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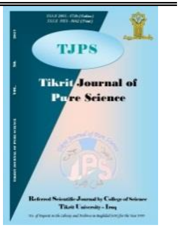

Design and feed two models for microstrip antenna in two different feed methods and compare their properties

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ABSTRACT

In any wireless communication, the antenna plays a very important role. The need in this technology is to reduce the size of the antenna, weight, and cost with a low profile, high performance, and low return loss (RL), which is what researchers are striving for. This paper attempts to implement a rectangular microstrip patch antenna and analyze its performance for different types of feeding techniques. In this research, we designed two thin slice antennas fed in two different ways, using FR4 epoxy as an insulating substrate with a dielectric constant of 4.3. Copper was used as a conducting material for the radiating patch and the transmission line, with nearly similar geometrical dimensions. The first antenna has dimensions of (31x 26x1.6) m3 and the second antenna has dimensions of (30x27x1.6) m3. The first antenna operates with a coaxial probe feed technique and the second one operates with a microstrip line feed technique. The return loss for the first antenna we obtained is -26.0113dB with a standing wave voltage ratio of 1.1053 at a frequency of 3.59GHz, and -24.743GHz with a standing wave voltage ratio of 1.8908 at a frequency of 5.529GHz. The return loss for the second antenna is -27.468dB with a standing wave voltage ratio of 1.0884 at a frequency of 3.45GHz. The design, simulation, and inclusion of shapes and graphics for both antennas were done using the CST (Computer Simulation Tool) program.

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تصميم وتغذية نموذجين من هوائيات التصحيح الشريطية الدقيقة باستخدام طرق تغذية مختلفة ومقارنة خصائصهما

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الملخص

في أي اتصال لاسلكي، يلعب الهوائي دورًا مهمًا للغاية. والحاجة في هذه التقنية هي تقليل حجم الهوائي ووزنه وتكلفته مع مظهر منخفض وأداء عالٍ وخسارة عودة منخفضة (RL)، وهو ما يسعى الباحثون إلى تحقيقه. يحاول هذا البحث تنفيذ هوائي تصحيحي مستطيل الشكل وتحليل أدائه لأنواع مختلفة من تقنيات التغذية. في هذا البحث، قمنا بتصميم هوائيين من شرائح رقيقة يتم تغذيتهما بطريقتين مختلفتين، باستخدام إيبوكسي FR4 كركيزة عازلة بثابت عازل قدره 4.3. تم استخدام النحاس كمادة موصلة للرقعة المشعة وخط النقل، بأبعاد هندسية متشابهة تقريبًا. الهوائي الأول بأبعاد (31x 26x1.6) m3 والهوائي الثاني بأبعاد (30x27x1.6) m3. يعمل الهوائي الأول بتقنية تغذية المسار المحوري ويعمل الهوائي الثاني بتقنية تغذية الخطوط الدقيقة. خسارة العودة للهوائي الأول الذي حصلنا عليه هي 26.0113 dB - مع نسبة جهد موجة ثابتة تبلغ 1.1053 عند تردد 3.59 جيجا هرتز، و 24.743 - جيجا هرتز مع نسبة جهد موجة ثابتة تبلغ 1.8908 عند تردد 5.529 جيجا هرتز. تبلغ خسارة العودة للهوائي الثاني -27.468 dB مع نسبة جهد موجة ثابتة تبلغ 1.0884 عند تردد 3.45 جيجا هرتز. تم تصميم ومحاكاة وإدراج الأشكال والرسومات لكلا الهوائيين باستخدام برنامج CST (Computer Simulation Tool)

1. Introduction

The Microstrip patch antenna have more advantages and provides better results as compared to the traditional antennas. Being lighter, foldable, easy to fabricate, multiple frequency operations, small in size, Microstrip patch antennas have replaced almost all the traditional antennas in almost all the wireless applications[1] .in recent years, there has been a growing and continuous demand for great (data rates) beyond existing wired and wireless networks. Radioover-Fiber technology is considered as an efficient and practical solution for providing broadband wireless. In this paper, many techniques are used to implement a system that has the capability to provide a great bit rate, broadband bandwidth, and minimum cost [2].. An antenna, as defined by the IEEE system, is a means of radiating or receiving electromagnetic waves [3]. Antennas are known as devices capable of transmitting and receiving signals. Therefore, an increase in the number of network users requires high-speed data transmission to cover a larger area. This necessitated the need for a wide bandwidth (BW) to cover mobile and wireless services, achieved through the use of Ultra-Wideband (UWB) antennas with low complexities and manufacturing costs [4]. Due to the possibility of antennas operating at multiple frequencies and diverse polarizations, which can reduce the size, simplify the configuration, and lower the cost of the antenna, these antennas can facilitate the provision of multiple services in an integrated structure. They are good candidates for use in the next generations of mobile and wireless communication systems [5].

