

## Recent Developments in 2.4GHz/5GHz Microstrip Patch Antenna for Using in Wi-Fi Techniques: Systematic Review

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### Abstract

The application of the Internet of Things (IoT) applications to requires integration with the wireless communication technology. What has been developing in our everyday lives is the number of devises was increased that are connected to internet and this is where compact Integrated wireless devices are required in order to accommodate the multi-frequency application in a standard platform. The current wireless and mobile communications have led to the design of appropriate antenna with low bouncing loss, high bandwidth, small size and with high efficiency. This is essential in amplifying the size of data being sent in wireless systems and improving the data transfer rates and continuity and speed of transmission to attain the intended goals of the antennas and provide access to data. In the case of the IEEE standards, the frequency of the Wi-Fi networks at 2.4 /5 GHz over the globe was IEEE 802.11n model. Thus, the antenna was selected to use the model since. The proposed antenna operates on two different frequencies. on the antenna resulting in a dual-band antenna. The preference of the use of microstrip antennas in communications and Wi-Fi applications is owed to the fact that they are small, low-cost, lightweight, and can be easily integrated into electrical circuits. This is a purposeful as well as an intended usage dual microstrip patch antenna that be used in applications of Wi-Fi at 2.4 /5 GHz.

**Keyword:** Dual-Band Antenna, Wireless Communication, Wi-Fi, IoT.

### التطورات الحديثة في هوائيات الرقعة الشريطية الدقيقة بتردد 2.4 جيجاهرتز/5 جيجاهرتز للاستخدام في تقنيات الواي فاي: مراجعة منهجية

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### الخلاصة

يتطلب تطبيق إنترنت الأشياء (IoT) التكامل مع تقنية الاتصالات اللاسلكية. يشهد حياتنا اليومية تزايداً مستمراً في عدد الأجهزة المتصلة بالإنترنت، مما يستدعي الحاجة إلى أجهزة لاسلكية متكاملة صغيرة الحجم لاستيعاب تطبيقات الترددات المتعددة ضمن منصة قياسية. وقد أدت الاتصالات اللاسلكية والمتنقلة الحالية إلى تصميم هوائيات مناسبة تتميز بفقدان ارتداد منخفض، ونطاق ترددي عالٍ، وحجم صغير، وكفاءة عالية. يُعد هذا أمراً بالغ الأهمية لتضخيم حجم البيانات المرسل في الأنظمة اللاسلكية، وتحسين معدلات نقل البيانات واستمراريتها وسرعتها، وذلك لتحقيق الأهداف المرجوة من الهوائيات وتوفير الوصول إلى البيانات. في حالة معايير IEEE ، كان تردد شبكات Wi-Fi في جميع أنحاء العالم 2.4/5 جيجاهرتز هو نموذج IEEE 802.11n لذلك، تم اختيار الهوائي لاستخدام هذا النموذج، حيث يعمل الهوائي في نطاقين تردديين مختلفين، مما ينتج عنه هوائي ثنائي النطاق. يُعزى تفضيل استخدام هوائيات الميكروستريب في تطبيقات الاتصالات والواي فاي إلى صغر حجمها، وانخفاض تكلفتها، وخفة وزنها، وسهولة دمجها في الدوائر الكهربائية. هذا هوائي رقعة ميكروستريب مزدوج مُصمم خصيصاً للاستخدام في تطبيقات الواي فاي بتردد 2.4/5 جيجاهرتز.

الكلمات المفتاحية: هوائي ثنائي النطاق، اتصالات لاسلكية، واي فاي، انترنت الأشياء.

## INTRODUCTION

Lately, growth in technology has been rising very fast. The Internet will influence most things in the world as well as the human life. Thus, the Internet of things internet of things enjoyed wide attention in observing and sensing applications (Wang, *et al.*, 2020) (Kumar, *et al.*, 2020). The internet of things is comprised of both the observation zone where the sensing data is detected, network zone where data are transmitted, and application zone where the objects will be linked with the cloud of network. In internet of things, numeral device, the sensors, equipments, and things interact with others via the cloud network (Goswami, *et al.* 2020). In recent years, many different types of antennas have been developed that are widely used in Internet of Things applications. Some general equipment can use single-band antennas. Nevertheless, new systems require multi-functionally and smart antennas, which are more efficient and small. Due to the high pace of technology advancement, contemporary wireless systems internet of think devices have multiple functions and must work at much than the single frequency without necessarily adding to the size of the proposed antenna. Various forms of single-band and multi-band of monopole antennas have been invented in the literature including the H-shaped, Circular-shaped, U-shaped open stub, M-shaped open stub, L-shape coupled branch strip, L-shaped stub folded into U-shaped, D-shaped, U-shaped with rectangular patch inside (Mao, 2018) (Jha, *et al.*, 2018) (Chen, *et al.*, 2014) (Lee, 2018) (Chung, *et al.*, 2018) (Abdulkawi, 2018). Small size antenna design is one of the most significant of the characteristics that are applicable. Palandoken *et al.* Small antenna design with 2.4, 5.2 and 5.8 GHz WLAN. and 3.5 and 5.5 GHz

