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Simulation 1x2 Microstrip Antenna Array with Truncated Corner and Partial Ground Modification at 2.4 GHz for WiFi Applications

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ABSTRACT

Wi-Fi performance strongly depends on antenna quality as a system for transmitting and receiving electromagnetic signals. A 1×2 microstrip array antenna for 2.4 GHz Wi-Fi applications has been successfully designed and simulated by applying truncated corner and partial ground techniques. The truncated corner technique involves cutting the patch corner to improve impedance matching and radiation performance, while the partial ground technique modifies the ground plane to enhance bandwidth and reduce signal reflection. The truncated corner technique was implemented by cutting all four corners of the patch in a rectangular shape, while the partial ground method was applied by modifying the ground plane beneath the feedline area. The design was carried out utilizing the CST Studio Suite. The results showed an increase in antenna performance in terms of return loss, bandwidth, and gain. The designed antenna showed a return loss of -28.57 dB, a bandwidth of 657 MHz, and a gain of 6.05 dBi. These results indicate excellent performance, as a return loss below -10 dB reflects good impedance matching, wide bandwidth supports reliable communication of array configuration, and structural modifications prove effective in improving microstrip antennas for Wi-Fi applications.

Keywords: *Antena, Microstrip, Wi-Fi, Partial Ground, Truncated Corner.*

Introduction

The rapid development of wireless communication technology drives the need for a reliable and stable data transmission system. One of the most popular is wireless fidelity (Wi-Fi), which is a component of the IEEE 802.11 based Wireless Local Area Network (WLAN) [1]. This technology utilizes the 2.4 GHz frequency band with a frequency range of 2400 - 24835 MHz. which is included in the Industrial, Scientific, and Medical (ISM) band [2]. The frequency allocation has the advantage of wide signal range and good penetration ability against physical barriers [3]. Wi-Fi performance is highly dependent on the quality of the antenna which functions as a transmission and reception system for electromagnetic signals [4].

Microstrip antennas are becoming a popular choice in Wi-Fi devices because they are compact, lightweight, easy to implement, and can be integrated with other electronic devices [5]. However, microstrip antennas have weaknesses in terms of narrow bandwidth and relatively low gain [6]-[9]. To overcome these weaknesses, this study applies two structural modification techniques are truncated corner and partial ground methods. the truncated corner method involves cutting or trimming corners of the patch in a specific shape such as a triangle, rectangle, or square, which helps enhance radiation characteristic and improve impedance matching. Meanwhile, the partial ground method reduces part of the ground plane area, particularly around the feedline, in order to control surface current distribution and widen the operational bandwidth.

Several previous studies have applied the Defected Ground Structure (DGS) technique, including partial ground configuration, where a section of the ground plane is removed to disrupt current flow and optimize impedance. Similarly, the truncated corner approach, where the corners on the patch are cut, is widely used to improve polarization and current uniformity across the antenna surface. The cutting technique on the patch corner is able to improve polarization performance and smooth current distribution, reducing the VSWR value [10]-[14].

DGS technique is a modification of the ground plane section that works by disrupting the current flow on the ground plane by creating a gap or certain pattern, thus affecting the impedance characteristics and allowing for increased bandwidth and control of the resonance frequency [15] - [16]. Partial ground is to reduce the reduction of the ground plane area. DGS technique with partial ground configuration on microstrip antenna increases antenna efficiency and reduces return loss and bandwidth values as well as gain [17] - [18].

While both truncated corner and partial ground have been applied separately in previous studies, their combined implementation in a 1x2 microstrip array antenna for 2.4 GHz Wi-Fi applications remains limited. The study addresses that gap by exploring their synergistic effect on antenna performance.

Research Methods

Determination of Specification of Proposed Antenna

The antenna design process was initiated by defining the performance specifications required for 2.4 GHz Wi-Fi applications, as presented in Table 1. This step served as the foundation for subs quent modelling, simulation, and optimization stages. The substrate selected was FR4-Lossy, a widely used dielectric with thickness of 1.6 mm and a relative permittivity of 4.3, chosen to ensure cost-effective fabrication and compatibility with the simulation environment.

