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Research Article

A Dual-Band Antenna Design for 2.4 and 5 GHz Wi-Fi Applications

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Abstract

In these days, with the improvement of wireless and mobile communication, Wi-Fi technology is everywhere in life. When wireless communication standards are examined, it is observed that 2.4 GHz (2.4-2.4835 GHz) and 5 GHz (5.15-5.825 GHz) frequency bands are used as the Wi-Fi frequency band. Therefore, in this paper, a microstrip Wi-Fi antenna design with dual band performance at 2.4 GHz and 5 GHz frequencies has been achieved. Thanks to the choice of microstrip antenna. It will be ensured that the proposed antenna has the advantageous features of microstrip antennas compared to other antennas. The feed of the antenna will realize with a microstrip line. FR-4 substrate is used as dielectric material with a thickness of 0.8 mm. Thanks to the preferred materials and cheap production cost, fabrication of the antenna is considered. The CST Studio Suite is preferred by the world's largest technology and engineering companies, as it provides a market advantage over the products by providing a shorter development period and lower cost. The design stages of the antenna have been carried out using CST Studio Suite. Also, important parameters of the antenna have been examined and optimized bandwidth, input impedance, resonance frequency, reflection coefficient, return loss, etc. As a result, dual-band Wi-Fi antenna design has been determined with wide bandwidth and high gain.

Keywords: Microstrip Antennas, Wi-Fi Technology, Dual-Band, 2.4/5 GHz Antenna, High Gain

2.4 GHz ve 5 GHz Wi-Fi Uygulamaları için Çift Band Anten Tasarımı

Öz

Günümüzde kablosuz ve mobil iletişimin gelişmesiyle birlikte Wi-Fi teknolojisi hayatın her yerinde bulunmaktadır. Kablosuz iletişim standartları incelendiğinde Wi-Fi frekans bandı olarak 2.4 GHz (2.4-2.4835 GHz) ve 5 GHz (5.15-5.825 GHz) frekans bantlarının kullanıldığı görülmektedir. Bu nedenle, bu bildiride, 2.4 GHz ve 5 GHz frekanslarında, çift bant performansa sahip bir mikroşerit Wi-Fi anten tasarımı elde edilmiştir. Mikroşerit anten seçilmesi sayesinde, mikroşerit antenlerin diğer antenlere göre avantajlı özelliklerinden faydalanarak önerilen antenin avantaj elde etmesi sağlanmıştır. Antenin beslemesi mikroşerit hat ile gerçekleştirilecektir. Dielektrik malzeme olarak 0.8 mm kalınlığında FR-4 malzemesi kullanılmaktadır. Antenin fabrikasyonu göz önünde bulundurularak tercih edilen malzemeler ona göre seçilmiş ve ucuz üretim maliyeti amaçlanmıştır. CST Studio Suite, CST ortamında geliştirilen ürünlere daha kısa geliştirme süresi ve daha düşük maliyet sağlayak diğer ürünlere göre pazar avantajı sağladığından dolayı dünyanın en büyük teknoloji ve mühendislik şirketleri tarafından tercih edilmektedir. Bu yüzden, antenin tasarım aşamaları CST Studio Suite kullanılarak gerçekleştirilmiştir. Ayrıca antenin önemli olan bazı parametreleri incelenmiş ve bant genişliği, giriş empedansı, rezonans frekansı, yansıma katsayısı, geri dönüş kaybı vb. parameteler optimize edilmiştir. Sonuç olarak, geniş bant genişliğine sahip ve yüksek kazançlı çift bantlı Wi-Fi anten tasarımı belirlenmiştir.

Anahtar Kelimeler: Mikroşerit Antenler, Wi-Fi Teknolojisi, Çift-Bant, 2.4/5 GHz Anten, Yüksek Kazanç

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1. Introduction

In latest years, the progress of wireless and mobile communication necessitates the development of the design of suitable antennas with low return loss, high bandwidth, and miniature size to enlarge the data volume to be transferred in wireless network communication, to increase the data traffic, to be uninterrupted and fast [1]. IEEE standards should be examined while determining the operating frequency of the proposed antenna. Wireless communication applications realized in various frequency bands according to IEEE standards can only be provided with a single antenna element, but with the multi-band performance of the relevant antenna. According to IEEE standards, the IEEE 802.11n model is used as Wi-Fi frequency at 2.4 GHz and 5 GHz all over the world. Therefore, the IEEE 802.11n model was chosen for the proposed antenna [2].

