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Parasitically Coupled F-Shaped Microstrip Antenna for 2.4 GHz Wi-Fi Applications

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Abstract – This paper focuses on the design of a Wi-Fi antenna aimed at operating efficiently in the 2.4 GHz frequency band and the implementation of an impedance matching circuit integrated into it. The impedance matching circuit was designed and integrated to operate the antenna, which does not operate at the target frequency, at the target frequency. Coupling is carried out using a circuit called L matching, which consists of a reactance and a susceptance element in the format jX and jB. AWR was used to design the impedance matching circuit and check whether the required simulation results were achieved. The antenna was designed in a simulation environment and then the designed matching circuit was integrated into the numerical computation model of the proposed antenna. These tools played a critical role in the paper in identifying and resolving issues with impedance matching and frequency alignment, ensuring the antenna operated efficiently in the desired frequency range. The antenna performance has been significantly increased, improving S11 parameter magnitude from 2.7dB to 30.1dB. The success of this study highlights the importance of impedance matching in the development of high-performance antennas. By addressing and overcoming initial challenges, the study not only achieved its primary goals but also provided valuable information and methodologies that can be applied to future antenna designs. Integration of impedance matching circuitry into Wi-Fi antenna design demonstrates the potential to improve the efficiency and performance of wireless devices, making this research a valuable contribution to the field of telecommunications.

Keywords – Wi-Fi, Antenna Design, Impedance Matching, AWR

I. Introduction

Antennas that are dependable and efficient are more important than ever in today's quickly developing wireless communication networks. Due to the growing number of wearables, smart homes, and Internet of Things devices, small, inexpensive, and high-performing antennas are essential. We discuss the design and optimization of a single-band antenna operating at 2.4 GHz in this research. Our goal is to create an antenna with the best possible performance in this frequency range, guaranteeing dependable and strong wireless communication. The utilization area of wireless technology is increasing with the result of demanding application specific versatility of communication systems while providing the flexibility in various wireless applications incorporating versatile microwave components such as microwave filters [1], rectennas [2], mmwave photonic transmitter modules [3], and microwave antennas [4-5]. For any wireless mobile component, RF/microwave designers today have four major challenges to overcome: compact size, lightweight, low profile, and low cost. The antenna is one of the most important components of any wireless system. Wireless Communication industry demands light and compact small antennas with low-cost fabrication [6]. A compact meandering slotted microstrip antenna has been proposed at [7] where it reduces the size of the antenna with a fixed frequency operation [8]. Besides, light and small antennas also reduce the bandwidth, gain and efficiency that is another challenge for communication technologies. Many techniques have been proposed by the researchers on enhancement of the gain, efficiency and bandwidth with satisfactory radiation characteristics by using meander shaped antennas [9]. One of the important limitations of a microstrip antenna is single frequency and narrow bandwidth. A fork like tuning stub is applied to the microstrip slotted antenna to solve this issue [10]. A capacitive load (C-load) on 1.6 mm thick FR-4 substrate has been applied to enhance the peak gain with a fractional bandwidth of 7.23% and to improve the impedance matching which is a well-known technique for performance improvement [11], [12]. In addition, embedded meander line slits have been applied at [13] to enhance the fractional bandwidth. In this case, a miniaturized meander shaped antenna is a suitable candidate as the space available for its installation is limited because it is introduced to achieve size reduction by implanting wire structure on a dielectric substrate [14]. Miniaturized meander-shaped antennas have become a promising option in this regard. These antennas are perfect for applications where space is at a premium because of their small form factors and affordable manufacture. A wire arrangement on a dielectric substrate allows meander-shaped antennas to reduce size significantly without sacrificing performance [15].

