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MAXIMIZING WIRELESS CONNECTIVITY USING ARRAYS OF MPA FOR WLAN APPLICATION

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Abstract- *This research suggests a novel method for using arrays of Microstrip Patch Antennas (MPA) to maximize wireless connection in WLAN (Wireless Local Area Network) applications. The main objective of the paper is to design and implement the microstrip patch array antenna of 2.4Ghz for wireless application. Signal degradation, interference, and restricted coverage are common problems for older WLAN systems. By improving coverage, reducing interference, and boosting signal strength, the MPA arrays seek to address these problems. This study discusses the design, implementation, and performance evaluation of MPA arrays and shows how effective they are at enhancing WLAN connectivity.*

Keywords: **WLAN, Microstrip Patch Antennas[MPA], Connectivity, Antenna Arrays, Wireless Communication, HFSS**

1. INTRODUCTION

In modern times, wireless local area networks, or WLANs, are ubiquitous because they offer lag-free connectivity for a variety of uses, including file sharing, multimedia streaming, and internet access. The difficulties in maintaining dependable and high-performance WLANs are growing along with the demand for wireless access, especially in crowded urban areas, sizable office buildings, and public areas.

Traditionally, WLANs have relied on single-source antennas to transmit and receive signals, which often resulted in limited coverage, capacity constraints, and susceptibility to interference. These limitations have spurred research and development efforts aimed at improving WLAN connectivity through innovative antenna technologies.

One such promising approach is the utilization of Multi-Source Antennas (MSA), which offer significant advantages over traditional single-source antennas. Unlike single-source antennas, MSAs consist of multiple radiating elements that can transmit or receive signals simultaneously from different spatial locations. By harnessing the spatial diversity provided by MSA arrays, it is possible to enhance signal strength, increase coverage, and mitigate interference effectively.

The objective of this paper is to explore the potential of MSA arrays in maximizing wireless connectivity for WLAN applications. This includes investigating the design considerations, implementation challenges, and performance evaluation of MSA-based WLAN systems. By leveraging the capabilities of MSA arrays, we aim to address the existing limitations of traditional WLAN setups and pave the way for more robust and efficient wireless communication networks.

2. RELATED WORK

The objective of this study was to design and characterize a wideband microstrip patch antenna with a single slot operating at 2.4 GHz specifically for WLAN (Wireless Local Area Network) applications. The aim was to enhance the impedance bandwidth compared to conventional patch antennas while maintaining a compact and low-profile design. The introduction of the single slot in the radiating patch, along with optimized dimensions, was intended to achieve this objective, enabling the antenna to cover a broader frequency range suitable for various wireless communication applications beyond WLAN. The study also aimed to validate the simulated performance through experimental results, thus confirming the antenna's suitability for practical implementation in diverse communication systems.[1]This paper presents the design, fabrication and testing of a rectangular circular patch array 1x8 microstrip antenna operating at 1800 MHz frequency for amplifying 4G cellular signals. The 4G technology provides high bandwidth of 75 MHz and operates in the 1800 MHz band. In receiving and transmitting information signals, the 4G system requires antennas to radiate the electromagnetic waves. However, the transmitted signals can get attenuated due to factors like air, building walls and weather conditions. To overcome this signal degradation, a device is needed to boost the signal strength from the evolved Node B (eNodeB) transmitters so that users can receive good signal quality. The proposed antenna design aims to serve as such a signal repeater device. The antenna parameters like return loss, VSWR, gain and radiation pattern are calculated and optimized through theoretical analysis and simulations. The designed antenna is then fabricated and its performance is experimentally measured. The test results show a return loss of -20.3 dB, VSWR of 1.208, gain of 7.32 dB and unidirectional radiation pattern, meeting the desired specifications. Finally, the antenna is tested as a 4G signal amplifier with various cellular providers in different locations, demonstrating its capability to significantly improve the received signal strength. [2] The objective of this study is to design and simulate edge-fed microstrip patch antenna arrays optimized for bistatic radar applications, specifically leveraging the Frequency Modulated Continuous Wave (FMCW) technique for simultaneous transmission and reception to analyze weather and climate patterns. The focus is on designing and simulating single patch, 1x4, 2x2, and 4x4 edge-fed microstrip patch antenna arrays operating at 1.48 GHz using an FR4 dielectric substrate. The design parameters include parallel feed connections and an inter-element spacing of 0.8λ in both horizontal and vertical directions.

