

Design and Analysis of a Rectangular Microstrip Patch Antenna for S-Band Wireless Communication Systems

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Abstract

Because of the growth of communication devices and systems, frequencies are becoming more suitable for the size and performance of this type of antenna. High dielectric constant materials are employed to accomplish greater size reduction due to recent developments in semiconductor technology, making it particularly helpful and popular in the design of mobile devices and wireless systems. However, microstrip patch antennas have limitations due to their small bandwidth and poor strength. In view of this, a 2.4 GHz rectangular microstrip patch antenna for wireless communication is presented with a substrate flame Retardant (FR4). This material has a thickness of 1.6 mm and a dielectric permittivity of 4.3. The antenna layout is simulated using the CST Studio suite. The result obtained has a lower return loss, higher gain, lower VSWR and a better directivity, and more importantly, an efficient operation within the S-band. The simulation revealed that the return loss, gain, VSWR and gain were correspondingly -27.01 dB, 6.75 dBi, 1.7 dB. The efficiency was 89.56%. It operates efficiently within frequencies 2.3716 GHz – 2.4361 GHz. The results from the simulation is better than the ones done in the recent past when benchmarked with similar designed. It will be efficient for wireless system communication in S-Band at its prescribed range.

KEYWORDS: CST, Flame Retardant (FR4), Microstrip Patch Antenna, Return Loss, Wireless communication.

1. INTRODUCTION

Microstrip patch antennas are getting an increasing number of considerable usage in latest Wi-Fi communication systems. Antennas come in a variety of shapes and sizes, including horn antenna, folding dipole antennas, slot antennas, patch antennas, and parabolic reflectors. Each antenna type has its unique set of properties as well as a specific use. We can say that antennas are the backbone of virtually everything in wireless communication, without which

the world would not have progressed to this age of technology, and there are various types of applications in this age of technology [10].

Radio frequency (RF) and wireless communication technologies are now widely used in daily life and a variety of industrial applications. In recent years, many wireless communication technologies have emerged, such as wireless local area networks, wireless interoperability for microwave access, wireless broadband, and so on. The microstrip patch

antenna is an excellent choice for RF communication system requirements, despite its low gain, disordered emission pattern, and limited bandwidth [11].

Many researchers have published the notion of a microstrip patch antenna, which is a new technique in electronics that may be built on printed circuit boards [16]. These are crucial in today's wireless communication systems.

Using a standard microstrip production technique, microstrip antennae are incredibly simple to construct. To construct a tiny microstrip patch antenna, a substrate with a greater dielectric constant must be employed, resulting in reduced efficiency. Technology and communication applications are rapidly expanding, including medical treatment and remote control of industrial equipment. The technology enhances societal safety by maintaining security and accelerates a country's economic progress. The wireless communication system has become the most important aspect of our lives. Almost every technology in our daily lives is dependent on it. A microstrip patch antenna is an excellent choice for wireless communication technology [17]. It can give greater bandwidth, greater efficiency, lower power consumption, and greater gain [2], [9]. High gain is required in antenna technology to provide maximum energy. FR4 is employed as a substrate in this work because it operates at a higher frequency [19]. A microstrip patch antenna is relatively simple to construct and utilises a more commonly used microstrip fabrication process. The patch can be set in any way imaginable, however, the rectangular and circular designs are the most commonly utilised. These patch antennas are used in the most basic method conceivable for the most diverse and demanding applications [10]. This section discusses the technical work of many microstrip patch antenna articles. The study in [6] provides the layout and fabrication of a microstrip line-fed patch antenna running at 2.4 GHz. The proposed antenna is a communication system that uses the S-band. This paper presents a rectangular microstrip patch antenna designed for use in wireless applications [13]. This microstrip patch antenna's primary purpose is to improve gain, directivity, and bandwidth. A patch antenna with a frequency of 2.4 GHz designed and investigated in [13], as a possible future technology for wireless communication. The goal of this study was to achieve a little return loss, a larger gain, and a lower voltage standing wave ratio (VSWR). This study demonstrates and builds [14], design and performance evaluation of elliptical microstrip patch antennas operating at 2.4 GHz for wireless applications. The performance of these antennas with and without a slot will be compared in this study. A study was performed