Objective: The research focuses on implementing a rectangular microstrip patch antenna and analyzing its performance with different feeding techniques. The main goals are to reduce antenna size, weight, and cost, while aiming for low profile, high performance, and low return loss (RL).

2. Material and Methods

2-1 - Antenna Design Parameters:

Substrate Material: FR4 epoxy with a dielectric constant of 4.3. FR4 is commonly used in PCB (Printed Circuit Board) applications due to its electrical properties.

Conductive Material: Copper was used for both the radiating patch and the transmission line. Copper is chosen for its excellent conductivity, which is crucial for minimizing losses in the antenna system.

2-2 - Antenna Geometry:

- Two antennas were designed with the following dimensions:
  - **First Antenna**: (31 x 26 x 1.6) mm³
  - **Second Antenna**: (30 x 27 x 1.6) mm³
- These dimensions suggest a thin profile, which is desirable for applications where low profile antennas are necessary.

2-3 -Feeding Techniques:

- **First Antenna**: Coaxial probe feed technique
- **Second Antenna**: Microstrip line feed technique
- Each antenna used a different feeding technique to determine the impact on performance metrics such as return loss and standing wave ratio

2-4- Performance Analysis:

- **First Antenna**:
  - Return Loss: -26.0113 dB at 3.59 GHz, with a standing wave voltage ratio of 1.1053.
  - Return Loss: -24.743 dB at 5.529 GHz, with a standing wave voltage ratio of 1.8908.
- **Second Antenna**:
  - Return Loss: -27.468 dB at 3.45 GHz, with a standing wave voltage ratio of 1.0884.

2-5- Performance Evaluation:

- **Return Loss**: The return loss measurements were provided for both antennas at specific frequencies. Return loss indicates how much of the transmitted signal is reflected back towards the source due to impedance mismatch.
- **Standing Wave Voltage Ratio**: This parameter indicates the magnitude of standing waves along the transmission line, providing insight into the impedance matching and efficiency of the antenna design

2-6- Simulation Tool: The design, simulation, and analysis of both antennas were carried out using the CST (Computer Simulation Tool) program. CST is a widely used electromagnetic simulation software that allows for detailed analysis of antenna performance, including characteristics like return loss, impedance matching, and radiation pattern.

2-7- Analysis and interpretation:

The results obtained from subsequent operations were analyzed using the feeding technique of each technology to achieve the required performance criteria (low loss, impedance information, etc.).

Comparisons were made with future projections for similar populations investigated in order to confirm or verify the findings in this study.

2-8- Graphical Representation:

- Shapes and graphics illustrating the antennas' design and performance characteristics were included in the study. These visuals help in understanding the antenna structure, electromagnetic field distribution, and radiation pattern

Related work

In 2020, researcher Reis, P., designed a thin slot antenna suitable for WiMAX, WIAN, and local WIFI applications on an FR-4 isolation base with a dielectric constant of 4.4 and a thickness of 0.162 at frequencies. This antenna operates in three frequency bands X, C, S. An input impedance of 500 was obtained with analysis of return loss, standing wave ratio, gain, and radiation pattern.[6]

In 2021, the researcher Abdulhussein, A. M and others designed a patch antenna with dimensions of (1.6 * 57.23 * 75.85). The antenna achieved a minimum return loss of -38.86 at a frequency of 2.393 GHz and a very good standing wave ratio (VSWR) of 1.02 with a bandwidth of 58 MHz. The simulation software CST was used for simulation, and the antenna was manufactured on an insulating substrate (FR-4).[7]

In the same period of 2021, researcher Shamim, S. M and others designed a similar microstrip antenna as the previous researcher, using the same simulation software, CST. However, they used graphene material due to its amazing electrical, mechanical, and optical properties. After conducting the simulation process using the same simulation software mentioned earlier based on the finite difference time domain method, they achieved a return loss of -59.97 dB, an ideal standing wave ratio (VSWR) of 1.007, and a good radiation pattern at a frequency of 0.72 THz, making it an excellent candidate for future wireless communications.[8]

As a continuation of what was mentioned in the previous studies, we also designed two antennas for the thin slice in two different feeding methods as mentioned earlier, using the same simulation program mentioned earlier, using the same FR-4 substrate material, and using copper material for both the ground plane and the radiating patch with different dimensions for both models as mentioned earlier. Perfect results were obtained for both return loss and VSWR, and these antennas were suitable for WiMAX applications.