Table 1. Specification Antenna

Parameter Antenna	Specification
Frequency	2.4 GHz
Bandwidth	≥ 100 MHz
Return loss	≤ -10 dB
Gain	> 3 dBi
VSWR	< 2

Rectangular Single Antenna Design

Subsequently, a single rectangular microstrip antenna was designed to serve as the baseline structure. The step involved calculating the physical dimensions of the patch, including its width (W), length (L), and substrate thickness (h), based on the predetermined specifications. The resulting geometry, illustrated in Figure 1, served as the initial model for simulation and performance evaluation in subsequent stages.

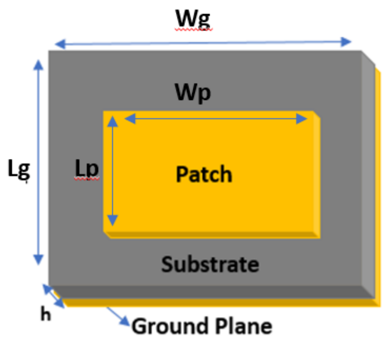


Figure 1. Structure of rectangular microstrip antenna

In the subsequent stage, the antenna was modelled by designing a rectangular microstrip patch structure. The patch dimensions. including length (L) and width (W), were calculated analytically using equations (1) to (4), as referenced in [5, 9] to ensure resonance at the designated operating frequency, the formula as follows:

$$Wp = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \tag{1}$$

$$Lp = L_{eff} - 2\Delta L \tag{2}$$

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} \tag{3}$$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\sqrt{\frac{1}{(1 + 12\,\frac{h}{w})}} \tag{4}$$

$$\Delta L = 0.412\, h\, \frac{(\varepsilon_{reff} + 0.3) + (\frac{W}{h} + 0.264)}{(\varepsilon_{reff} + 0.258) + (\frac{W}{h} + 0.8)} \tag{5}$$

The description of symbols for equations (1) trough (4) are as follows: f_r the antenna frequency (Hz), c is the speed of light of 3.10^8 m/s, and h is substrate thickness (mm).
The following formulas, (5) and (6) [5], [9], are used to determine the ground plane length and width:

$$\text{Lg} = xh + L \tag{5}$$

$$\mathrm{Wg} = xh + W \tag{6}$$

The description of symbols for equations (5) to (6) L_g is the length of ground plane (mm), W_g is the width ground plane and substrate (mm), dan x is a multiplier factor with minimum value of 6.

Rectangular Patch Design using Truncated Corner Method

In this stage, the truncated corner technique was applied to the patch antenna to improve current distribution and impedance matching. The corner cuts were implemented based on analytical design and further optimized through simulation.

The truncated corner technique is a structural modification used to improve the performance of microstrip patch antennas. In this approach, each corner of the patch is cut diagonally at a specific angle, commonly 45°, into defined geometric shapes such as a triangle, square, rectangle, or semicircle. This alteration influences the antenna's electrical properties by modifying the current distribution along the patch edges, which in turn affect the input impedance, radiation patterns, and resonant frequency [10]. As a result, improvement can be observed in bandwidth, return loss and polarization characteristics. Due to its simplicity and effectiveness, the truncated corner technique is widely used compact wireless application, including, mobile and indoor Wi-Fi device [11]

The dimensions of the truncated corner used rectangular cut applied symmetrically to all four corners of the patch with a certain angle of 45° [10]-[14] shown in Figure 1(a). The dimensions of the truncated corner use the following equation [13]:

$$\Delta_L = \frac{Lp}{4} \tag{7}$$

To determine optimal shape and size of these cuts, parametric variation of the corner dimensions, specifically the length and width, was analyzed through simulation using CST Studio Suite. The simulation focused on evaluating the impact of the truncation on key parameters such as bandwidth, VSWR, and return loss. The optimization process was observed by S-parameter analysis to achieve antenna performance to meets the predefined targets.

Ground Plane Design using Partial Ground Method

In the structural modification stage, the partial ground method inspired by the defected ground structure (DGS) concept was implemented. This technique involves intentional modification to the ground plane of an antenna to improve key performance parameters such as polarization characteristics, radiation efficiency, and bandwidth [15]-[18]. A common implementation of DGS is the partial ground technique, which involves partially removing the ground plane beneath the radiating patch, typically up to the level of the feedline. This modification changes the distribution of return current on the ground plane, significantly improving impedance matching between the feed and radiating patch. As a result, it can enhance bandwidth and reduce signal reflection, leading to better return loss performance.