on three designs of small size, cost-efficient, wide-band microstrip patch antennas utilising FR-4 substrate with suitable dimensions for the 2.5 GHz wireless band. A square microstrip patch antenna is fed from the internal in [12]. As a result, a one-of-a-kind particle swarm optimisation method based on IE3D was utilised to create a linearly polarised inset feed and a rectangular microstrip patch antenna with a four-element array. It is a significant quantity that governs the resonance frequency of the antenna. Given the planning and decision-making that went into the width, height, and depth of the patch and feed line, the length of the antenna is roughly half the length of a wavelength. The antenna was originally designed as a single patch, but after considering its operation frequency, radiation patterns, reflected loss, efficiency, and gain, we chose to redesign it as a 2x1 linear array. The final consideration was how to improve the directivity, growth, efficiency, and radiation patterns of the 4x1 linear antenna array. A low-profile patch antenna was used in 5G communication systems as part of this research [3]. The resonant frequency for 5G has been simulated at 3.5 GHz. The substrate measures 25.2 with the aid of using fortyeight millimetres square. The primary radiating patch is shaped like an ellipse and was created using the line feed method. CST Microwave Studio is the programme that does the simulation. Several parameters, including the S-parameter, antenna gain, directivity, and efficiency, have been measured. With a gain of more than 5 dB, the antenna is a good solution for various sorts of communication. The antenna's design is centred on applications that require 5G connectivity. The research study in [4], built and tested microstrip antennas operating at 3.5 GHz and intended for use in fifth-generation (5G) applications. The required criteria were calculated using Huawei's public policy attitude, Qualcomm's general policy stance, and a Rel-15 3rd Generation Partnership Project (3GPP) article. Because microstrip antennas have limited bandwidth, several changes are required. The first step is to compute the antenna's initial dimension, the final step is to simulate and optimise the antenna.

2. METHODOLOGY

This segment examines the layout and improvement of a patch antenna for wi-fi communication exchange as it is well known that it can be put on a printed circuit board for various communication devices. CST and other simulation software are available for designing, simulating, and analysing microstrip antennas. Figure 2 depicts the antenna's dimensions,

including the length and width of the ground, patch, substrate, and feed line. The CST microwave studio was used to design, develop, and simulate the microstrip patch antenna. This paper used FR4 as the substrate material in this proposed prototype patch antenna design, with a dielectric of 4.3 and a thickness of 1.6 mm.

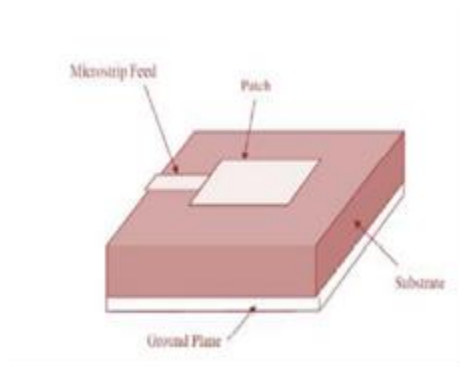


Figure 1: Microstrip patch antenna

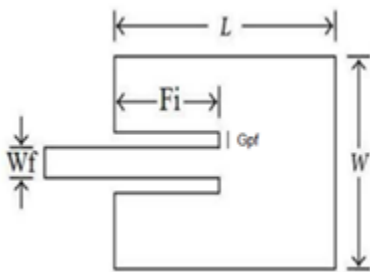


Figure 2: Diagram of the patch antenna

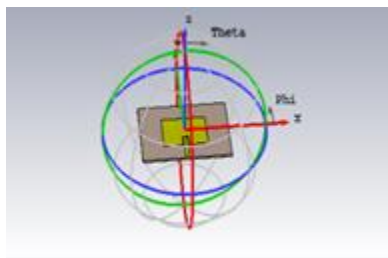


Figure 3. Simulation of the microstrip patch antenna in CST

The following equations are used to calculate the parameters in this work.

- a. The effective dielectric constant

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h_s}{W} \right]^{-\frac{1}{2}} \quad (1)$$

- b. The effective dielectric constant

$$W = \frac{c}{2f_k \sqrt{\epsilon_{eff}}} \quad (2)$$

- a. Extended length

$$\Delta L = 0.412 h_s \frac{(\epsilon_{eff} + 0.3) \left(\frac{W}{h_s} + 0.264 \right)}{(\epsilon_{eff} - 0.258) \left(\frac{W}{h_s} + 0.8 \right)} \quad (3)$$

$$L_{eff} = L + 2\Delta L \quad (4)$$

$$L_{eff} = \frac{c}{2f_k \sqrt{\epsilon_{eff}}} \quad (5)$$

The proposed microstrip patch antenna design has other parameters such as Width, Length and the height of patch.