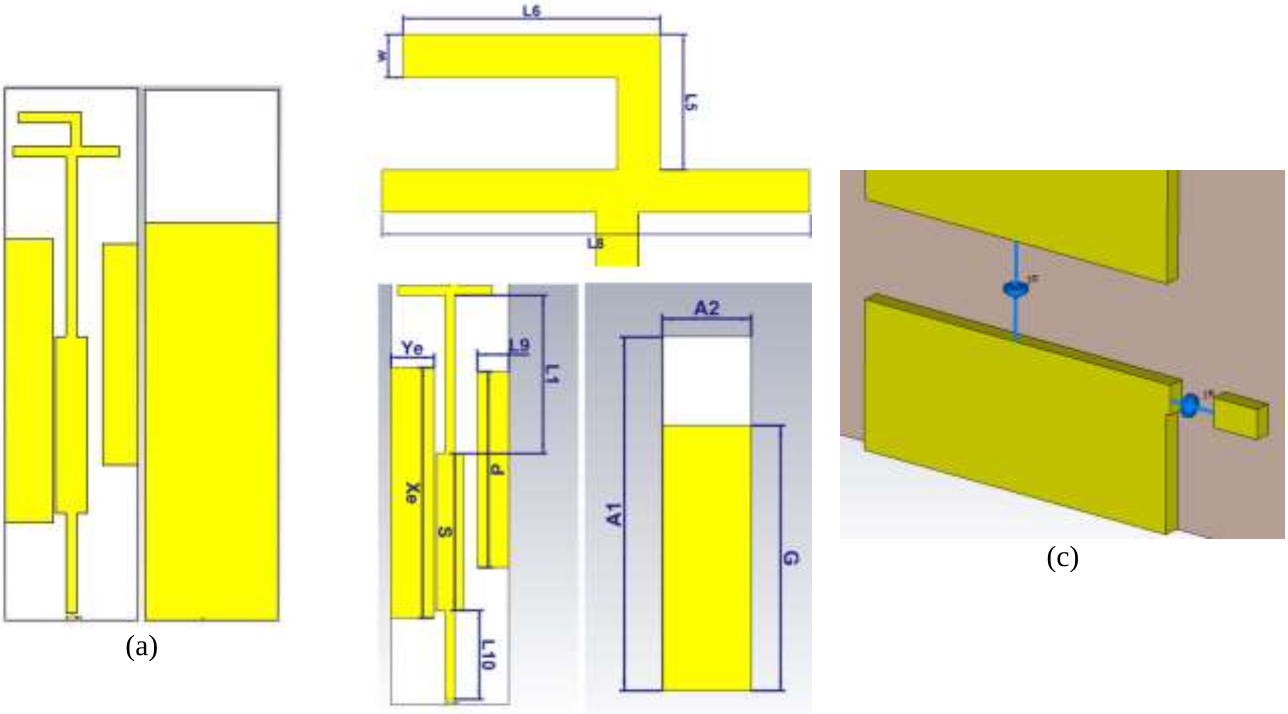
This paper presents a microstrip Wi-Fi antenna. The antenna can perform in the 2.4 GHz frequency band. The antenna consists of patch, substrate, and ground. With a view to low production cost, as substrate material FR-4 material with dielectric constant (ε_r) of 4.4 and loss tangent of 0.02 has been chosen. The antenna has compact structure with a total size of 60 mm x 15 mm.

II. Materials and Method

The antenna is designed on FR4 substrate with the relative permittivity ε_r of 4.4, loss tangent of 0.02 and thickness of 1.6 mm. The antenna design is shown in Fig. 1. Additionally, the geometric parameters of the antenna design shown in Fig. 1b are stated in Table 1.

