Journal of Engineering Research and Education
Volume 13, 2021 [73-81]

Dual-Band Monopole Antenna for Wi-Fi Applications

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ABSTRACT

Wi-Fi is a wireless network technology that allows computers, laptops, mobile devices, and other devices like printers and video cameras to connect to the Internet. For Wi-Fi applications, a two-band microstrip-fed monopole antenna was introduced in this work. The antenna covers the 2.45 GHz and 5.8 GHz Wi-Fi working bands and operates in the frequency ranges of 2 GHz - 2.48 GHz and 5 GHz - 5.8 GHz. It's made of FR-4 dielectric and has an overall dimension of 38mm, 45mm and 1.6 mm^3. The antenna's basic features, such as return loss, Smith Chart, phase, radiation pattern, and antenna addition, were investigated and found to be positive. Computer simulation technology (CST) software is used to run the simulations.

Keywords: Wi-Fi, dual-band antenna, microstrip monopole antenna

1. INTRODUCTION

In recent years, wireless technology has grown in popularity and has become a need in communication systems [1]. This form of wireless system is less complicated than cable systems, giving it an immediate advantage [2]. Antenna design is rapidly being researched in business and commerce due of the necessity for any small design antenna with high data rate capability. A print technique is utilised in antenna design because of the simplicity of materials, such as light weight, small size, ease of manufacture, and low-scale antennas that do not sacrifice antenna performance. Antennas are simple to incorporate into today's communication systems [3]. This is due to many applications operating on multiple frequency bands.

Wireless Local Area Network (WLAN) technology uses 2400 MHz to 2500 MHz, 5150 MHz to 5350 MHz, Frequency 5470 MHz to 5650 MHz, and 5725 MHz to 5875 MHz [4], and is specified in IEEE 802.11 WLAN to operate in two separate frequencies. Dual-band monopole antennas will be designed on the basis of existing specifications. The antenna must be able to function as a transmitter, transmitter or receiver of signals. There are journals that discuss inverted F band design [4] and straight band design based on studies and studies. Printed monopole antennas are used in two ways for WLAN applications.

In this study, we present a monopole antenna design for Wireless Fidelity (Wi-Fi) that has dual band capability. The two rectangular elements are connected by a monopole strip and arranged together at the top of the antenna, with a truncated ground field at the back of the substrate. The two rectangular pieces vary in size when making double bands at 2 GHz–2.45 GHz and 5 GHz–5.8 GHz, covering 2.45 GHz and 5.8 GHz Wi-Fi operation bands. The main radiation field of the antenna is functional. A gap is also added to the bottom right corner of the secondary rectangular element to reduce return loss and expand the bandwidth for both frequencies. A standard 50 Ohm microstrip line can be used to feed this antenna.

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2. ANTENNA DESIGN

2.1 Design

Figure 1 depicts a copper-based monopole antenna structure, whereas Figure 2 depicts an aluminum-based monopole antenna construction with band capabilities for Wi-Fi applications [5]. The front and back perspectives are divided into two categories. The front view is made up of a variety of shapes that come together to form a rectangular monopole antenna. Three rectangular monopole antennas are put together, with the upper operating mode controlled by a bigger rectangle and the lower operating mode controlled by a middle rectangle. The land plane's structure can be seen from the back. The thickness structure of the substrate and soil surface may be viewed from the front view.

Return loss responsiveness and impedance bandwidth are also improved with slots [6]. Slit is used to adjust the operational frequency in Wi-Fi applications. Structural monopole antennas are constructed using FR-4 boards. This monopole antenna's substrate and patch are comprised of two distinct materials [7]. FR-4 is extensively used because of its low cost. The dielectric constant of FR-4 is 4.4 and it has a thickness of 1.6 mm. The ground plane is printed on the reverse side. This antenna is also built of copper with a 0.035 mm substrate.

