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Design of Dual-Band Microstrip Patch Antenna for Wireless Local Area Network Applications †

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Abstract: This study focuses on the design of a dual-band microstrip patch antenna, which is capable of operating in two different frequency bands, specifically the 4.9 GHz and 6.7 GHz WLAN (Wireless Local Area Network) bands. With the growing popularity of wireless communication technology and the ability to utilize frequency bands without the need for authorization, WLAN usage is becoming increasingly widespread. The design of the antenna is conducted using the High-Frequency Structure Simulator (HFSS) electromagnetic simulation software. The proposed antenna is made on a low-cost FR-4 substrate with a dielectric permittivity of 4.4, which offers benefits such as affordability and compactness. The resulting antenna has a compact size of 17.952 mm by 16.896 mm, including a substrate thickness of 1.6 mm, making it one of the smallest dual-band microstrip patch antenna. The antenna utilizes microstrip line feeding, and its radiating patch is formed by cutting inverted C-shaped from the patch and inverted U-shaped grooves from the feed line, allowing it to be compatible with 4.9 GHz and 6.7 GHz WLAN bands. The design and simulation results demonstrate that the proposed antenna has a dual-band capability and favorable transmission characteristics within its operating frequency range, meeting the demands of WLAN communication.

Keywords: WLAN; dual-band; WIFI; patch antenna

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1. Introduction

As technology advances in the design of microwave and millimeter wave components, the need for more compact and minimalist devices arises. Microstrip antennas are becoming increasingly popular in this regard, as they can be directly printed onto a circuit board. Among the various types of microstrip antennas, patch antennas stand out for their low cost, low profile, and ease of fabrication [1]. They are also small in size, lightweight, and easy to integrate, making them an ideal choice for dual-band antenna design applications such as laptops and smartphones. They are also relatively easy to manufacture and can be integrated into a wide range of electronic devices. They work by radiating energy from a metallic patch (or "patch") that is suspended above a dielectric substrate [2]. The patch is connected to a feed line, which provides the energy that is radiated by the antenna. The operating frequency bands can be achieved by adjusting the size, shape, and dielectric constant of the substrate material. In recent years, wireless communication technology has developed rapidly, and as a result, WLAN communication systems have also seen significant growth and an expanding range of applications in the market [3].

Wireless communication systems require quick, efficient, and dependable two-way data transmission, which is reflected in the design of their antenna subsystem. The antenna plays a vital role in such systems [4]. In today's information-based society, there is a growing demand for antennas that not only have a broad frequency band and are compact and easy to install but also exhibit high radiation efficiency, anti-interference performance, and other desirable characteristics [5]. The microstrip patch antenna is a type of directional antenna, meaning it transmits signals in a specific direction [6]. It can be designed to have omnidirectional or directional characteristics, which is beneficial in WLAN applications as it can provide higher gain in specific directions and overcome obstacles that may block signals [7]. The microstrip antenna functions as a resonant radiator, emitting electromagnetic waves continuously between its top radiation patch edges and the grounding plate, creating a radiation field via the mutual electromagnetic interaction between these two objects. Hence, a dual-band microstrip patch antenna is designed to operate in two different frequency bands in the WLAN (Wireless Local Area Network) spectrum [8]. A dual-band microstrip patch antenna typically consists of a patch of conductive material, such as copper, mounted on a dielectric substrate, such as FR-4. The patch is usually fed using a microstrip transmission line, and it radiates the energy into the surrounding space. The design of the patch and the transmission line can be optimized to support the desired frequency bands. The design of a dual-band microstrip patch antenna operating at 4.9 GHz and 6.7 GHz is challenging, as it needs to meet the requirements of both frequency bands while maintaining the compactness and low-profile features of a patch antenna. A dual-band microstrip patch antenna is designed to operate in the 4.9 GHz and 6.7 GHz WLAN bands. This allows for increased flexibility and versatility over single-band antennas [9] by allowing devices to connect to both older and newer wireless networks. This would enable the antenna to support wireless communication in both frequency bands, which could be useful in applications where multiple wireless communication systems are used simultaneously [10].

For example, a Wi-Fi network may use wireless communication in the 6.7 GHz WLAN band to connect laptops and other devices to the internet. A dual-band microstrip patch antenna would enable both communication systems to operate using the same antenna, which could save space and reduce costs. Designing a dual-band microstrip patch antenna that operates at WLAN frequency bands is challenging [11], as the antenna needs to meet the requirements of both frequency bands. Researchers may focus on developing new antenna designs that can support both frequency bands and optimize the performance of the antenna in both frequency bands.