Microstrip patch antenna

The antenna is a type of transducer that converts electrical energy into electromagnetic radio waves. According to the IEEE standard[9]. Microstrip antennas have more advantages and provide better results compared to traditional antennas due to their lightweight, foldable, easy to manufacture, work on multiple frequencies, and small size.[10] Strip antennas are a class of planar antennas that have been studied and developed in recent decades, with several advantages such as simple design, potential compact design, and low cost. Strip antennas are widely used in various fields of science and technology. Because the size of these antennas depends directly on the wavelength of the oscillating frequency, a small strip antenna is a common choice for ultra-high frequency applications. It consists of regular geometric shapes such as square, circular, or rectangular, and consists of three parts; the top part (radiating patch) and the bottom part (ground plane) are made of a conductive material such as copper, and between them is an insulating material called the substrate[11].

Strip line feed

The Common-Mode Strip Line (CPS), consisting of parallel lines on the same plane, is a balanced transmission line. The typical characteristic impedance range of a CPS line is higher than other transmission lines under the same manufacturing conditions. CPS lines are often used to feed a balanced antenna surface due to its high radiation efficiency and its structure consisting of parallel and balanced lines, while most commercial circuits are implemented using Microstrip Line (MSL), an unbalanced transmission line.[12] In this type, the conductor strip is directly connected to the edge of the microstrip patch as shown in figure (1), and the patch is wider than the conductor strip. Therefore, the feed can be etched on the same substrate to provide a flat structure.

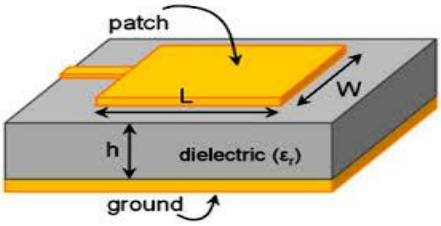

Fig. 1: illustrates the technique of line striping.

Coaxial Wire Feed

Axial feeding or probe feeding is a very common technique used to feed microwave patch antennas. Microstrip patch antennas primarily use axial feeders. In this method, the inner coaxial connector extends through the insulator and is welded to the patch element. The outer connector is grounded. The feeder can be placed in any location, making this category of feeders more advantageous.[13] Axial feeding advantages include simple production, convenient tuning, and low radiation interference. The disadvantage is the low frequency bandwidth as shown in Figure 2.

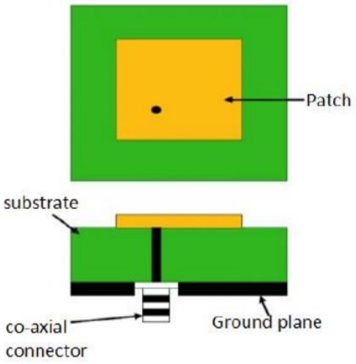

Fig. 2: illustrates the technology of the axial sensor.

Returned loose

It generally refers to the reflection proposal represented by (S11), which indicates a proportionality between inputs and outputs and represents the power consumption reflected from the antenna. The return plot provides information about how well the feed line is connected to the antenna. If (S11) equals 0 dBm, it means that all trust is in the antenna and nothing is being radiated [14]. The return is usually expressed in decibels and depends on the standstill ratio (SWR) and the reflection coefficient (Γ). I have been returned to my escort with part of the standing SWR.

$$RL= 10\log\frac{P_r}{P_i} \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

RL(dB): is the return loss in dB.

P_i: is the incident power.

P_r: is the reflected power.

The return loss is related to both the standing wave ratio (SWR) and the reflection coefficient (Γ).

$$\Gamma= \frac{V_r}{V_i} \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

Vi : is the reflected wave.

Vr : is the incident wave.