In this design, the partial ground is realized by cutting the ground plane vertically to a height equal to the feedline length while maintaining the full substrate width. This configuration allows the antenna radiating elements to emit energy more effectively and is proven to yield optimal reflection coefficient values. The dimensions of the cut on the ground plane are determined based on the width of the feedline and are calculated using equations (6) and (12), as illustrated in figure 1(b).

Design of Feeding Line on Microstrip Antenna

In the feed network design stage, a 1x2 antenna array was configured using T-junction feed model to distribute power evenly to both elements. Impedance values of 50 Ω, 75 Ω, and 100 Ω were assigned to different segments of the feed line. The feed line width (Wf) was calculated using standard impedance equation for FR-4 substrate material, as describe in[19]-[20]:

$$B = \frac{60\pi^2}{z_0\sqrt{\varepsilon_r}} \tag{8}$$

$$Wf = \frac{2h}{\pi}\left\{B - 1 - In(2B-1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}\left[In(B-1) + 0{,}39 - \frac{0{,}61}{\varepsilon_r}\right]\right\} \tag{9}$$

The length of the feed channel (Lf) uses the equation:

$$\lambda_o = \frac{c}{f} \tag{10}$$

$$\lambda_g = \frac{\lambda_o}{\sqrt{\varepsilon_{reff}}} \tag{11}$$

$$Lf = \frac{\lambda_g}{4} \tag{12}$$

The description of symbols used in equations (8) to (12) are as folllow: B represents the width transmission feeding line, Wf denotes the width feedline, λ_o is the wave length in free space, c refers to the speed of light (3.10^8 m/s), f is the antenna's operating frequency (Hz), λ_g indicates the guided wavelength in the dielectric material, ε_{reff}f is the effective dielectric constant, Lf represent the length of feedline.

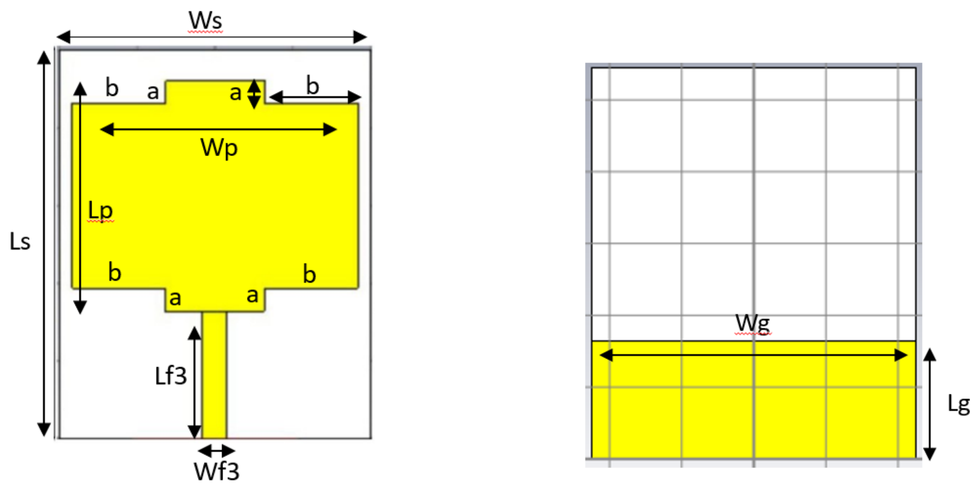
The results of the calculation of the width and length dimensions of the feeding line are used to design a feeder channel that is in accordance with the 1x2 antenna array configuration and to perform optimization to ensure impedance compatibility between antenna elements.

Antenna Design for Microstrip Rectangular Patch Array 1x2

The design process begins with a single-element microstrip rectangular patch antenna, which combines a truncated corner on the patch and a partial ground on the ground plane. The antenna specifications are determined based on the application requirements and are listed in Table 1. The initial dimensions of the single element are calculated using equations (1) to (8). The dimensions presented in Table 2 are the results of simulations that have been optimized with a single element size of 34.40 mm × 52.86 mm using a substrate thickness of 1.6 mm. The resulting antenna geometry is shown in Figure 3. The design was simulated and optimized using CST Studio Suite to evaluate key performance parameters such as return loss, bandwidth, and radiation pattern. The performance evaluation confirmed that the single element meets the desired antenna specifications, which serves as a foundation for developing a 1×2 array configuration.