6.7 GHz WLAN antennas typically focus on designing and optimizing antennas for high-speed wireless communication, investigating ways to improve the coverage and capacity of wireless networks, and reducing interference. This can include optimizing antenna performance [12] for Wireless routers and access points, smartphones, laptops, high-speed wireless backhaul, wireless broadband, Smart Homes and Buildings, and Industrial Automation. A dual-band microstrip patch antenna may be useful in a variety of applications, such as wireless sensor networks, wireless local area networks (WLANs), Wi-Fi, WiMAX, and cellular networks, because of their compact size and ease of integration [13].

This study aims to explore the dual-band capabilities of an antenna operating in the 4.9 GHz and 6.7 GHz WLAN bands. The antenna configurations are optimized using Ansoft HFSS electromagnetic simulation, and the results show satisfactory performance. The paper is structured as follows: Section 2 presents a comparison of the proposed antenna with those in the literature. The antenna design specifications are outlined in Section 3, and the design specifications are defined in Section 4. The parametric analysis is detailed in Section 5, followed by the conclusion in Section 6.

2. Previous Research

The design and optimization of dual-band microstrip patch antennas for WLAN applications have garnered significant attention in recent years. With the rapid advancement of wireless communication technology and the increasing demand for compact and versatile antennas [14], researchers have focused on developing antenna designs capable of operating in multiple frequency bands while maintaining a low-profile form factor.

The literature on dual-band microstrip patch antennas has explored various aspects of antenna design, optimization techniques, and performance analysis. Researchers have investigated novel designs that enable simultaneous operation in different frequency bands, aiming to improve antenna efficiency, gain, bandwidth, and radiation pattern characteristics [15]. Additionally, studies have focused on antenna performance enhancements specific to the WLAN frequency bands, such as coverage improvement, interference reduction, and capacity optimization for high-speed wireless communication systems. These efforts have encompassed applications ranging from wireless routers [16] and access points to smartphones, laptops, wireless backhaul, and industrial automation.

We aim to provide a comprehensive overview of the existing research and advancements in dual-band microstrip patch antennas for WLAN applications. We will compare different antenna designs, optimization approaches, and performance evaluations conducted in previous studies [17]. This review will serve as a foundation for our proposed antenna design and optimization framework, addressing the challenges associated with achieving dual-band operation, compactness, and high performance in WLAN frequency bands.

Antennas for modern wireless communications must be able to work across various frequency bands. Multifunctional, intelligent, and small antennas are needed for modern systems. Modern wireless systems perform a number of tasks and need to operate at numerous frequencies without expanding antenna size as a result of quick technological advancements [18]. Compact, multifunctional, multiband antennas are currently more in demand than ever, thanks to the continuously growing number of wireless communication applications. For today's multiband wireless applications, this form of antenna is more cost-effective. Compact printed antennas that can operate across many bands have already been developed [19]. Various techniques have been employed to achieve multiband characteristics, such as the use of metamaterial, multi-radiating components, cutting slots, parasitic coupling elements, modified fed lines, defective ground structure, added slots, and meander lines, among others [20]. A modified fork-shaped strip covering the 2.4/5.2/5.8 GHz WLAN and 3.5 GHz WiMAX bands was used as a multiband antenna. To provide coverage for the 3.5 GHz WiMAX band, two L-shaped parasitic planes were added to the bottom of the FR-4 substrate. A cavity antenna with an artificial magnetic conductor metamaterial was utilized [21] to produce a dual band with a high gain of 15.2/18.8 dBi and a unidirectional pattern. A step-impedance resonator with the first four electrical length resonances and a strip line was used to create a bandpass filter [22]. A meander line and an inverted L were combined into a monopole antenna to produce dual-band operation. This study describes a dual-band microstrip antenna for WLAN applications that operates at 4 GHz and 6.7 GHz.

3. System Model

The overall shape of the suggested dual-band microstrip patch antenna is shown in Figure 1. The suggested antenna is constructed using a low-cost FR-4 substrate with a dielectric constant of 4.4. This constructed antenna is one of the smallest dual-band antennas, with an overall size of 17.952 mm by 16.896 mm, and includes a substrate thickness of 1.6 mm. The antenna's small size and metallic coating on one side of the substrate make it straightforward to incorporate into network circuitry. A compactly designed microstrip patch antenna with an inverted C-shaped and inverted U-shaped slot may operate on two frequencies. This antenna might be thought of as two connected, different-sized resonators. The radiating patch has slots that can be utilized to direct meandering currents and produce a variety of resonances. Slots of various dimensions and lengths can be inserted into the ground plane, feed line, or radiating patch in order to achieve the dual band. The first band was made by cutting an inverted U-shaped groove out of the feed line having a spacing of 0.5 mm, and the second band was made by cutting an inverted C-shaped groove out of the radiating patch having a spacing of 0.288 mm, which is why the prototype has a frequency range of 2.98–5.34 GHz and 6.6–7.2 GHz. To estimate the resonance frequency generated by the patch antenna, using the formula:

$$F = \frac{c}{2L\sqrt{\varepsilon_{ff}}}$$

where c is the speed of light, L is the total length of the substrate, and ε_{ff} is the effective dielectric constant, which is equal to $\frac{\varepsilon_r+1}{2}$. Here, ε_r denotes the substrate's dielectric permittivity. The Ansoft HFSS 15.0 simulator has been employed to optimize and simulate the proposed radiation pattern. The following are the optimized parameters that provides the dimensions of the proposed antenna and its ground in Table 1.

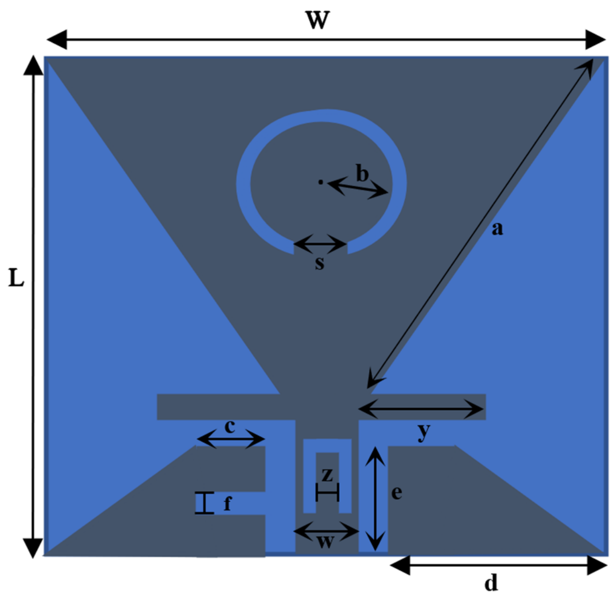


Figure 1. Design of Dual-Band Microstrip Patch Antenna.

Table 1. Optimized Parameters.

Parameter	Value (mm)	Parameter	Value (mm)	Parameter	Value (mm)
L	17.952	W	16.896	w	2.88
Y	4.32	a	13.8	b	2.5
S	2	c	1.795	e	3.936
f	0.532	d	6.528	z	1.344

4. Design Specification

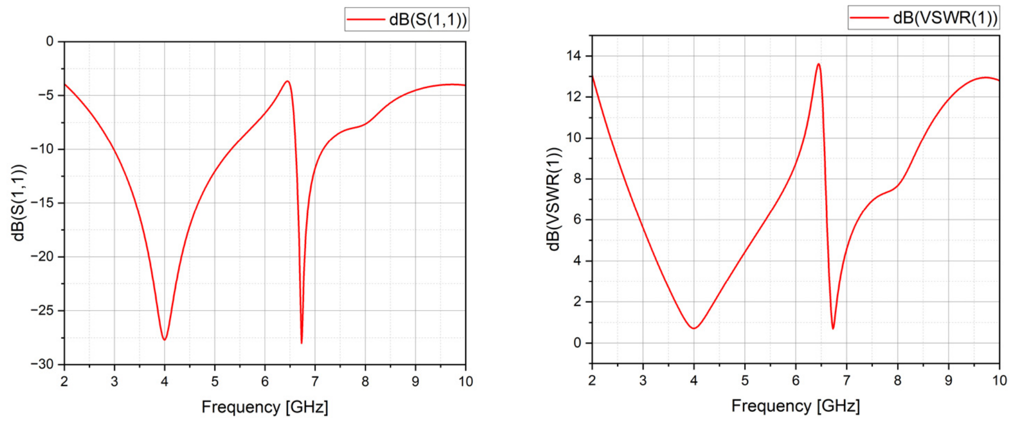
Specifications that are found in two bands of WLAN antenna are displayed in Table 2.

Table 2. Design Specification.