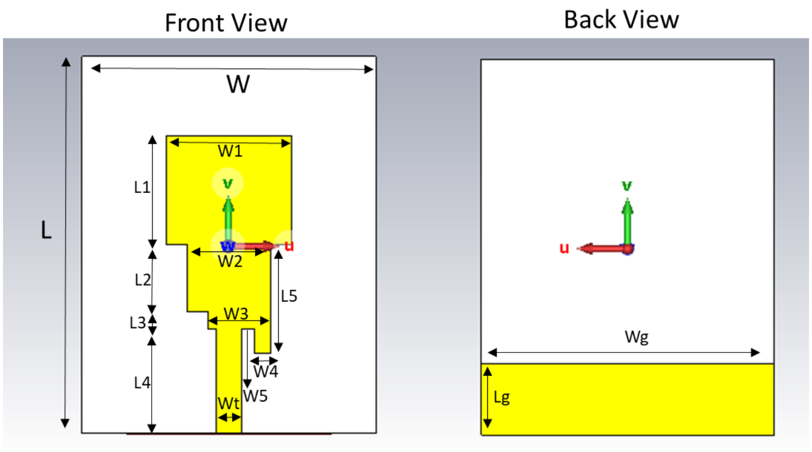


Figure 1. Copper Material Monopole Patch Antenna (Front and Back View).

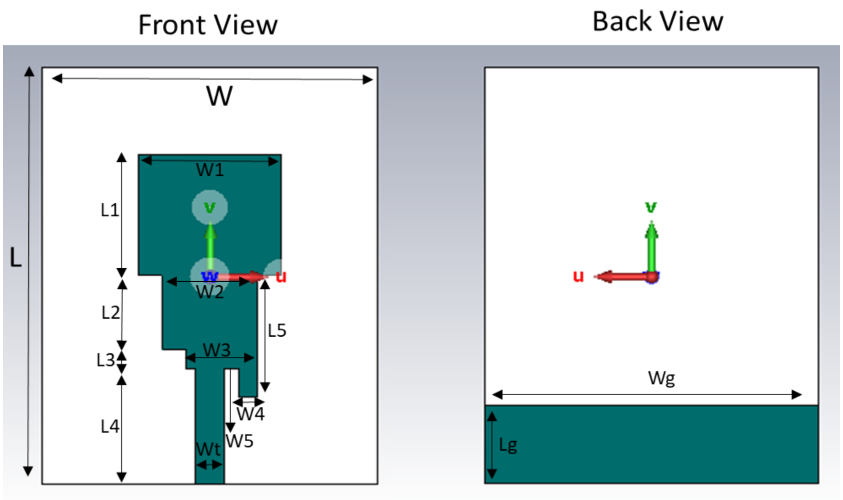


Figure 2. Aluminum Material Monopole Patch Antenna (Front and Back View).

2.2 Dimension table

The values of the antenna parameters after optimization are shown in Table 1. Some of them do not alter, while others do. Some parameter values are calculated using equations, :

The width of the patch is calculated using the following equation [5][3][6]

$$W = \frac{C_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (1)$$

Where,
W = Width of the patch
C_0= Speed of light
ε_r= value of the dielectric substrate

The value of the effective dielectric constant (ε_{reff}) is calculated using the following equation [5][3][6]:

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}[1 + 12\frac{h}{W}]^{-\frac{1}{2}}, \frac{W}{h} > 1 \quad (2)$$

Therefore, the actual increase in length (ΔL) of the patch is to be calculated using the following equation [5][3][6]:

$$\frac{\Delta L}{h} = 0.412\,\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}+0.258)(\frac{W}{h}+0.8)} \quad (3)$$

Where 'h'= height of the substrate

The length (L) of the patch is now to be calculated using the below mentioned equation [5][3][6]:

$$L = \frac{C_0}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L \quad (4)$$

Length (Lg) and width (Wg) of ground plane:
Now the dimensions of a patch are known. The length and width of a substrate is equal to that of the ground plane. The length of a ground plane (Lg) and the width of a ground plane (Wg) are calculated using the following equations [7]:

$$L_g = 6h + L$$
$$W_g = 6h + W$$

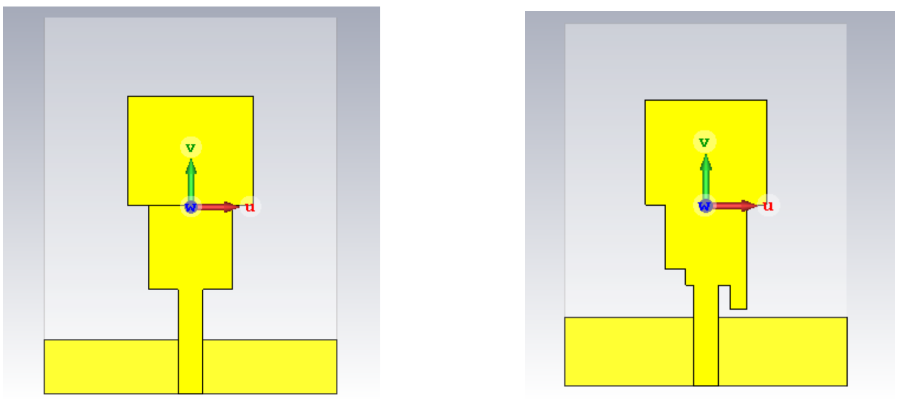
while others are calculated using trial and error approaches or so-called parametric studies. The goal of this parametric analysis was to find the best values and match the design requirements for bandwidth and return loss [8].