(WiMAX) frequency bands compatible with the 802.11.ac/n standards have been realized. The developed metal antenna would consist of a copper plate 0.5 mm thick with a small overall physical size of Antenna 60 mm x 50 mm. It achieves the required characteristics as far as size is concerned (BAYTÖRE, *et al.*, 2019). This technology involves the use of much high-performance antennas (Wang, *et al.*, 2019). It must also be cheap and simple to produce. On the same note Microstrip antenna, the most favorable option that fits the demand, has been addressed in accordance with this definition. Rachmansyah *et al.* developed the lowest profile microstrip patch antenna. This antenna has a gain value of 11 dB, and the narrow frequency of microstrip antennas is the primary issue. To resolve these issues, (Rachmansyah, *et al.* 2020). To address this issue, Haydar Ahmet, Y. Tesneli and N. Berna Tesneli have compared the outcomes of the various of feeding techniques and provided the most suitable feeding that would be applicable in developed model. The optimal feeding technique was the copper planar feeding that had bandwidth of 60 percent (Kütük, *et al.* 2000). However, Afridi *et al.* developed an antenna with 8.27 dB gain value and 21.29 dB return loss value with a very low bandwidth (Afridi, 2015). The other way of resolving this issue is to open slots on the antenna. In the study, Raad. Thaher and Zainab. Jamil conducted parametric research on the antenna and opened slots in some areas. Their antenna is designed to operate at 2.4 and 5 GHz frequency in Wi-Fi/Wi-MAX applications. The return loss is 32.77 dB at 2.4 GHz at 7.4 percent bandwidth and 25.955 dB at 5.8 GHz at 8.17 percent bandwidth (Thaher, *et al.*, 2018). In reference to the Ali Hanafiah Rambe *et al.* study, the gain value of the antenna whose operation occurs in a range of 2,404

GHz- 2,482 GHz is 6 dB and the value of the Return loss was 13.75 dB (Mikrostrip, *et al.*, 2019). All these studies were done considering the IEEE 802.11 standard. The name of general developed wireless networks is IEEE 802.11 standards protocols that are developed above the WLAN in the local network. The out and the best possible dimensions were attempted to be reached in this study through open slots on the chosen surface (Kim, 2000). It is directed to develop the most appropriate microstrip antenna concerning the return loss and the gain of the antenna. The graphs were analyzed and conclusions brought about as a consequence of the simulations (Karmokar, *et al.*, 2010).

Indeed 2.4/5 GHz applications use a rectangular patch antenna of microstrip in this paper. It is a radial patch printed on a 4.3 substrate that has a thickness of 1.6mm and the dielectric constant is FR-4. This substrate FR-4 is used because it has no defects, it is easy to obtain and can be manufactured in large quantities. The antenna was supplied by microstrip feeding line because it has been simple and easy to integrate. The antenna proposed has a modified ground plane and is in the following dimensions 60x50 mm.

#### **METHODOLOGY OF THE SYSTEMATIC REVIEW**

This research was conducted using a systematic methodology. In this research the studies have been collected from IEEE Xplore and Google Scholar databases and the keywords that was used was "Wi-Fi, IoT antennas ,2.4/5 GHz .and this research was included a published from year 2016 to the 2025 and these studies addressed 2.4/5 GHZ microstrip patch antenna for IoT and Wi-Fi and the research that duplicated and irrelevant has been excluded.

#### **LITERATURE SURVEY**

In recent years, there has been considerable interest in microstrip antenna designs due to their widespread use in the Internet of Things systems and the applications. The most important features of these antennas are their low weight, small size, and ease of integration into electrical circuits. These characteristics make them very suitable for modern Internet of Things applications. and modern applications. There are many studies that have addressed the design of microstrip antennas, and these antennas operate at frequencies of 2.4/ 5 GHz for applications, the most important of which is Wi-Fi. In this research, we focus on improving the

main characteristics of the antenna, the most important of which are gain, efficiency, reflection coefficient, and bandwidth by using insulating materials and modifying the main dimensions of patch used in the antenna. In another study, single or dual-band antennas with more than one frequency, for example 2.4/ 5 GHz. The aim of this research is to support wireless applications in a single antenna, and this has been achieved by adding improvements such as changing the shape of the patch used, adding additional antenna slots, or using different feeding methods in the design. There is also research focused on reducing the size of the antenna without affecting on the overall performance of the antenna, because the smaller the antenna, the better. All of these techniques have greatly helped to make antennas more suitable for mobile devices. Many recent studies have also focused on improving the radiation pattern and efficiency, as well as reducing loss and interference. The programs that used like CST are often for analyzing results and the performance of antenna, and a review of the literature shows that microstrip antennas are still a broad field for research and development.