The 2.4 GHz band is generally used in single-band Wi-Fi antennas. However, there are devices other than Wi-Fi devices in this band. Therefore, the band became crowded and could not respond to requests [3]. In line with this problem, the 5 GHz band has also been used in Wi-Fi devices. This band is an emptier band than the 2.4 GHz band, and higher speeds have been achieved in this band [2]. Microstrip antennas are frequently preferred in wireless communication applications due to their light weight, cheap, small volume, easy adaptation to circuits and non-directional radiation performance [4]. Also, it is used in a wide frequency range from approximately 100 MHz to 50 GHz [5]. So, in this paper, a microstrip antenna was preferred for a Wi-Fi antenna. Microstrip antennas consist of a very thin metallic strip placed usually above a ground plane [6].

With the fast progress of innovative wireless communication systems, the technological need for mobile devices is growing by the day. Compact size, lightweight, low profile, and low cost are currently critical issues for RF/microwave designers to overcome for every wireless mobile component. One of the most essential aspects of any wireless system is the antenna. In addition to physical requirements, good directivity, high gain, and efficient and broadband antenna operability are becoming increasingly important in wireless systems. Many approaches have been studied to fulfill specific needs, including from the means of different shaped slots, or radiating patches [7],[8],[9] with the use of artificial metamaterials [10],[11] and the engineering of the ground plane in the case of EBG structures.

This paper presents a dual band microstrip Wi-Fi antenna. The antenna can perform in the 2.4 GHz and 5 GHz frequency bands. 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 4.3 and loss tangent of 0.02 has been chosen. The antenna has compact structure with a total size of 10 mm x 50 mm.

2. Material and Method

2.1. Antenna Configuration and Design

Geometrical configuration of the proposed antenna shown in the figure 1. It uses FR-4 substrate with a thickness of 0.8mm and a relative permittivity of 4.3. Copper was used as the conductive material with thickness of 0.035mm. The antenna is fed by a microstrip line. The proposed antenna is designed to realize in 2.4 GHz and 5 GHz Wi-Fi applications.

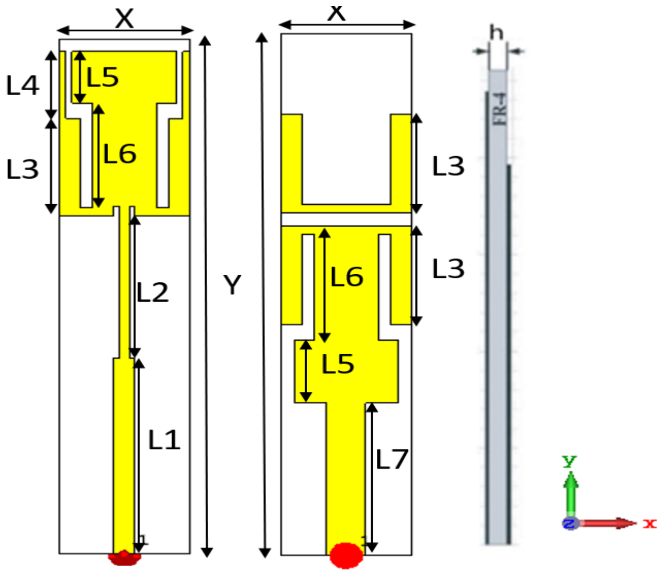


Figure 1. Design of Proposed Antenna

All dimensions of the proposed antenna are given in the table 1. Simulations of the designed antenna were achieved by using CST Microwave Studio.