Table1. Parameter of Monopole Antenna Design (Copper and Aluminum).

Parameter	Value (mm)	Placement of structure.
W	35	Width of Substrate
L	45	Length of Substrate
Wt	3	Microstrip line Width
W1	15	Width of Upper rectangular
W2	10	Width of Middle rectangular
W3	7.5	Lower rectangular width
W4	2.00	Slot width
W5	1.5	Slot gap
L1	13	Length of upper rectangular
L2	8	Length of middle rectangular (left)
L3	2	Slit length
L4	12.5	Microstrip line length
L5	13.00	Middle rectangular length (right)
Lg	8.5	Ground plane length

3. RESULTS AND DISCUSSION

The goal of the proposed design is to create a dual-band capability for Wi-Fi applications [9]. This was accomplished through the use of an antenna design with a modified radiation slot. As comparison, the return loss characteristics of a rectangular monopole antenna (Figure. 3a) and an antenna with an adjustment slot for obtaining the desired Wi-Fi frequency range (Figure. 3b) are shown.



(a) (b)

Figure 3. (a) Rectangular monopole antenna and (b) adjusted structure with slots.

The CST software was used to simulate and construct a rectangular patch antenna with notches and slots in the ground surface [10]. The primary purpose of this antenna is to enhance bandwidth while reducing antenna loss. Other antenna factors including as gain, directivity, and antenna radiation pattern were also taken into account throughout the antenna design process. The results were documented in order to compare and analyse them.

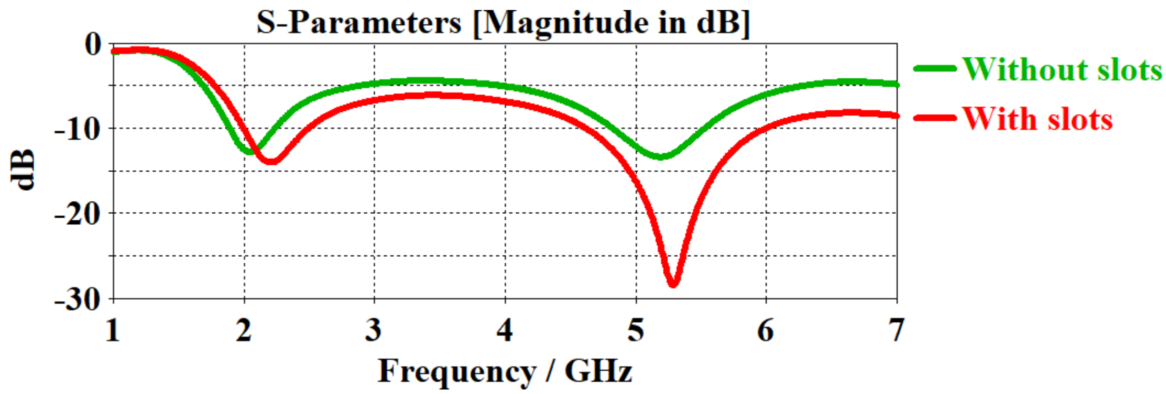


Figure 4. Return loss of the simulation result for rectangular monopole antenna and adjusted structure with slots.

Figure 4 Return loss of simulation results for rectangular monopole antenna and adjusted structure with slots show that the adjusted structed antenna is better in return loss. From the simulation, the rectangular monopole antenna of copper and aluminum material antenna has 2 GHz frequency is obtained with antenna return loss is -12dB with planned antenna bandwidth achieved at 341MHz and for rectangular monopole antenna of copper and aluminum material design obtained 5 GHz, with antenna return loss is -13dB with the planned antenna bandwidth is achieved at 666MHz.