Table 2. Dimension of single element antenna

Parameter Antenna	Nilai (mm)
Width of Patch (Wp)	34.40
Length of Patch (Lp)	36.46
Width of Substrate (Ws, Wg)	45.00
Length of Substrate (Ls, Lg)	54.50
Width of Feed Line (Wf)	3.24
Length of Feed Line (Lf)	16.40
Width of Truncated Corner (b)	12.00
Length of Truncated Corner (a)	3.00



(a) (b)

Figure 1. Geometry of the single element: (a) patch use truncated corner, and (b) ground plane use partial ground

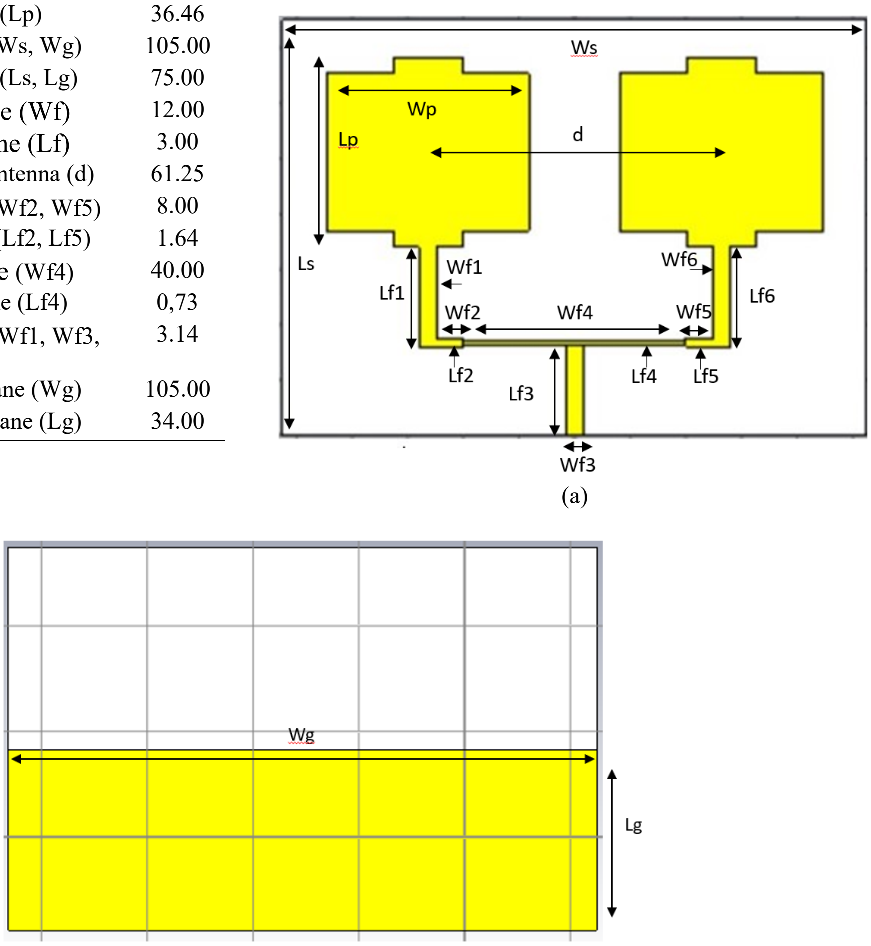
After the single-element antenna was successfully designed, a 1x2 array configuration was developed by arranging the modified patch elements linearly in horizontally orientation. The spacing between the elements was designed to be approximately half the wavelength (d = λ/2), in accordance with standard antenna array design principle [19],[20]. A transmission line based on the T-junction model was employed to distribute RF power equally to each patch element using calculated impedance value of 50 Ω, 100 Ω, and 70.7 Ω, as illustrated in Figure 4.

To achieve optimal performance in accordance with the target antenna specifications, the array antenna was simulated and optimized using CST Studio Suite. The optimization process was carried out by adjusting key geometric parameters such as patch dimensions feedline lengths, and element spacing through a parametric sweep feature. Performance indicators, including gain, bandwidth, VSWR, and return loss, were monitored in each iteration to identify the most effective configuration. The optimized dimensions of the array antenna are presented in Table 3. Furthermore, the antenna's performance was evaluated based on several key parameters to determine its compliance with the Wi-Fi standard requirements.