Using CST Microwave Studio, the study aims to assess the performance of the 4x4 array configuration by analyzing key parameters such as return loss, bandwidth, directivity, and radiation pattern, with the ultimate goal of determining the suitability of the antenna arrays for bistatic radar applications. [3] The objective of this paper is to present the design and analysis of a rectangular microstrip patch antenna using HFSS software for 2.4 GHz Wireless Local Area Network (WLAN) applications. The antenna utilizes an FR-4 dielectric substrate with specified dimensions. Design equations are provided to calculate the patch and substrate dimensions. HFSS simulation results including return loss, voltage standing wave ratio (VSWR), 2D and 3D radiation patterns are presented and analyzed. The designed antenna achieves a return loss of -12.0505 dB at 2.4 GHz with an omnidirectional radiation pattern suitable for WLAN. The authors conclude that the low-profile microstrip patch antenna with a simple microstrip feed line can be easily fabricated and deployed for 2.4 GHz WLAN applications.[4] This paper presents the design and performance analysis of different microstrip array antenna configurations with optimized parameters for X-band applications around 10 GHz frequency. Microstrip antennas offer advantages like low-profile, light-weight, simple construction and compatibility with printed circuit technology, making them suitable for modern wireless communication systems. However, their key limitations are narrow bandwidth and low power handling capability. Arranging the microstrip elements in an array configuration can overcome these limitations and provide high gain, wide bandwidth and improved efficiency. The paper investigates three array configurations - series feed, corporate feed, and combined corporate-series feed networks. The design parameters like dielectric substrate material, substrate height and operating frequency are optimized to achieve compact dimensions as well as desirable performance metrics. The Taconic TLY-5 substrate with permittivity of 2.2 and height of 1.588 mm is used.

Simulation studies are carried out using SONNET software. For the 4x1 series feed array at 10 GHz, a gain of 11.97 dB and return loss of -4.21 dB are obtained. The 4x1 corporate feed array exhibits a higher gain of 14.14 dB and significantly lower return loss of -25.456 dB at 10 GHz. The combined 4x2 corporate-series feed array provides the highest simulated gain of 17.48 dB while maintaining a moderate return loss of -7.55 dB. It merges the advantages of reduced feed network losses from series feed and better directivity from corporate feed. The designed antennas operating around 10 GHz are potential candidates for X-band applications like satellite communications, radar, wireless systems due to their simple structure, ease of fabrication, high gain and efficiency. The combined corporate-series feed array offers the best overall performance among the three configurations studied. [5] This paper presents the design and development of an 8x1 microstrip patch antenna array operating in the X-band frequency range for military and satellite communication applications. The antenna array is designed using a series corporate feeding technique with quarter-wave transformers and T-junction power dividers to achieve enhanced gain, directivity, bandwidth, and return loss. The design process starts with a single rectangular microstrip patch antenna element on an FR-4 substrate. Subsequently, 2x1, 4x1, and 8x1 antenna arrays are designed by arranging the patch elements linearly and employing series corporate feeding networks. The simulated results obtained using the HFSS software demonstrate that the 8x1 antenna array achieves a maximum gain of 14.56 dB at 10 GHz, an impedance bandwidth of 86.72%, and an efficiency of 99%. The radiation patterns, reflection coefficients, and gain performances of the different antenna array configurations are presented and compared. The proposed 8x1 antenna array exhibits directive radiation characteristics and an improved peak gain compared to existing designs, making it suitable for applications such as downlink X-band satellite communication, military applications, WLAN, WiMAX, and vehicular communication [6]

This paper presents the design of a 3x3 rectangular microstrip patch antenna array operating in the Ku-band frequency range from 12 to 18 GHz. The antenna array is designed and simulated on an FR4 substrate with a dielectric constant of 4.4 using the finite element method (FEM) based HFSS 14.0 software. The array elements are spaced at a distance of λ/2, and the excitation technique used is probe feeding. The design considerations, including the dimensions of the substrate, patch elements, and feed configuration, are provided. The simulated results demonstrate that the proposed 3x3 antenna array achieves a maximum gain of 17.29 dB at the operating frequency of 13.33 GHz. The return loss at this frequency is found to be -13.33 dB, and the voltage standing wave ratio (VSWR) is 0.7807, indicating good impedance matching. The radiation characteristics, including the 3D polar plot, directivity, radiation pattern, and E-field and H-field radiation patterns, are presented and analyzed. The simulated results show that the proposed antenna array exhibits good performance in terms of return loss, VSWR, and gain, making it suitable for Ku-band applications in wireless communication systems[7].