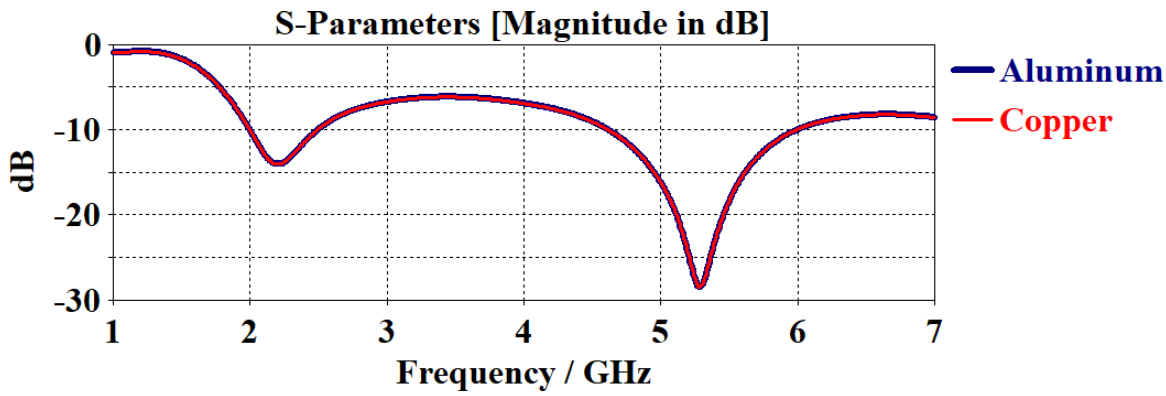


Figure 5. Return loss of the simulation result for copper and aluminum material.

Figure 5 S -Return loss of simulation results for copper and aluminum show that the simulations are optimized antenna simulation results planned in CST software. From the simulation, the monopole antenna of copper material antenna design resonance frequency is obtained at 2–2.45 GHz, covering 2.4 GHz with antenna return loss is -14.06dB with planned antenna bandwidth achieved at 493.33MHz and for monopole antenna of aluminum material design obtained 2 GHz–2.45 GHz, covering 2.4 GHz with antenna return loss is -14.04dB with the planned antenna bandwidth is achieved at 491.14MHz then, at 5 GHz–5.8 GHz, covering 5 GHz copper material monopole antenna, the simulated return loss is obtained approximately -28.47dB with 1359.97MHz bandwidth and for 5 GHz–5.8 GHz, covering 5GHz aluminum material monopole antenna, the loss of the simulated return is obtained to be approximately -28.48 with a bandwidth of 13.26.86MHz. It's concluded that both copper and aluminum material antenna give roughly same return loss.

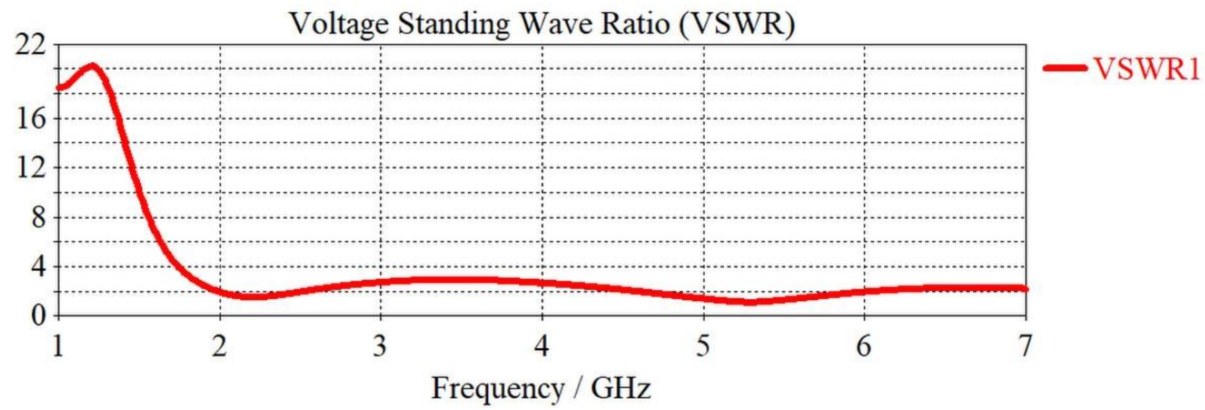


Figure 6. Voltage Standing Wave Ratio Vs Frequency.