Specs	Frequency	Polarization	VSWR	Impedance (Ω)	Radiation Pattern	Material
First Band	4.9 GHz	Linear	<2	50	Bidirectional	FR-4
Second Band	6.7 GHz	Linear	<2	50	Bidirectional	FR-4

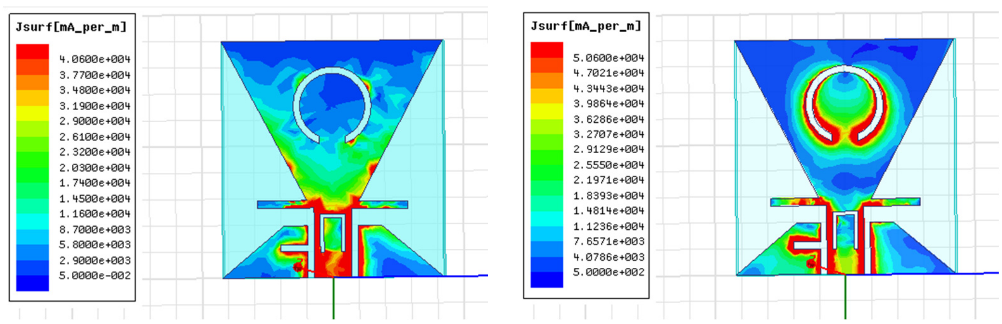
5. Results and Analysis

The proposed antenna is simulated using the Ansoft HFSS 15.0 simulator. Figure 2a displays the antenna's observed S-Parameter. These results of the suggested configuration's simulated VSWR are shown in Figure 2b. The suggested antenna covers the WLAN band with a VSWR < 2. The antenna's functional frequency band spans the range of 2.98–5.34 GHz and 6.6–7.2 GHz. The main causes of a little variance in results are fabrication tolerance and the impact of the SMA connector. Figure 3a,b simulate the desired antenna's surface current distribution at 4.9 GHz and 6.75 GHz.



(**a**) (**b**)

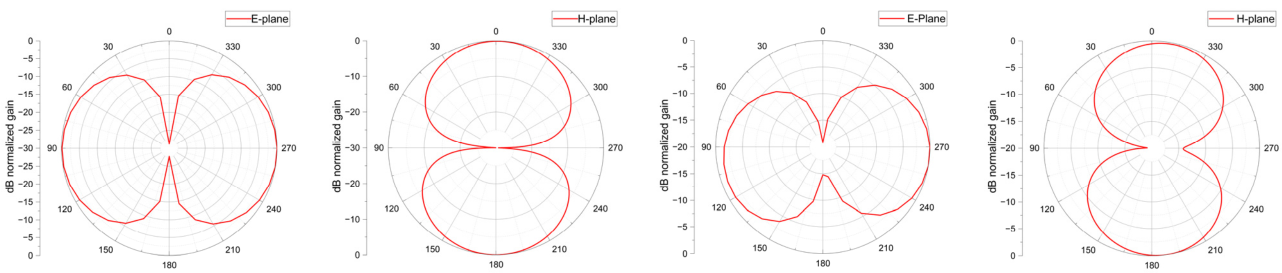
Figure 2. Stimulated results (**a**) reflection coefficient (**b**) VSWR Graph.



(**a**) (**b**)

Figure 3. Stimulated Current Distribution Graph at (**a**) 4.9 GHz, (**b**) 6.75 GHz.

The appropriate dual-band microstrip patch antenna features are tiny, uncomplicated, and easy to produce on a substrate at a fair price. In terms of antenna size, impedance bandwidth, and notch characteristics, throughout the publications, the implementation of the envisioned work is contrasted with the performances of other contemporary antennas. This contrast suggests that the suggested antenna structure, despite having a relatively simple and modest structure and better impedance bandwidth. The E-plane and H-plane radiation patterns for the suggested antenna are depicted in Figure 4 for the frequencies simulated at 4.9 GHz and 6.75 GHz.



(**a**) (**b**) (**c**) (**d**)

Figure 4. E-Plane and H-Plane Radiation Characteristics at (**a**) 4.9 GHz, E-Plane (**b**) 4.9 GHz, H-Plane (**c**) 6.75 GHz, E-Plane (**d**) 6.75 GHz, H-Plane.

The results show that the antenna exhibits a steady and bidirectional pattern in the H-plane. The E-plane radiation pattern resembles the features of a dual-band antenna with bidirectional characteristics. An antenna is a fantastic option for WLAN systems since the patterns are frequently continuous over the optimum operational band.

6. Conclusion

The proposed design is a dual-band microstrip patch antenna for use in Wireless Local Area Networks (WLANs). The dual-band capability is achieved by adding slots of different shapes to the radiating element. The first band is created by cutting an inverted U-shaped groove, and the second band is created by cutting an inverted C-shaped groove, resulting in a frequency range of 2.98–5.34 GHz and 6.6–7.2 GHz. The size and placement of the slots can be adjusted to fine-tune the dual-band performance. The final prototype showed excellent results, with an efficiency of over >90 percent. The simulation results were found to closely match the measured results. This design is ideal for WLAN applications due to its low profile and consistent radiation patterns. It can be used in a variety of wireless communication systems, including wireless sensor networks, WLANs, and 5G networks.

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