Voltage Standing Wave Ratio

Voltage oscillation rate (VSWR) represents the power reflection of the antenna. The value of the voltage fluctuation rating must be a positive and actual number. Antenna performance improves as the value of the voltage swing rate decreases. Shows how the impedance of a transmission line matches[15]. When the standing wave voltage is

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high, it means that the transmission line is inefficient, and the reflected power may also be high, which can cause damage to the transmission device, thus reducing its efficiency. The standing reflection rate usually represents the voltage ratio, and is referred to as the voltage standing wave rate (VSWR), and has an inverse relationship with the voltage reflection coefficient (Γ) through the following equation:

$$\mathrm{VSWR} = \frac{V_{\max}}{V_{\min}} = \frac{1+\Gamma}{1-\Gamma} \text{ .... } (3)$$

$\mathbf{V_{max}}$: The highest voltage capacity on the transmission line.

$\mathbf{V_{min}}$: The lowest voltage capacity on the transmission line.

Γ: Reflection coefficient.

1. Microstrip antenna design

The design is implemented to obtain good performance, as it operates at an operating frequency of 3.4 Ghz. There are several steps to designing this antenna, such as determining the specifications, determining the composite material used, engineering design, and then calculating the physical parameters of the designed microstrip using the formula used in designing the microstrip. Then the simulation is done using Computer Simulation Technology (CST) 2014 software. In this research, a thin strip antenna was designed to suit WIMAX applications, which have frequencies between (3.4 GHz - 3.7 GHz). Epoxy FR-4 was used as an insulator with a dielectric constant of 4.3 and a thickness of 1.6 mm. We also used copper as a conductive material for the radiated patch and the ground plane. Both models of the thin strip antenna were designed using mathematical equations to calculate the dimensions of the rectangular radiated patch as follows.

Calculating the effective dielectric constant of the thin strip antenna (ε_{reff})

The effective dielectric constant was calculated and was equal to 3.89 by applying the following mathematical relationship .

$$\mathcal{E}_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{w}\right]^{-1/} \text{.................} \quad (4)$$

2.1. Calculating the width of the radiated patch (wp)

Width of radiation patch at frequency 3.45 GHz was calculated by applying the following mathematical relationship :

$$W = \frac{c}{f_r}\sqrt{\frac{2}{\varepsilon_{r+1}}} \quad \text{..........} \quad (5)$$

3.1. Calculating the effective length of the radiating muscle (electrical length) (L_{eff})

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} \quad \text{.........} \quad (6)$$

4.1. Calculate the discrepancy between the physical and electrical distances of the radioactive patch(ΔL)

The difference between the physical and electrical length of the radiated patch is calculated and its value is found to be 0.737mm, by applying the following equation .

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff}+0.3)(\frac{w}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{w}{h}+0.8)} \quad \text{.......} (7)$$

1.Calculating the length of the radioactive patch(L_P)5

The length of the radiated patch was calculated and its value was equal to 19.5738 mm, by applying the following mathematical relationship.

$$L = L_{reff} - 2\Delta L \quad \text{....} (8)$$

2. Results

2.1Return loss

1- From Figure (3), it is clear that the return loss of the first antenna that was fed by the strip-line method is equal to -27.468dB at the resonant frequency of 3.45 GHz. This is a good and logically acceptable result in the world of thin-chip antennas.

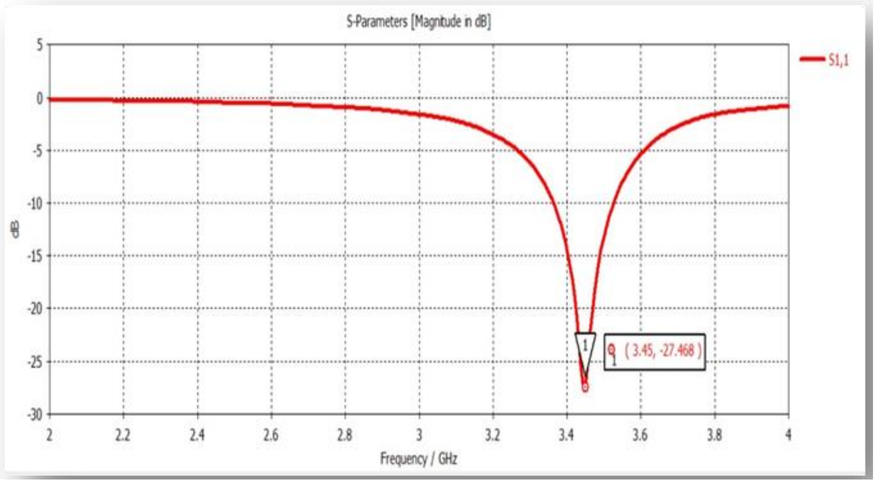

Fig. 3: Return loss of the first antenna.