The Voltage Standing Wave Ratio, or VSWR, is a quantity that indicates how well the antenna impedance has been matched, and it describes the force reflected from the antenna. As shown in Figure 6, the VSWR for the two operating frequencies is less than VSWR = 2, indicating a corresponding load of 1.84 at 2.45 GHz and 1.68 at 5.8 GHz.

Table 2. Gain and Directivity (copper and aluminum).

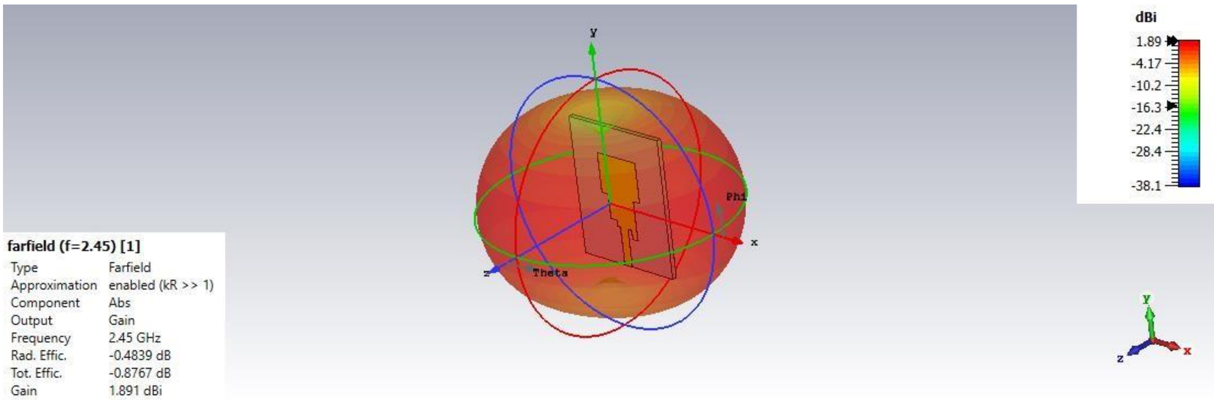
Parameter/Frequency	2.45 GHz	5.8 GHz
Directivity	2.375 dBi	4.355 dBi
Gain	1.891 dBi	3.459 dBi

At 2 GHz-2.45 GHz and 5 GHz-5.8 GHz, Table 2 displays the gain and direction of the suggested antenna simulations. As the target frequency rises, the proposed antenna's gain and orientation increase. At the 5.8 GHz frequency, the maximum gain and direction are 3.459 dBi and 4.355 dBi, respectively.

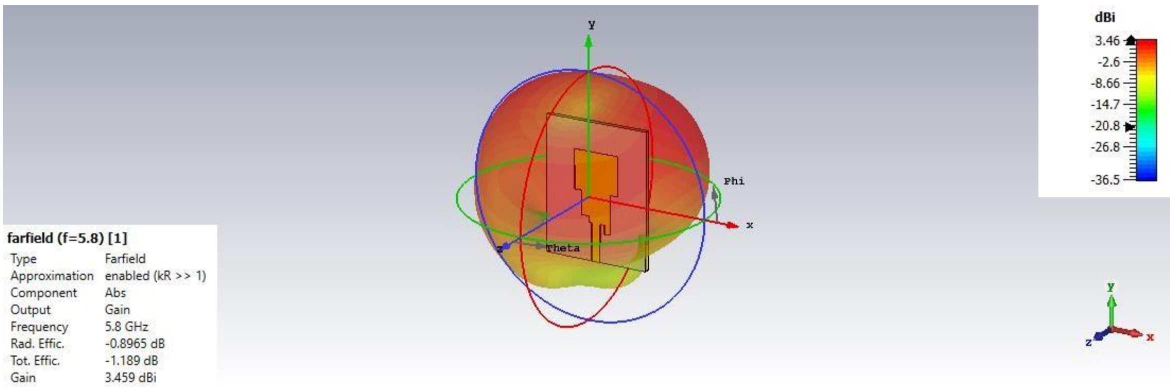
Table 3. Radiation Efficiency and Total Efficiency (copper and aluminum).

