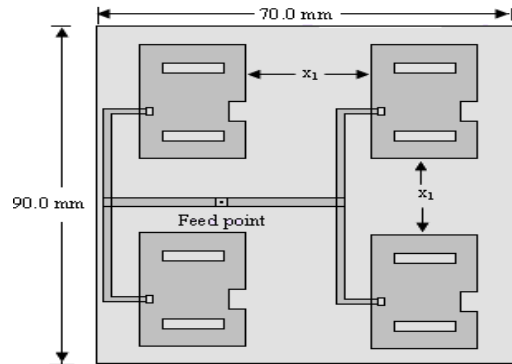


Figure 8. Geometry of (2x2) circularly polarized planar antenna array.

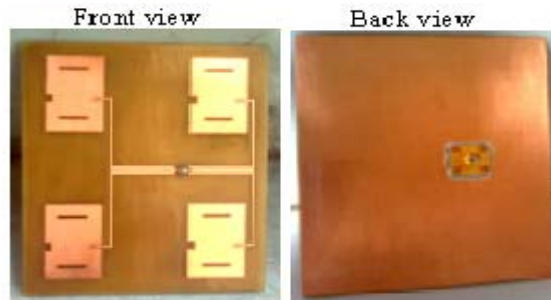


Figure 9. The prototype of the proposed array.

## 5. Results of The Array

### A. Radiation pattern

The microstrip patch antenna radiates normal to its patch surface. So the elevation pattern for  $\phi = 0$  and  $\phi = 90$  degrees are important for the measurement. The simulated E-plane and H-plane pattern, 3D pattern view and the impedance characteristics of the array are illustrated in the Figure 10 and Figure 11. The measured and simulated values of VSWR are shown in the Figure 12. The simulated results for isolation between ports of the antenna elements with  $x_1 = 3.0\text{ cm}$  are shown in the Figure 14.



**B. Return Loss and other Characteristics.**

The return loss (shown in Figure 13) of the antenna is -26 dB at 5.25 GHz and from RL curve, the bandwidth obtained for  $RL > -9.5$  dB is 180 MHz. The measured value of VSWR, obtained from the curve is 1.5.

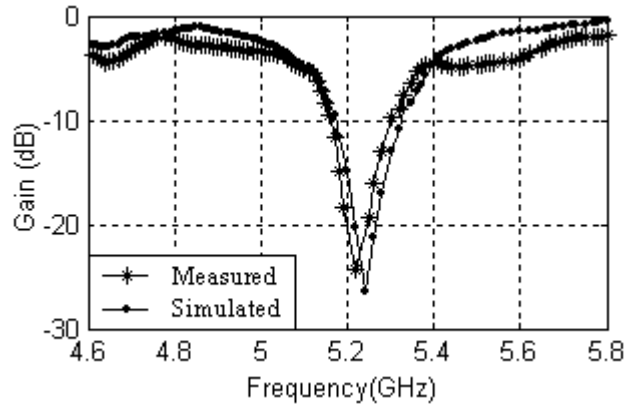


Figure 13. Return Loss curve at 5.25 GHz.

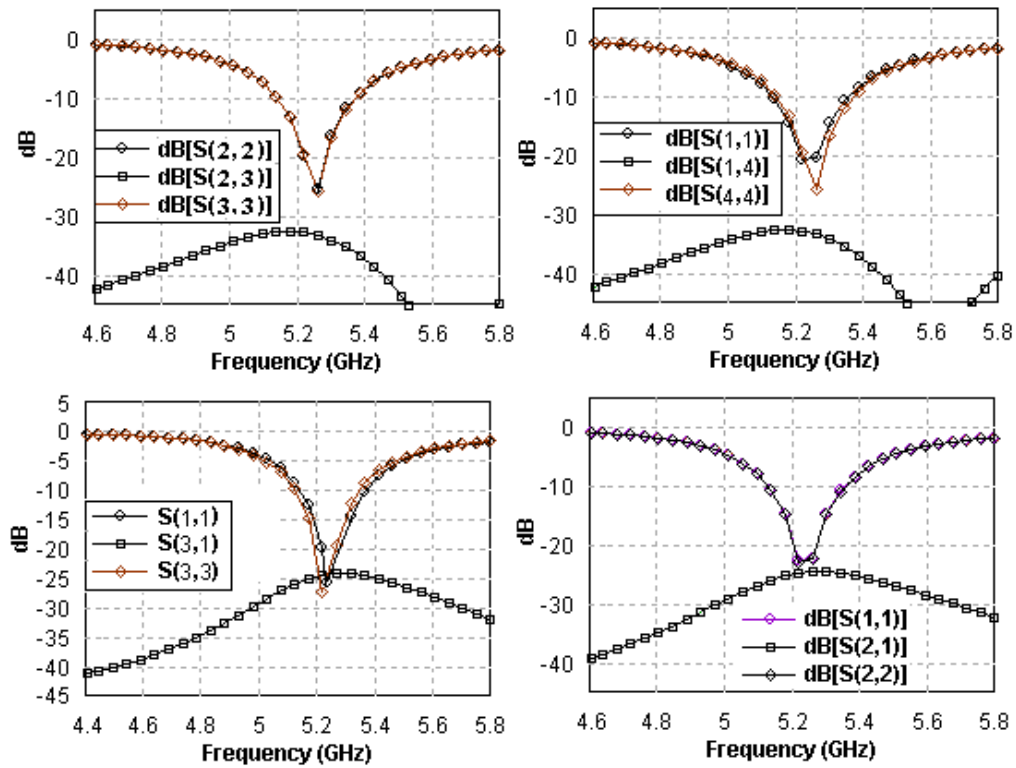


Figure 14. Simulated results of S-parameter keeping the distance between the elements of 3.0 cm.



## 6. Conclusion

The proposed slotted microstrip antenna array is electrically small and suitable to handle easily. From the results it is observed that the maximum gain obtained in the broadside direction and the peak gain at design frequency for the array is 13.88 dBi for both  $\phi = 0^\circ$  and  $\phi = 90^\circ$ . The measured value of RL ( $< -25$  dB) and VSWR ( $< 1.5$ ) fairly tallied with the simulated result. If the dielectric constant is high, the electrical length of the antenna will be reduced but the bandwidth would be narrow.

In this investigation, the B.W of 180 MHz and isolation between the antenna elements of less than -25 dB has been achieved. It is clearly observed that the impedance bandwidth, radiation efficiency improved significantly by employing proposed (2x2) array antenna. In case of single element it has been observed that the antenna gain is quite low. But while employing the array, gain increases significantly. This is one of the most advantages of the array structure. All S-parameters have been studied by inserting the feed point to each element separately.

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