The simulations were conducted using the Frequency Domain Solver in CST, with open boundary conditions to emulate free-space behaviour. A waveguide port with 50ohm impedance was assigned at the feed point. The simulation frequency range was set from 1.8 – 2.8 GHz to capture the full operating bandwidth. Automatic mesh refinement was applied to enhance accuracy around the feed and modified structure regions. All simulations were normalized to 1 W input power, and te evaluation results were based on reliable extraction of S-parameters, gain, VSWR, and far-field radiation characteristics. These comprehensive settings ensured that the simulation environment closely represents realistic operating conditions, reinforcing the reliability of obtained results.

Table 3. Dimension of Antenna Array 1x2

Parameter Antenna	**Nilai (mm)**
Width of Patch (Wp)	34.40
Length of Patch (Lp)	36.46
Width of Substrate (Ws, Wg)	105.00
Length of Substrate (Ls, Lg)	75.00
Width of Feed Line (Wf)	12.00
Length of Feed Line (Lf)	3.00
Distance of element antenna (d)	61.25
Width of Feed Line (Wf2, Wf5)	8.00
Length of Feed Line (Lf2, Lf5)	1.64
Width of Feed Line (Wf4)	40.00
Length of Feed Line (Lf4)	0,73
Width of Feed Line (Wf1, Wf3, Wf6)	3.14
Width of Ground Plane (Wg)	105.00
Length of Ground Plane (Lg)	34.00



(a)

(b)

Figure 4. Geometry of antenna of Array 1×2 (a) Patch Antenna (b) Ground Plane

Results and Discussion

In addition to examining the performance of several parameters, including gain, bandwidth, VSWR, and return loss, this section describes how to simulate a 1x2 array antenna design. For ease of data analysis, the findings are compiled in a table. Next, review the required antenna specs to satisfy Wi-Fi standards.

Return Loss and Bandwidth

The performance simulation of the S-parameter of the 1×2 array antenna in Figure 5 shows that the antenna satisfies the expected performance requirements because the return loss value is less than -10 dB. For S11, the measured return loss is -28.57dB. The antenna bandwidth of 657 MHz is determined by taking the return loss value below -10 dB in the working frequency range of 2.610 – 1.953 GHz.

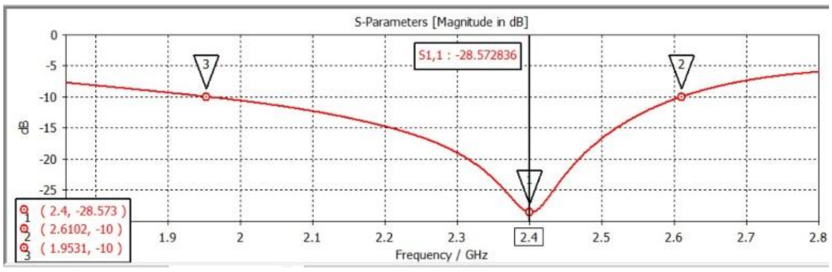


Figure 5. Return Loss and Bandwidth

VSWR

As depicted in Figure 6, the simulated VSWR value of the 1×2 microstrip array antenna reaches 1.07 at the resonant frequency of 2.4 GHz. This low VSWR indicates excellent impedance matching between the feed line and the radiating patch, which minimizes power loss due to reflection. Such performance confirms that the combination of the truncated corner and partial ground techniques effectively improves the antenna's impedance characteristics, meeting the desired specification of VSWR < 2 for Wi-Fi applications.

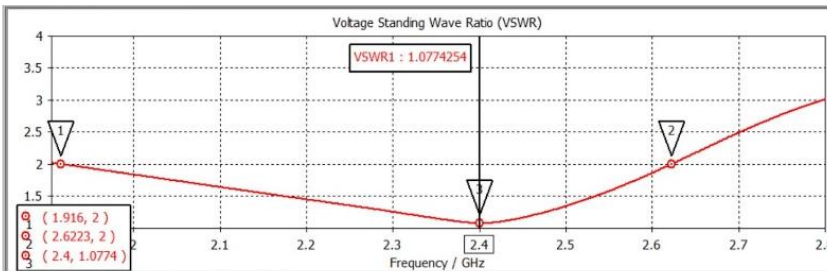


Figure 6. VSWR

Gain

Figure 7 illustrates the simulated 3D radiation pattern of the proposed antenna. The peak gain achieved is 6.05 dBi, which signifies that the antenna is capable of directing more energy toward the desired direction. The observed uniform main lobe and suppressed side lobe levels suggest high radiation efficiency, contributing to the antenna’s suitability for stable signal transmission in Wi-Fi environments.