Table 1. Parameters of Designed Antenna

Parameters	Values	Parameters	Values
A1	60 mm	L1	20.25 mm
A2	15 mm	L5	3.8 mm
G	45 mm	L6	7.2 mm
Xe	32 mm	L8	12 mm
Ye	5.5 mm	L9	4 mm
S	20 mm	L10	12 mm
P	25 mm	w	1.2 mm
Substrate Thickness	1.6 mm	hc	0.035 mm



(a) (b) (c)

Figure 1. (a) Front and Back Side of Designed Antenna (b) Parameters of Proposed Antenna and (c) Proposed Antenna with Lumped Elements Integrated

III. Results

The antenna designed with the specified geometric parameters is operated at the resonance frequency of 2.2 GHz, rather than the intended 2.4 GHz target frequency. The input impedance value of the antenna is calculated to be 15.87 + 35.22j. Therefore, an impedance matching circuit was designed to integrate this antenna into its design. When the B and X values of the circuit to be designed were calculated, both would be designed as capacitors since X was a negative value and B was a positive value. The impedance values of the proposed antenna were obtained from the numerical computation software and used as a load in the AWR simulation application, and the circuit below was established with the calculated capacitor values. As a result of integrating the impedance matching circuit, when the simulation was run again via 3D EM Field Solver, the S1.1 value, which was previously -2.7dB at 2.4 GHz, was reduced to -30.1 dB. This showed that the designed impedance matching circuit was successful and study achieved its purpose. The S11 graph of the matching circuit after it is integrated are shown in the Figure 2.

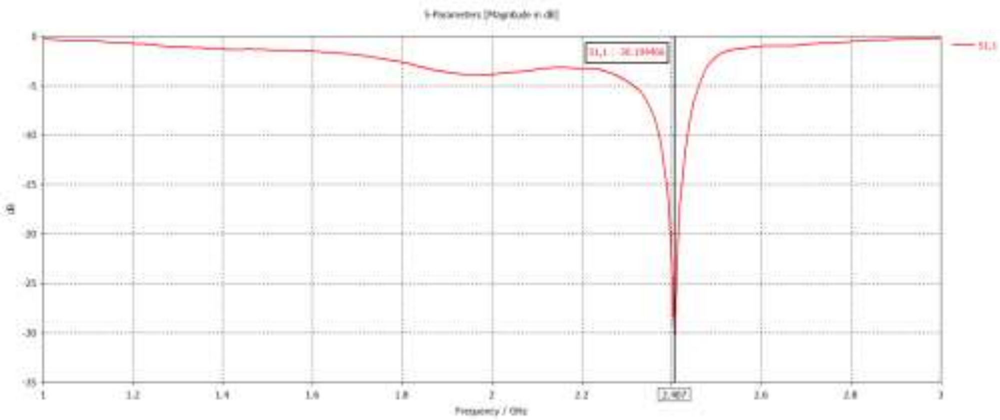
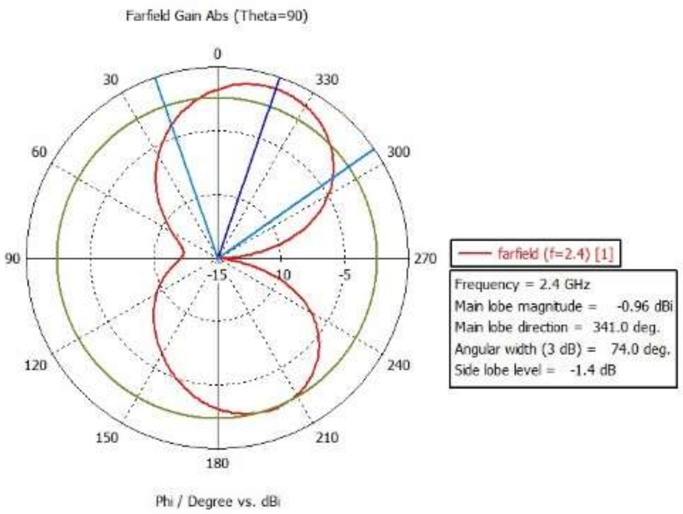
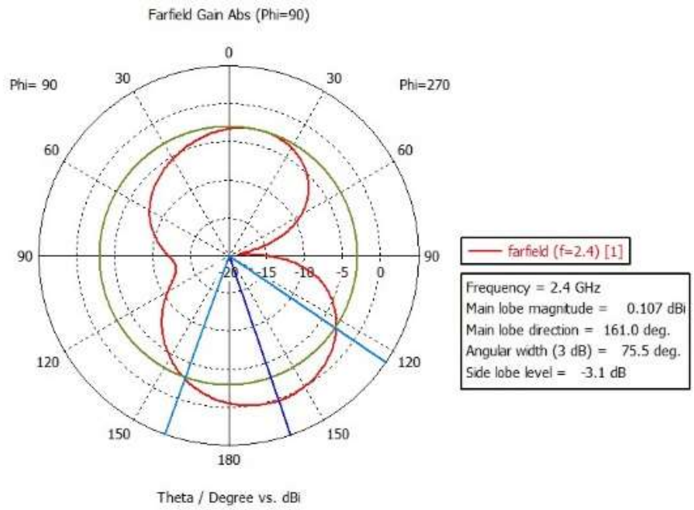