As for Figure (4), the results we obtained show that the return loss of the second antenna, which was fed by the coaxial probe method, which is equal to -26.0113dB at the resonance frequency of 3.69GHz and equals -24.74318GHz at the resonant frequency of 5.529GHz.

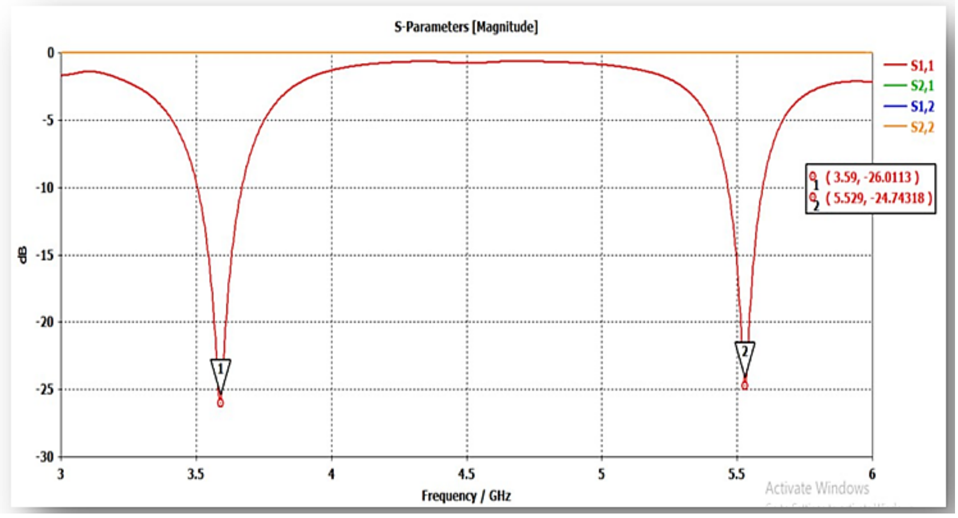

Fig. 4: Return loss of the second antenna.

From the results above, which we obtained from simulating the two antennas, we found that the return loss of the two antennas is good and close, even in the case of a slight difference in frequencies. The return loss is good the lower its percentage and the closer it is to zero, that is, the two antennas radiate most of the energy, and this indicates that the two antennas are ideal, but there is a loss The return is better when feeding the antenna with the strip line.

2.2 Standing wave voltage ratio of the first antenna

From Figure (5), it was found that the standing wave voltage ratio of the antenna is equal to 1.0884 at the resonant frequency of 3.44995GHz. This value is good for compatibility, and this indicates that the antenna is ideal and suitable for WIMAX applications.