The table 1 below shows the number of studies conducted by researchers at Magan Microstrip Patch Antenna also used in the Internet of Things. These studies, included in this paper, began in 2016 and will continue until 2025. The table below shows the all dimensions of the proposed antenna, the frequencies used, and the bandwidth value, covering Wi-Fi frequencies from 2.4 to 5 kHz.

**Tabel 1. Microstrip Patch Antenna Performance Comparison**

<b>References</b>	<b>Year</b>	<b>Size of Antenna in (mm)</b>	<b>BW (%)</b>	<b>The Operating Frequency (GHz)</b>
[19]	2016	50×50	12.4-13.2	2.4-5.8
[20]	2017	46×50	0.5-0.56	2.4-5.2
[21]	2017	50×110	0.88-1.69	2.4-7.7
[22]	2018	32×36	2.35-12.9	2.4-12
[23]	2018	48.8×34.3	0.59-3.22	2.4-6.9
[24]	2019	1.29×0.36	0.3-1.22	2.4-5.2
[25]	2019	20×30	0.59-1.08	2.4-5.2
[26]	2020	56×56	1.3-40	2.4-5.5
[27]	2020	24×21	0.01-2.2	2.5-5.8
[28]	2021	53×33	0.7-2.2	2.4-5.5
[29]	2021	40×30	2.04-3.44	2.45-5.8
[30]	2022	50×50	0.53 -2.2	2.41 - 5.8
[31]	2022	29×26	1.4-0.52	2.4 - 5
[32]	2023	35×35	0.3-3.06	2-5.8
[33]	2023	30×24.8	0.05-0.20	2.4 - 5.8
[34]	2024	48×38	0.27-0.21	2.4-5
[35]	2024	60×50	6.02-5.67	2.4-5
[36]	2025	26.9×20.7	0.76-1.6	2.45 - 5.8
[37]	2025	39.6×39.6	1.7-8.16	2.4-5
<b>Suggested Antenna</b>	2026	60×50	0.23-0.34	2.4-5

## ANTENNA PARAMETERS

Various parameter like VSWR, Return Loss, Gain, Directivity, Efficiency and Bandwidth are evaluated (Oahidul, *et al.*, 2010).

### (a) Gain

Gain of antenna is the ratio of intensity at a certain direction, to the isotropic intensity of radiations that would have been produced had the power the antenna receives been isotropic ally radiated. Gain formula,  $G = 4\pi U(\theta, F) / P_{in}$ , in which,  $U(\theta, F)$  is the intensity in a given direction,  $P_{in}$  is input power.

### (b) Radiation Pattern

The radiation pattern refers to a mathematical expression or a graphical expression of radiation characteristics of the antenna with respect to space coordinates.

### (c) Antenna Efficiency

It is the ratio of an overall power emitted by an antenna to input power of an antenna.

(d) VSWR the ratio of Voltage standing wave to minimum is  $VSWR = V_{max} / V_{min}$ . It should lie between 1 and 2.

### (e) Return loss

The reflection of a signal power as a result of inserting a device into a transmission line is known as return loss. Therefore, the RL is a parameter that is the same as the VSWR to show the extent to which matching between the transmitter and the antenna has occurred. The RL is expressed as by as:  $RL = -20 \log_{10}(G)$  dB as the perfect of matching between transmitter and antenna,  $G = 0$ , and  $RL = [?]$  which means that no power would be reflected back, whereas  $G = 1$ , has the  $RL = 0$  dB which means that is all incident power is reflected.

## ANALYSIS AND DESIGN EQUATIONS

To develop a rectangular patch antenna of microstrip which is based on the parameters of the dielectric constant ( $\epsilon_r$ ), resonant frequency ( $f_0$ ) and height ( $h$ ) are taken into consideration in calculating the length and width of patch and extended length and Effective electrical length and effective dielectric constant (Oahidu, *et al.*, 2010 Neha I, *et al.*, 2010).