3. METHODOLOGY

The design methodology for the microstrip patch antenna array involves several key steps:

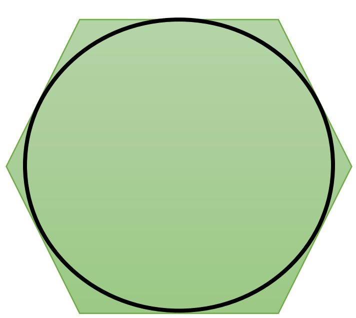
3.1 Substrate Selection

The choice of substrate material plays a crucial role in determining the performance of the antenna array. Factors such as dielectric constant, loss tangent, substrate thickness, and cost need to be considered. In this study, FR-4 substrate material with a dielectric constant of 4.4 and a thickness of 1.6mm was selected due to its widespread availability and low cost.

3.2 Patch Design:

The dimensions of the microstrip patch antenna elements are determined based on the desired operating frequency of 2.4GHz.

Various analytical formulas and empirical equations are available for calculating the dimensions of the patch antenna, including the length, width, and feed location. However, numerical electromagnetic simulation tools such as HFSS are often employed for accurate and efficient optimization of the patch geometry to achieve desired performance parameters such as impedance matching and radiation characteristics.



- **Radius of circular patch:** The radius (a) of a circular patch inscribed in hexagonal microstrip patch can be determined using empirical formulas or simulation tools based on the desired resonant frequency.

$$a = \frac{X_{mn} c}{2\pi f \sqrt{\varepsilon_r}}$$

where: f – Resonant frequency

$\varepsilon_r - dielectric\ constant\ of\ substrate$

$X_{mn} -\ 1.84118\ for\ the\ dominant\ mode\ 11$

- **Circular patch effective radius:** The effective radius (a_e) of the substrate can be estimated using the following formula for a microstrip transmission line,

$$a_e = a\{1 - \frac{2h}{\pi a \varepsilon_r}\left(ln\frac{\pi a}{2h} + 1.7726\right)\}^{\frac{1}{2}}$$

$Where: h - \ height\ of\ dielectric\ substrate$

$\varepsilon_r\ -\ relative\ permittivity\ of\ the\ substrate$

- **Length of sides of hexagonal patch:** The actual length (S) of the patch can be calculated by considering its effective radius (a_e).

The numerical connection between round fix reception apparatus sweep and hexagonal fix receiving wire side is given by

Sides of hexagonal patch,

$$\pi {a_e}^2 = \frac{3\sqrt{3}}{2} S^2$$

$$S = \frac{\sqrt{2\pi}\, a_e}{\sqrt{5.1962}}$$

The ground plane width and length are 225 mm x 60 mm, the sides of the hexagonal fix is 16.393mm.

3.3 Array Configuration

The number of elements in the antenna array and their spatial arrangement significantly impact the overall performance of the array. Common array configurations include linear, circular, planar, and conformal arrays. In this study, a linear array configuration with four elements was chosen for simplicity and ease of analysis. The spacing between the elements is optimized to achieve the desired radiation pattern and impedance characteristics.

- **Array Factor:** The Array Factor (AF) for an N element linear array is given by,

$$AF(\theta) = \sum_{n=1}^{N} exp\left(j(n-1)2\pi\left(\frac{d}{\lambda}\right)\sin\theta\right)$$

Where: θ – Observation angle with respect to the array axis
d – spacing between elements

For Broadside array θ = 0 because maximum radiation is expected in the direction perpendicular to the array. Therefore, the equation simplifies to:

$$AF(0) = \sum_{n=1}^{N} 1$$

$$AF(0) = N$$

This means that the broadside direction is enhanced by a factor of N compared to the radiation from a single element.

- **Element Spacing:** For a broadside array, the element spacing (d) is typically half of the wavelength:

$$d = \frac{\lambda}{2}$$

3.4 Feed Network Design

The feed network of the antenna array is designed to provide proper phasing and impedance matching for the individual elements. Various feeding techniques, such as corporate feed, series feed, and parallel feed, can be employed depending on the specific requirements of the application. The feed network design is crucial for achieving uniform excitation of the array elements and minimizing mutual coupling effects.

- **Microstrip Width (W_s):** The Microstrip line width for a characteristic impedance (Z_0):

$$Z_0 = \frac{60}{\sqrt{\varepsilon_{eff}}}\ln\left(\frac{8h}{W_s} + \frac{W_s}{4h}\right)$$

Spacing between patches	68.25mm
100 ohm feedline width	0.7mm
70.7 ohm feedline width	1.6mm
50 ohm feedline width	3mm

Solve for W_s $using$ Z_0

3.5 Simulation

Comprehensive electromagnetic simulation using software tools such as HFSS is performed to analyze the performance of the antenna array. The simulation includes characterization of the radiation pattern, gain, directivity, impedance matching, bandwidth, and efficiency.