Table 1. Parameters of the design

Parameter	Dimension (mm)
Width of Patch W	38
Length of Patch L	29
Length of feedline Fi	8.85
Width of the feedline Wf	3.137
Space between patch and feedline Gpf	1
Ground Length Lg	58
Ground Width Wg	76
Height of Patch hs	0.035
Height of Substrate hs	1.6

3. RESULT AND DISCUSSION

3.1 Return Loss

A standard value of -10dB is accepted as the benchmark for good performance for communication systems. The proposed patch antenna resonates at the desired resonance frequency of roughly 2.4GHz within the S-band frequency spectrum, with a return loss of -27dB. In two ways, the proposed design performs better than the benchmarked patch antenna design. First off, compared to the benchmarked patch antenna design, the proposed patch antenna design has a lower return loss (-27dB). Second, the suggested patched antenna was created with the goal of resonating at 2.4GHz, but after design, it actually resonated at 2.4034GHz, which is a fair value, with minimum and maximum operational frequencies at 2.3716GHz to 2.4361 GHz

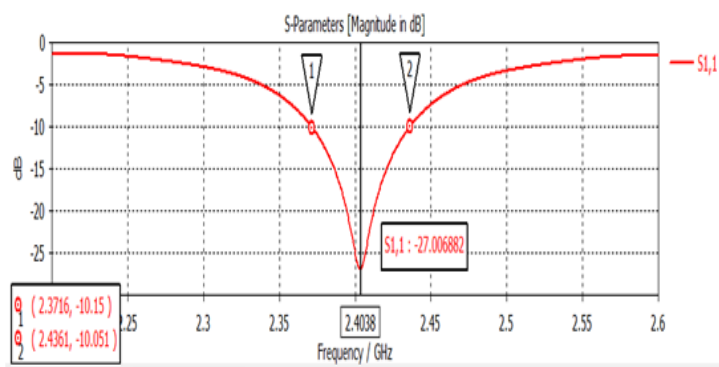


Figure 4. Return loss vs frequency

3.2 Voltage Standing Wave Ratio

By the IEEE standard, effective impedance matching and minimal reflected power, requires that the value of VSWR of an antenna falls between 2.0dB and 1.0dB for a communication system operating in the S-band. At a resonant frequency of 2.4GHz we obtained a VSWR of 1.03dB for this antenna design. When compared to the benchmarked patch antenna design, the patch antenna's VSWR performance has significantly improved. The fact that the VSWR remained below the 2.0 dB baseline spanning the operational frequency band of 2.37GHz to 2.44GHz is another advantage of the suggested patch antenna design.

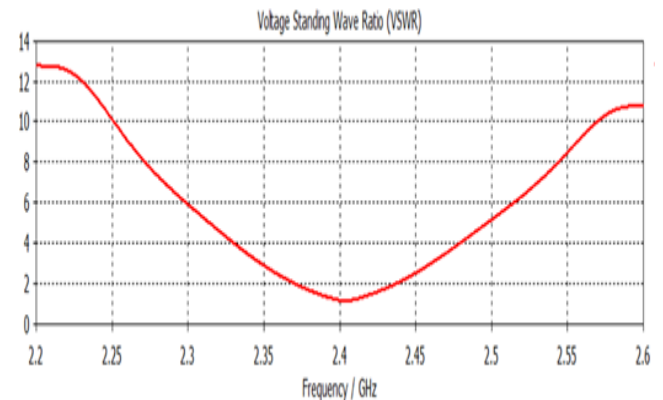


Figure 5. VSWR vs Frequency

3.3 Bandwidth

From the Figure 5 bandwidth of the antenna is 0.0645 GHz between 2.3716GHz and 2.4361 GHz. The bandwidth achieved is perfect for an S-band application for wireless communication.