### Step:1

Patch width calculation below,

$$W = \frac{c}{2f} \sqrt{\frac{2}{\epsilon_r + 1}} \quad \dots\dots\dots(1)$$

### Step:2

Dielectric constant calculation

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[ 1 + 12 \frac{W}{h} \right]^{-1/2} \quad \dots\dots\dots(2)$$

### Step:3

Calculate effective length,

$$L_{eff} = \frac{c}{2f \sqrt{\epsilon_{reff}}} \quad \dots\dots\dots(3)$$

### Step:4

Normalized extension of length,

$$\Delta L = 0.412h \frac{(\epsilon_{reff} + 0.3) \left( \frac{W}{h} + 0.264 \right)}{(\epsilon_{reff} - 0.258) \left( \frac{W}{h} + 0.8 \right)} \quad \dots\dots\dots(4)$$

### Step:5

Length of the patch,

$$L = L_{eff} - 2\Delta L \quad \dots\dots\dots(5)$$

Step:6

Ground plane width calculation,

$$W_g = W + 6h \quad \dots\dots\dots(6)$$

All these equations are applicable in prediction of resonant frequency, width, patch thickness and dielectric constant.

### THE ADVANTAGE AND DISADVANTAGE

Step:7

Ground length calculation,

$$L_g = L + 6h \quad \dots\dots\dots(7)$$

The Microstrip patch antenna has a number of strengths as compared with traditional microwave antenna. Table 2 provides the different advantage and disadvantage.

Step:8Antenna Efficiency,  $\dots\dots\dots(8)$ 

$$= \frac{P_{rad}}{P_r} * 100\%$$

Table 2: The Advantage And The Disadvantage Of Patch Antenna

Sr.No	Advantage	Disadvantage
1	Low weight	Low efficiency
2	Low profile	Low gain
3	Thin profile	Large ohmic loss in the feed structure of arrays
4	Required no cavity backing	Low power handling capacity
5	Linear and circular polarization	Excitation of surface wave
6	Capable of dual and triple frequency operation	Polarization purity is difficult to achieve
7	Feed lines and matching network can be fabricated simultaneously	Complex feed structure required high performance arrays

## **SIGNIFICANCE OF THE STUDY**

The significance of the conducted research is the introduction of a theoretically and practically designed antenna that could be used in the contemporary wireless communication technology either Wi-Fi or Internet of Things (IoT). The study is also important in offering a resourceful guide to the students and novice researchers in the same field of designing microstrip antennas; as the design process is very easy and the analysis procedure is well explained. Moreover, the study aims at making a small antenna, capable of operating in two frequencies on the same antenna, i.e. 2.4/5 GHz. This antenna is programmed to be used in Wi-Fi and IoT operations, and it is meant to ensure that the networks are more efficient.

## **CONCLUSION**

In this work, a theoretical review of microstrip patch antenna is given. It was therefore established after consideration of many research papers that low gain and low power handling capacity can be defeated either by array set up and slotted patch design. The design proposed is a dual-band patch antenna made of microstrip, which is based on CST Microwave Studio software. The proposed antenna supports the ultra-wideband at the frequency of 5 GHz and a wide band at 180 MHz bandwidth of WiMAX in mobile devices which can be used in WiMAX (2.4 GHz) and Wi-Fi, Bluetooth and WLAN applications due to its small size and lightweight as well as its ability to be easily integrated into electrical circuits. The gain, direction, and reflection values and the directional (VSWR) are also very good. The present research is a systematic review of the dual-band microstrip patch antennas related to Wi-Fi applications that is quite comprehensive

and up to date, covering design trends within the research, trade-offs in performance, and future research directions.

## **FUTURE WORK**

The antenna design proposed has good resonance behavior in reflectance (S11), gain and beamforming in the Wi-Fi frequency range. Practical applications and real-world testing can also be used to expand the use of microwave antennas to test the outcomes through simulation. The performance of the antenna can be enhanced in a number of ways such as the addition of bandwidth in the antenna, addition of gain via slots in the patch design among others. In addition, this design may be designed to work in more than one frequency, including 2.4 GHz and 5 GHz, in a single antenna but in two different frequencies. It is therefore applicable to a broader range of applications such as the Internet of Things (IoT) and contemporary communications. Another feature of the antenna is its easy construction and compact size, which makes it easier to manufacture and incorporate it into the modern ones. The other concept of improvement employed is the array antenna concept which comprises of four elements of which each element is a dual microstrip at two frequencies 2.4/5 GHz. These elements are linked in a particular manner to allow the elements to act as one antenna. Its advantages are augmented gain, augmented directionality, less interference, superiority in quality of signals, augmented coverage range, augmented signal-to-noise ratio, augmented communication efficiency and minimized power loss. Thus, such an improvement is an appropriate solution in the congested environment of IOT devices and is suitable in the Internet of Things (IOT) modern application employed today.

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