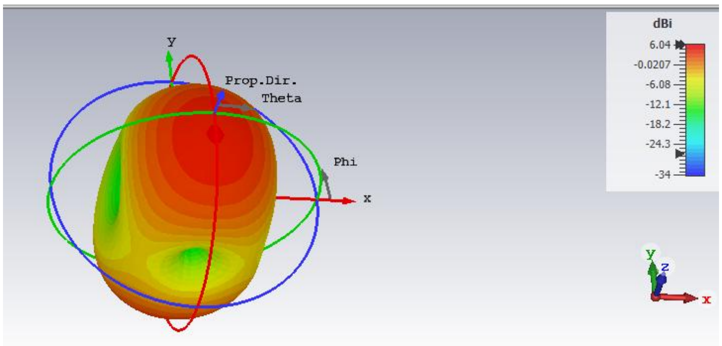


Figure 7. Gain

Figure 8. SLL dan *Beamwidth*

The 2D polar radiation pattern of the 1x2 array antenna in a horizontal position on the E-plane (elevation) phi=90° is shown in Figure 8. Based on the radiation pattern, the major lobe magnitude is 6.05 dBi, reflecting the maximum gain achieved by the antenna. An angular beamwidth (3 dB) of 75.9° was observed, and a low side lobe level (SLL) of -1.2 dB. These results confirm the antenna's efficient bidirectional radiation performance, making it well-suited for symmetrical signal coverage in Wi-Fi applications.

Comparison of Proposed Antenna

For simplicity of analysis, Table 4 displays the antenna performance values for Array 1x2.

Table 4. Simulation results for antenna performance parameter

Parameter	Specification Antenna	Antenna of Array 1x2
Return Loss (dB)	≤ -10	-28.57
Bandwidth (MHz)	≥ 100	657
VSWR	< 2	1,07
Gain (dBi)	> 3	6.05

The simulation results of the parameter performance that resulted in a wider bandwidth and higher gain for the antenna of array 1x2 are displayed in Table 4. This antenna is suggested for Wi-Fi applications since the simulation results of the antenna design performance match the intended antenna specifications.

Table 5. Comparative of performance of microstrip antennas for 2,4 GHz Wi-Fi applications

No	Reference	Technique Used	*Return Loss* (dB)	*Bandwidth* (MHz)	Gain (dBi)
1	[6]	Rectagular Patch 1 x2 array, inset feedline	-18,50	150	6,67
2	[8]	Rectagular Patch 1x2 array	-15.72	168	7
3	[10]	Truncated Corner 2×1array	-21,90	480	5,30
4	[18]	Rectagular Patch with partial ground	-19,60	105	-
5	[19]	Rectagular Patch 1x2 array	-35,80	-	5,12
6	**Tnis Work**	Truncated Corner and partial ground 1x2 array	-28,7	657	6,05

The performance of the proposed antenna has been demonstrated to be superior compared to previous designs, as presented in Table 5. A significantly wider bandwidth of 657 MHz has been achieved, exceeding those reported in earlier studies. A return loss of -28.70 dB has been obtained, indicating better impedance matching than most existing designs. Although the gain of 6.05 dBi is slightly lower than that of some references, it is considered sufficient, especially when balanced with the enhanced bandwidth. These improvements have been attributed to the application of both truncated corner and partial ground techniques in the antenna design. In addition, the proposed antenna offers advantages in terms of design simplicity, compact size, and ease of fabrication, making it well-suited for integration into 2.4 GHz Wi-Fi communication systems.

Conclusion

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A 1x2 microstrip array antenna was successfully designed and simulated at 2.4 GHz by implementing an antenna with truncated corners and a partial ground technique. Significant performance improvements were observed in the simulation, with a return loss of -28.57 dB, a bandwidth of 657 MHz, and a gain of 6.05 dBi. Compared to previous studies, enhanced bandwidth and better impedance matching were achieved through the combined structural modification. Due to its compact size, simple geometry, and improved performance, the proposed antenna is considered suitable for Wi-Fi applications. Future research will focus on the fabrication and empirical testing of the antenna to validate simulation outcomes, as well as exploring the use of high-permittivity substrates to further optimize antenna compactness and efficiency.

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