3.4 Gain and Radiation Pattern

The radiation pattern is a significant aspect since it displays an antenna's overall performance. The 3D radiation pattern of the microstrip patch antenna is depicted as shown below. The gain is 6.75 dBi, and the radiation efficiency is 83%, making S-B technology exceptionally effective and efficient. Furthermore, the main-lobe direction, angular breadth (3 dB), and side-lobe level are 0.0 degree, 78.2 degree, and -16.8 degree, respectively.

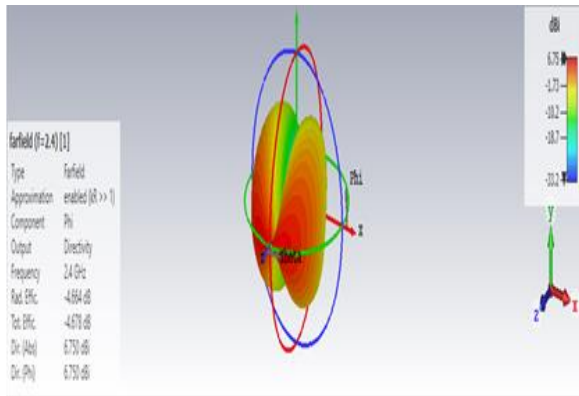


Figure 6. Antenna 3D radiation pattern

The microstrip patch antenna's 3D gain plot is depicted in Figure 6. Gain performance and patch antenna efficiency are closely related. In this case of tiny antenna design, the antenna's gain of 4.25 dB or 6.75 dBi is deemed acceptable.

Figure 4.4 depicts the microstrip patch antenna design's 2D radiation pattern. A more omnidirectional radiation pattern is produced by the design, making it appropriate for use in all communication systems

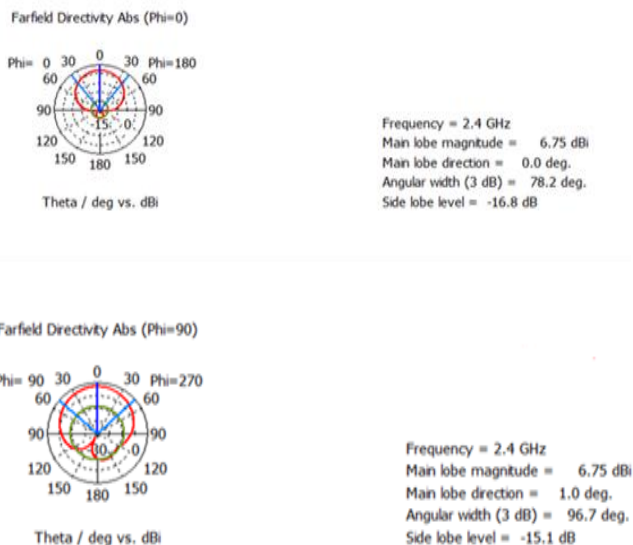


Figure 7. The microstrip patch antenna's 2D radiation pattern

3.5 Comparison with other Works

Table 2. A summary of selected results and benchmarked of the patch antenna

S11 (dB)	Gain	VSWR	BW (GHz)	REF
-18.27	4.46	2.13	0.2	[14]
-13.48	6.63	1.538	0.847	[1]
-17.436	6.6	1.31	65.2MHz	[7]
-41.3	4.45	1.01	1.13	[13]
-26.347	3.68	1.10	0.64	[15]
-19.61	6.58	1.82	10	[18]
-12.54	5.5	1.6	3.5	[5]
-27.00	6.75	1.03	0.0645	This work

The microstrip patch antenna has a radiation pattern with a gain of 6.75 dBi, a return loss of -27 dB at 2.4 GHz, and a low profile structure of 38 mm 29 mm 1.6 mm. The antenna design outperforms a benchmarked patch antenna design in terms of performance.

4. CONCLUSION

A compact-sized microstrip patch antenna has been designed for high gain resonating at 2.4 GHz. The gain, return loss, bandwidth, VSWR, and radiation efficiency are 6.75dBi, -27.00 dB, 0.0645 GHz, 1.03, and 84%, respectively. These results demonstrate that the proposed antenna is well suitable for use in an S-band. Using alternative methods such as circular and ring-type array patching can provide additional enhancement. However, future study can employ a range of methodologies and materials. The simulation results show that the proposed antenna could be a viable candidate for wireless communication systems.

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