Table 1. Dimensions of Proposed Antenna (in mm)

L1	**L2**	**L3**	**L4**	**L5 – W6**
19	13.8	9.5	6.5	5
W1	**W2 - H**	**W3**	**W4**	**W5**
1.65	0.8	1.6	0.5	8
L6	**L7**	**X**	**Y**	**W7**
11	14.6	10	50	3

Microstrip antennas can be fed through contact and non-contact feeding types. The most prominent of these feeding types are microstrip feeding, coaxial feeding, aperture feeding, and proximity feeding methods [12]. The microstrip feeding method was used in the antenna design designed in this paper.

It is available in the literature that one of the important techniques affecting antenna performance is to open slots at the feeding point [12]. So, 0.4 x 1 mm slots opened in the feeding point. To provide more information about the proposed antenna optimization and design, parametric studies had been carried out through CST Microwave Studio to analyze the results of the key geometrical sizes proposed antenna. Some of them, changing the length of the transmission lines on both sides by same length as seen in the figure 2. As seen in the figure 2, the length of the transmission lines is a variable that affects the resonant frequency in 2.4 GHz and return loss parameter. Changing the length of L3 patch on both sides by the same length as seen in the figure 3. As seen in the figure 3, the length of the L3 patch is a variable that affects the resonant frequency in 5 GHz.

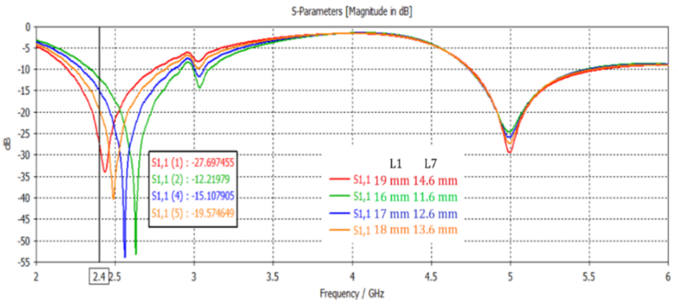


Figure 2. The Return Loss Parameter According to different L1 and L7 Lengths.

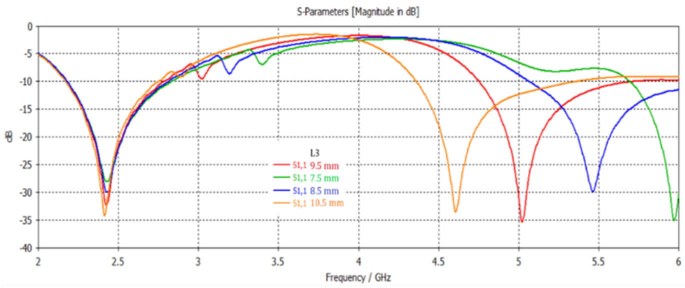


Figure 3. The Return Loss Parameter According to different L3 Lengths.

After calculating all the parameters that may affect the performance of the antenna, the optimum parameters were determined as seen in the table 1 and the design process has been completed.

3. Results and Discussion

The proposed antenna in figure 1 have been designed with CST Microwave Studio and simulation results were investigated as seen follows. The simulated return loss parameter of the proposed antenna shows in the figure 4. The antenna can operate at both bands of 2.4 GHz and 5 GHz. Bandwidth is the performance of the antenna according to its specifications to a specified standard is the appropriate frequency range. In other words, it is used to express the capacity of the communication channel [13]. In wireless communication, bandwidth of antenna is less than -10 dB return loss across the frequency. Frequencies where return loss is -10 dB the difference between gives bandwidth of antenna [14]. Simulated bandwidth is from 2.19 GHz to 2.75 GHz and from 4.74 GHz to 6 GHz as seen figure 4.

