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Wi-Fi 2.4 GHz and 5 GHz Dual Band Antenna Design for IoT Based Smart Media Application

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Abstract – Internet of Things (IoT) based application requires integration with the wireless communication technology to make the application data readily available. In this article, a dual band microstrip patch antenna operating at 2.4 GHz and 5 GHz frequencies is designed for use in Wi-Fi applications. The main purpose is to design a compact, easy to manufacture, cheap and high-performance microstrip patch antenna. The antenna is printed on the substrate of FR4 with two C-shaped strips and a microstrip feed line on the front side. There is L-shaped slot in the ground plane on the bottom side. The overall geometric size of the antenna is 29x26x1.6mm^3. The antenna bandwidth is 140MHz and 552MHz at 2.45GHz and 5GHz respectively.

Keywords – Wi-Fi , WLAN ,Dual-Band , Patch Antenna , Microstrip

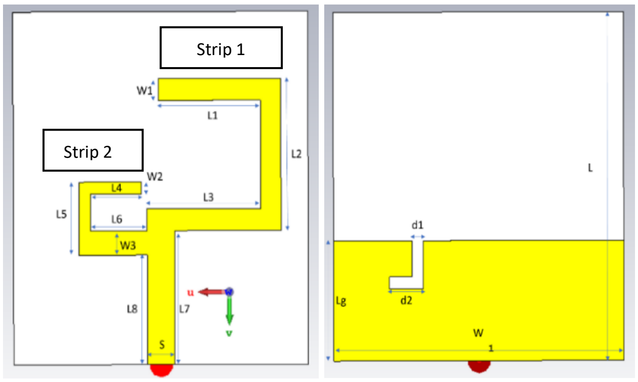
I. Introduction

With the developing technology in microwave and millimeter wave components design necessitates the replacement of conventional wireless components to be replaced with more minimal technological devices [1]-[5]. Microstrip antennas are therefore becoming increasingly useful because they can be printed directly onto a circuit board. Patch antennas are low cost, have a low profile and are easily fabricated and small in size, light in weight, easy to integrate, and inexpensive, making them an ideal choice for dual-band antenna design applications [6]. Modern wireless communications require antennas that can operate in multiple frequency bands for instance 1575.42/1227.60/1176.45 MHz for Global Positioning System (GPS), 900/1800 MHz in Global System for Mobile Communication (GSM), 2.4/5.2/5.8 GHz for Wireless Local Area Networks (WLANs), 2.5/3.5/5.5 GHz for Interoperability for Microwave Access (WiMAX), 700/2300/2600 MHz for Long Term Evolution (LTE)[7]. While using multiple antennas can achieve multiband operation, this methodology increases the cost and complexity of the system. In addition, using multiple antennas creates the coupling problem which in turn degrades the performance of the antennas. An alternative solution is to modify the antenna such that it can be used for multiband wireless communications.[8] Modern systems require multifunctional and smart antennas that are more efficient and compact. As technology evolves rapidly, modern wireless systems (IoT devices) perform a variety of functions and require operation at multiple frequencies without increasing antenna size. 5 GHz band is new where fewer wireless devices use it. A less cluttered frequency provides a faster and more stable wireless connection[9]. The antenna designed in [10] is 75 x 75mm in size and FR-4 material is used as the substrate. There are 4 triangle slot on the antenna. The antenna resonates at 2.4 GHz and 5.4 GHz. The antenna designed in [11] is 50x40mm in size and FR-4 material is used as the substrate. There is a slot loop cut on the ground plane underneath the patch. The top patch acts as a wideband radiating element at the upper operating band. The antenna resonates 2.5GHz and 5.5 GHz . Bandwidth and gain values obtained are low compared to their size. The antenna designed in[12] is 17x18mm in size on FR-4 substrate material with geometric structural form of double-psi-shape. The antenna resonates at 2.2 GHz only. The antenna designed in [13] is 60x70mm in size on FR-4 substrate material. There are five slits on the antenna and one rectangular slot on the ground. The antenna resonates 2.5GHz and 5.8 GHz. The antenna designed in [14] is 40x40mm with the FR-4 material as the substrate. There are five rectangular slots on the antenna. The antenna resonates at 2.4 GHz and 5.8 GHz.

In this article a dual-band microstrip antenna resonating at 2.4 GHz and 5 GHz frequencies is designed for use in Wi-Fi applications. The overall dimensions of the antenna are 29 x 26 x 1.6 mm^3 . For the antenna to operate at two different frequencies, the antenna is printed on the substrate of FR4 with two C-shaped strips and a microstrip feed line on the front side. L-shaped slot in ground plane.