Parameter/Frequency	2.45 GHz	5.8 GHz
Radiation Efficiency	0.8946	0.8135
Total Efficiency	0.8172	0.7605

Table 3 illustrates the proposed antenna's simulated radiation efficiency and total efficiency at 2.45 GHz and 5.8 GHz. The suggested antenna's radiation efficiency and total efficiency are both high, with a reasonable proportion of efficiency at the target frequency. The 2.45 GHz frequency's maximum radiation efficiency and total efficiency were 0.8946 (0.8946x100% = 89.46%) and 0.8172 (0.8172x100% = 81.72%), respectively. The radiation efficiency and overall efficiency for the 5.8 GHz frequency were 0.8135 (0.8135x100% = 81.35%) and 0.7605 (0.7605x100% = 76.05%), respectively.

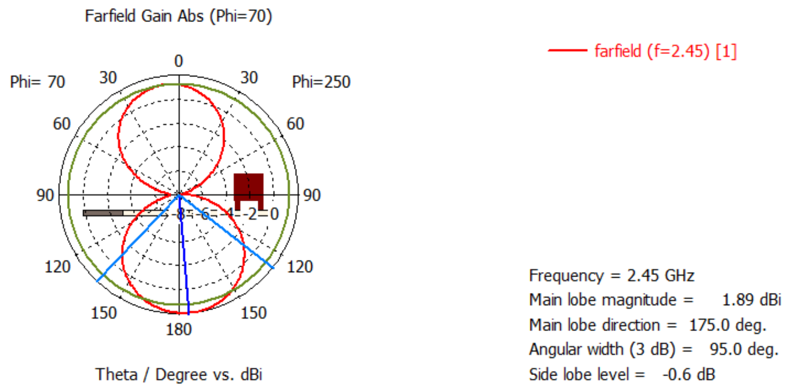


(a)

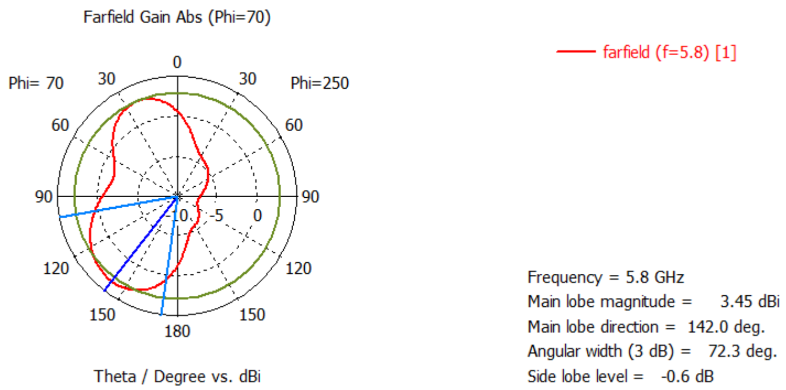


(b)

Figure 7. Simulated view of 3D radiation pattern for (a) 2.45 GHz and (b) 5.8 GHz.



(a)



(b)

Figure 8. Simulated view of 2D radiation pattern for (a) 2.45 GHz and (b) 5.8 GHz.

Figure 7 dual band Monopole antenna radiation patterns in planes are observed. The radiation patterns in planes are approximately omnidirectional antenna, especially for the upper operating frequencies. Figure 8 shows simulated antenna gain for 2.45 GHz and 5.8 GHz of the proposed dual band Wi-Fi antenna. The maximum gain of 2.45 GHz is 1.891dBi and 5.8 GHz is 3.459 dBi. The gain proved that the antenna is having good efficiency omnidirectional [11].

4. CONCLUSION

In this paper, we have featured a dual-band monopole antenna design covering 2 GHz-2.45 GHz and 5 GHz-5.8 GHz for Wi-Fi applications. At CST Studio, the antenna was successfully designed. The antenna was measured, and the results showed that the return loss and bandwidth increase were successful. Although the results differ from the simulations, the results are still limited by the minimum requirements for antenna operation. We also have compared the result of return loss by replacing the copper material with aluminum for the dual-band monopole antenna. Finally, it can be concluded that the monopole antenna with copper and aluminum material are almost the same results as been discussed in this project. Moreover, we also can be enhanced by adding slits and a shortened ground plane to do tunning for the dual-band monopole antenna. The design can be improved even more by identifying additional approaches that can considerably boost performance. Both material antenna have same return loss and same efficiency. So, I choose copper material antenna because the copper material antenna is easy to fabricate.

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