Parametric studies are conducted to optimize the design parameters and achieve the desired performance objectives.

Initially we have designed single hexagonal microstrip patch antenna. Further we have designed 2x1 & 4x1 array antenna

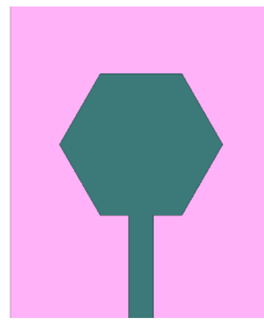


Fig 1single patch from HFSS

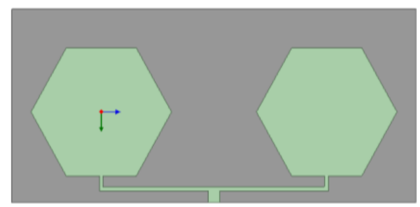


Fig 2 2x1 array

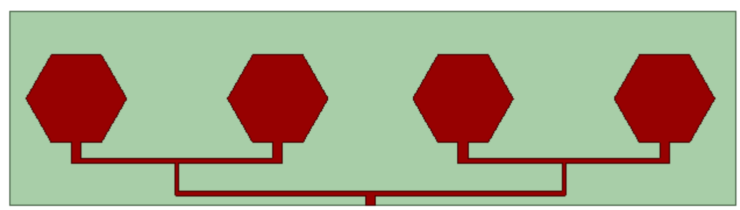


Fig 3 Front view of Hexagonal Microstrip patch Array Antenna

4. EXPERIMENTAL ANALYSIS

After designing and fabricating, the next step was antenna parameter testing. The measured parameter were return loss, VSWR, directivity and gain. Based on simulation result the value of return loss was obtained as -34.9476dB and from testing result the value was obtained as -11.185.

By comparing the results of a single element and array element plot, we can ensure, with increasing elements the enhancement of return loss, gain, VSWR and radiation pattern performance is done and the proposed antenna potentially serve as a best option for short range 2.4Ghz of band wireless communication application

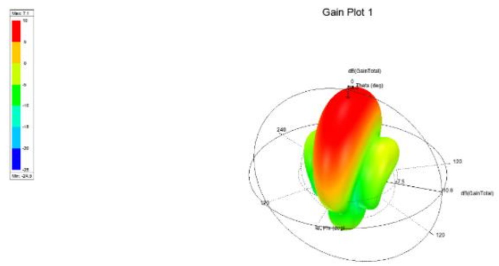


Fig 4 Gain plot

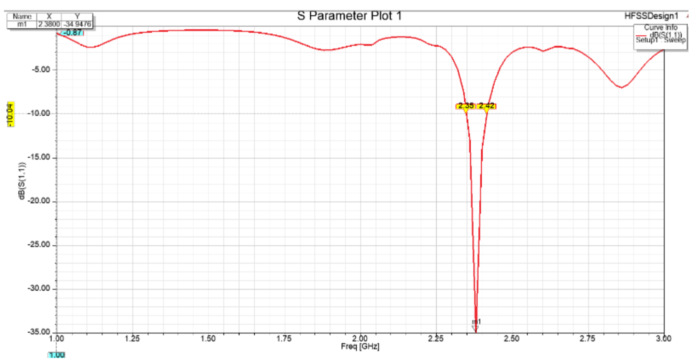


Fig 5 S-Parameter

From fig 4, gain of the antenna is 7.1dB, Fig 5 represents s-parameter. Based on simulation result the value of return loss was obtained as -34.9476dB.

6.CONCLUSION

In summary, this paper presents a detailed study on design and simulation of a microstrip patch antenna array for 2.4GHz wireless communication. The array configuration offers significant improvements in gain, directivity, and radiation pattern control over single-element antennas. Utilizing HFSS simulation software, the design achieves efficient radiation characteristics with a return loss of -34.9476dB at 2.4GHz. The optimized resonance at the desired frequency is facilitated by a microstrip feed line, ensuring adequate bandwidth. Simulation results align closely with design objectives, affirming the suitability of the proposed antenna array for modern wireless communication systems. This study highlights the importance of advanced simulation techniques in achieving optimal antenna performance.

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