II. Materials and Method

In this section, the antenna design is explained. The specified geometric parameters are determined through the numerical computation tools. In order to improve the antenna, the geometric parameters are studied and the most efficient antenna is aimed to be designed. Also, detailed information about the antenna is presented in this section. The geometric shape of the designed antenna is shown in the Fig.1 . There are two C-shaped slots on the antenna and one L-shaped slot on the ground. The dimensions of the designed antenna are 29x26x1.6mm^3. FR-4 material is used as substrate material with the thickness of 1.6 mm and dielectric constant of $\mathcal{E}$r=4.3. The designed antenna operates at 2.4GHz and -5GHz frequencies.



(a) (b)

Fig. 1 Geometry of the proposed antenna. (a) Top view; (b) Bottom view

The design parameters of the antenna are listed in Table 1.

Parameter	W	L	L1	L2	L3	L4	L5	L6	L7
Value(mm)	26	29	9	12.5	10	4.5	6	5	11
Parameter	**L8**	**Lg**	**S**	**W**	**W1**	**W2**	**W3**	**D1**	**D2**
Value(mm)	9	10	2.4	26	1.8	1	2	1	3

Table 1. Design parameters of the proposed antenna

III. Results

The graph of the antenna S11 is shown in Fig. 2. While the bandwidth of the antenna at 2.45 GHz resonance frequency is 140 MHz (2.38-2.52 GHz), the bandwidth obtained at 5 GHz resonance frequency is 552 MHz (4.78-5.34 GHz). These obtained bandwidths and frequency ranges show that the antenna complies with IEEE 802.11 a/b/g standards.

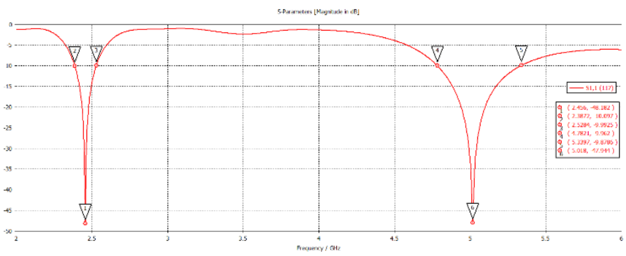


Fig. 1 S11 parameter of the propesed antenna

The gain and directivity values of the antenna are given in Fig. 3. The radiation pattern shows the variation of radiation intensity over large distances in different directions of space and which direction radiates better [15]. Fig. 3 is the simulated gain response of the proposed antenna. The gain of the lower band is in the range of 1dBi while the gain of the upper band is in the range of 3.7dBi.The gain of the proposed antenna is acceptable for the requirement in WLAN applications.

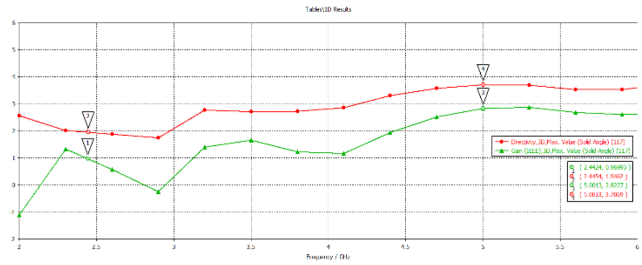
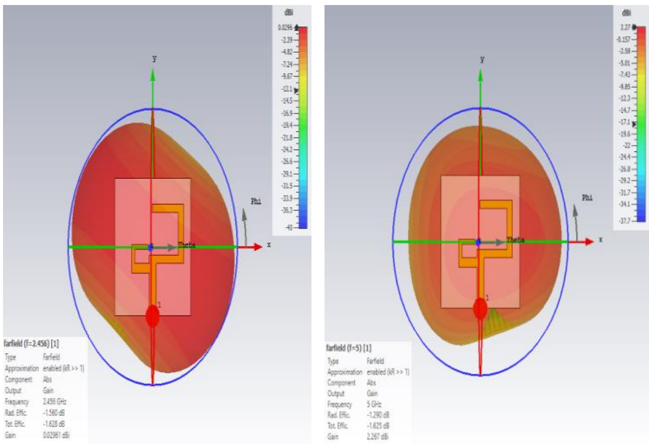


Fig. 3 Gain (IEEE) and Directivity of the proposed antenna

The numerically computed radiation patterns on E and H planes at 2.45GHz and 5GHz is shown in Fig. 4. The radiation patterns have the characteristic of bidirectional. Besides, the 3D radiation graph indicates that the radiation orientation changes as the frequency shifts. The radiation intensity is higher along with X-axis and Y-axis at 2.45GHz, while it is highly directed along with X axis and Z axis at 5 GHz. The radiation pattern shows the variation of radiation intensity over large distances in different directions of space and into which direction the radiation is better.