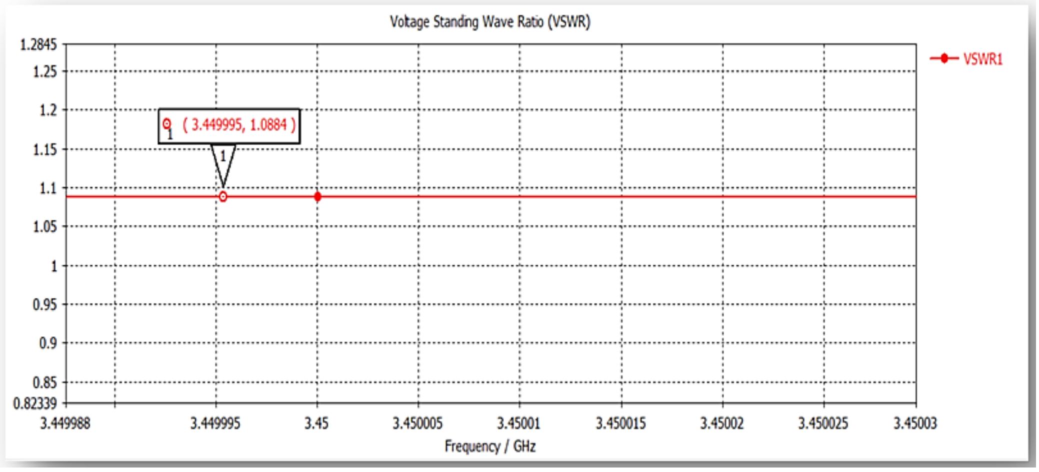

Fig. 5: standing wave voltage ratio

2.3. Standing wave voltage ratio of the second antenna.

From Figure (6), which represents the standing wave voltage ratio of the second antenna, which was fed to the coaxial probe, it was found to be equal to 1.105387 at the frequency of 3.59 GHz and equal to 1.890823 at the frequency of 5.592 GHz. So, from Figure (5), we have good results for the standing wave voltage, which is closer to the correct one, and it is better than the results we obtained from Figure (6).

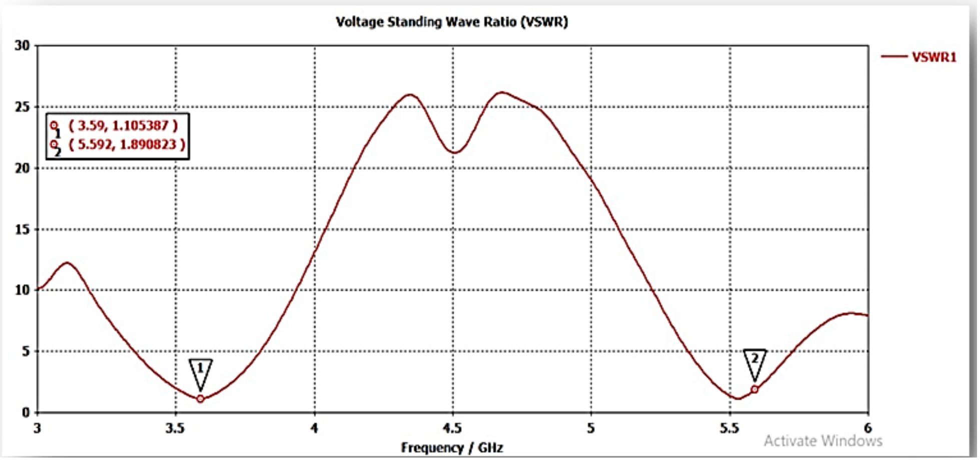

Fig. 6: shows the ratio of on and off voltages.

Conclusion

This study aimed to investigate the performance of rectangular microstrip patch antennas using different feeding techniques. Two antennas were designed and analyzed, both utilizing FR4 epoxy substrate and copper material for the radiating patch and transmission line. The antennas were constructed with similar geometric dimensions but employed different feeding methods: coaxial probe feed for the first antenna and microstrip line feed for the second. From all that we have done in designing and demonstrating small radiating antennas, the research is clear in implementing antenna analysis using useful techniques, which leads to achieving a satisfactory goal in terms of absence of return, voltage ratio, and signal confirmation across different frequencies. In summary, the abstract outlines the methodology, key findings, and tools used in the research on microstrip patch antennas, setting the stage for the detailed analysis and conclusions presented in the full paper.

☐ Explore further optimization of antenna dimensions to achieve better performance metrics such as return loss and bandwidth. This could involve parametric studies to understand how different dimensions affect antenna characteristics.

☐ Investigate the performance of microstrip patch antennas using substrate materials other than FR4 epoxy (e.g., Rogers RO4003C with a higher dielectric constant or Teflon with a lower dielectric constant). This comparison could provide insights into how substrate selection impacts antenna performance.

- Expand the study to include more feeding techniques beyond coaxial probe and microstrip line feeds. Consider techniques like aperture coupling, proximity coupling, or inset feeding, and analyze their impact on antenna performance and design complexity.
- Expand the study to include more distinct techniques including main probe, fine line feed, slot coupling, proximity coupling, or inline feed, and analyze them on antenna performance and design complexity.
- Design microchip patch antennas capable of operating across multi-frequency bands or achieving wide-band performance. They can include techniques such as the use of synthetic material structures, multilayer designs, or the use of frequency selectivity.

Each of these future study areas could contribute to advancing the understanding and practical applications of microstrip patch antennas in wireless communication systems. They would also help address ongoing challenges in antenna miniaturization, performance enhancement, and cost-effectiveness.

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