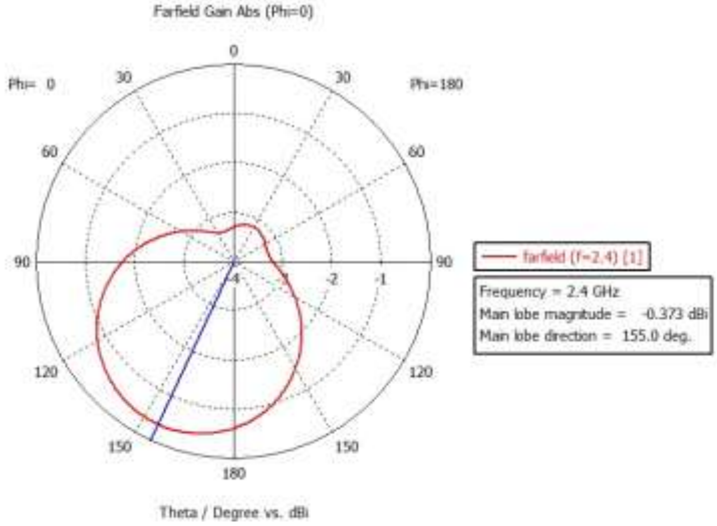
Figure 2. S11 Parameters of the Proposed Antenna



(a)



(b)



(c)

Figure 3. (a) Gain at Theta = 90 (b) Gain at Phi = 90 (c) Gain at Phi=0

IV. DISCUSSION

In this paper, an impedance matching circuit is integrated to improve the performance of the Wi-Fi antenna at 2.4 GHz. Using an L-shaped matching network, the S11 parameter of the antenna increased from -2.7 dB to -30.1 dB at 2.4 GHz with an initial impedance of 15.87 + 35.22j. As a result of the study, it was observed that the designed proposed antenna worked at 2.4 GHz, which is the Wi-Fi frequency, and the study was concluded. Gain values of the proposed antenna at Theta=90, Phi=90 and Phi=0 is -0.96 dBi, 0.1 dBi and -0.3 dBi respectively. It has been observed that the applications used in the design work properly and help to achieve the results of the study. This study provides a basis for more advanced Wi-Fi antenna designs in the future.

V. CONCLUSION

In conclusion, the goal of this study was to design and build a Wi-Fi antenna that would operate efficiently at the target frequency of 2.4 GHz. The study was successful in achieving this goal. The design of an L-shaped impedance matching network efficiently handled the issues of frequency misalignment and impedance mismatch, resulting in a significant improvement of the S11 parameter. The design was improved and the intended performance metrics were attained with the help of the EM Field Solver and AWR simulation tools. This effort offers insightful information and useful techniques that can be used in future designs, underscoring the significance of impedance matching in improving antenna performance.

Further research and experimental validation may offer additional improvements and broader applications, building on the foundation laid by this work for the development of more efficient and high-performance wireless communication systems.

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