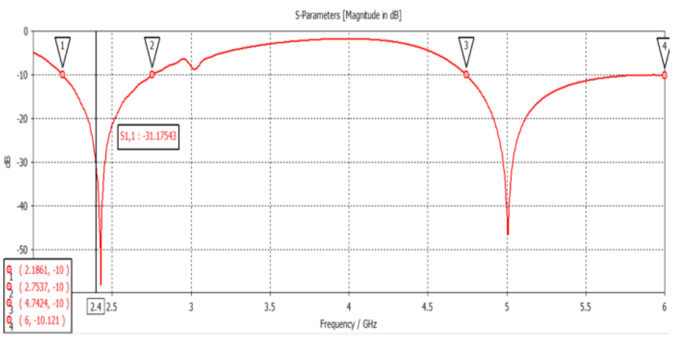
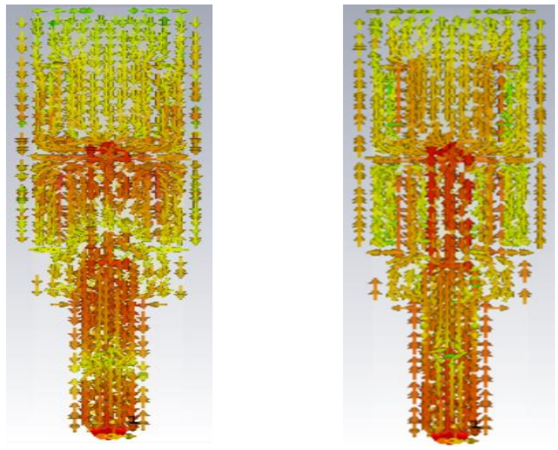


Figure 4. S_{11} Parameter of Proposed Antenna

Figure 5 (a) and (b) shows current distributions of antenna at 2.4 GHz and 5 GHz respectively. By examining these graphs, the regions where the current is concentrated can be determined. By observing the regions where the current is concentrated, information about the radiation characteristics of the antenna can be obtained. Gain is a measure of the antenna's ability to convert the input power received by the antenna into radiation in a certain direction [15]. Therefore, the gain is an important criterion in determining the performance of the antenna. realized gain of the antenna at 2.4 GHz and 5 GHz respectively. It is 1.918 dBi and 2.303 dBi at 2.4 GHz and 5 GHz respectively.



(a) (b)

Figure 5. Proposed Antenna Current Distributions: a) 2.4 GHz, b) 5 GHz.

There are many antenna designs developed for Wi-Fi applications in the literature. The results of some antenna designs with similar center resonance frequencies are shown in Table 2. When considering some parameters of proposed antenna, the dimensions, return loss, bandwidth etc. it has been observed that the proposed antenna has better performance compared to other antennas in the literature. When the data in table 2 is examined, the proposed antenna has the best results at 2.4 GHz and 5 GHz, although it has the smallest dimensions. These results reveal the importance of the proposed antenna.

Table 2. Comparison of the proposed antenna with the antennas in the literature

Ref.	Dimensions (mm)	Operating Frequency (GHz)	S_{11} (min. value in dB)	Bandwidth (MHz)
[16]	24 x 21 x 1.6	2.5	-29.9	100
[12]	18.7 x 17.6 x 1.6	5	-15.7	190
[17]	30 x 40 x 1.5	2.43 5.4	-23 -20	340 1180
[1]	38 x 46.6 x 1.6	2.4	-24	301
[18]	50 x 50 x 1.6	2.4 5.2	-17.6 -12.8	210 1010
Proposed Antenna	10 x 50 x 0.8	2.4 5	-31.17 -42.05	600 1250

4. Conclusions

Microstrip antennas, since it is designed using printed circuit technology, it is easy to manufacture. Also, it is low cost and has small volume antennas. So, it is preferred in Wi-Fi applications. In this paper, a microstrip antenna designed for Wi-Fi applications. The designed antenna can operate both frequency bands in 2.4 GHz and 5 GHz. Thanks to its performance in the 5 GHz frequency band, it provides faster, and uninterrupted data traffic compared to traditional antenna designs. The design stages of the antenna were carried out with CST Microwave Studio. Then, all simulation results obtained were examined and important variables optimized according to simulation results. The geometry and dimensions of final design are given in the figure 1 and table 1. Proposed antenna has resonant frequency in 2.42 GHz and 5 GHz. Proposed antenna has -31.17 dB and -42.05 dB return loss value in 2.4 GHz and 5 GHz respectively. Its bandwidth is 600 MHz and 1250 MHz, from 2.19 GHz to 2.75 GHz and from 4.74 GHz to 6 GHz respectively in 2.4 GHz and 5 GHz. It has 1.918 dBi and 2.303 dBi realized gain.

5. Acknowledge

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