(a) (b)

Fig.4 3D Radiation pattern of the proposed antenna at (a)2.45GHz (b)5 GHz

IV. Parametric Sweep

A parametric study is done to obtain the best parameters for the final antenna design. The effects of changing the width, length of patch and width of transmission feed on the return loss are studied as shown in Fig. 5, Fig. 6 and Fig. 7.

During the design of the antenna, some selected geometric parameters have important effect on the antenna's RF performance. To get further analysis of the dual-band design, L2 within the strip1, L6 within the strip2 and the ground length Lg are studied. The results of the effect of these parameters are shown in Fig. 5, Fig. 6 and Fig. 7, respectively. L2 and L6 are parts of strip1 and strip2 that used to achieve resonant frequency and improve impedance match at 2.4GHz and 5GHz band. From Fig. 5, it can be seen when L2 increases from 12mm to 13.5mm, the center frequency of the lower band decreases from 2.5 to 2.4GHz. In Fig. 6 it can be obviously observed that as the value of L6 increases from 4.5mm to 6mm, the center frequency of the upper band decreases from 5.1 to 4.9GHz. Though the situation of impedance match also changes as the varying of L2 and L6, the center frequency of the upper band and the center frequency of the lower band are not effected. That is to say, the resonant bands for both bands can be independently optimized by choosing proper parameters of L2 and L6. Besides, the length of the ground plane also effects the characteristics of the antenna. From Fig. 7, it is clear that there is a severe effect on the performance of this antenna by Lg. Not only the upper resonant band is shifted as it changes, but the value of S11 is affected within the both resonant bands. The resonant band is changed when Lg gets smaller or bigger.

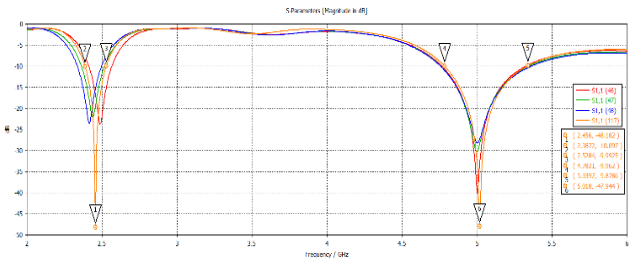


Fig. 5 Parametric Sweep L2

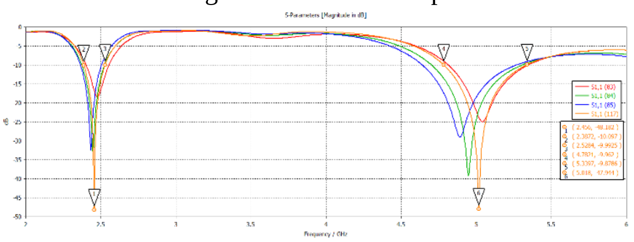


Fig. 6 Parametric Sweep L6

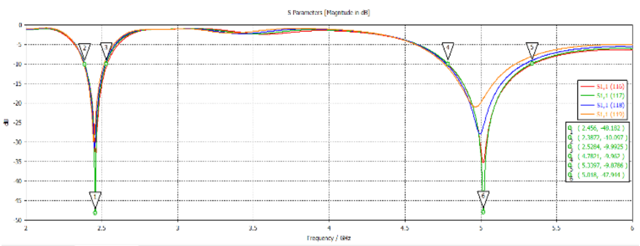


Fig. 7 Parametric Sweep Lg

V. DISCUSSION

Considering the dimensions of the proposed antenna, it has the performance to meet the demand. These features make the antenna preferable in Wi-Fi applications. In addition, due to the simplicity of the design, it can be developed and is easy to manufacture.

Frequencies (GHz)	2.45	5
S11(dB)	-48	-48
Bandwidth (MHz)	140	552

Table 2. Performance parameters of the proposed antenna

VI. CONCLUSION

This article proposes a novel dual-band patch antenna for satisfying the Wi-Fi operation requirements in 2.4 GHz and 5 GHz bands. The numerically computed S11 results show that the antenna meets the IEEE 802.11 standards. The compact size of the designed antenna ensure that it is easy to fabricate and can be easily integrated into dedicated wireless communication systems.

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