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 ٢.٤ جيجاهرتز/٥ 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 تزايدًا مستمرًا 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 أمرًا بالغ الأهمية لتضخيم حجم البيانات المرسلة في الأنظمة اللاسلكية، وتحسين معدلات نقل البيانات واستمراريتها وسرعتها، وذلك لتحقيق الأهداف المرجوة من الهوائيات وتوفير الوصول إلى البيانات. في حالة معاييرIEEE ، كان تردد شبكات Wi-Fi في جميع أنحاء العالم ٥/٢.٤ جيجاهرتز هو نموذج IEEE 802.11n. لذلك، تم اختيار الهوائي لاستخدام هذا النموذج، حيث يعمل الهوائي في نطاقين ترددين 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 خصيصًا للاستخدام في تطبيقات الواي فاي بتردد ٥/٢.٤ جيجاهرتز.

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

I. 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 thinks enjoyed wide attention in observing and sensing applications(Wang, *et al*,2020 ; Kumar , *et al.*,2020). The internet of thinks 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 thinks, 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.(BAYT ÖRE *et al*., 2019)Small antenna design with 2.4, 5.2 and 5.8 GHz WLAN. and 3.5 and 5.5 GHz 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 x50 mm. It achieves the required characteristics as far as size is concerned. 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*., 2011)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; then to address this issue, (Haydar *et al*. 2013), 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. However, (Afridi *et al.* 2015) developed an antenna with 8.27 dB gain value and 21.29 dB return loss value with a very low bandwidth. The other way of resolving this issue is to open slots on the antenna. In the study, (Thaher, *et al.*, 2018) 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 band width and 25.955dB at 5.8 GHz at 8.17 percent bandwidth. In reference to the (Gokcen D. and Ekrem A.,2022) 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. 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.

II. 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.

III. 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 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 1 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.

Table 1. Microstrip Patch Antenna Performance Comparison

Study	Size of Antenna in (mm)	BW (%)	The Operating Frequency (GHz)
Raghuraman S., 2016	50×50	12.4-13.2	2.4-5.8
Imran K., 2017	46×50	0.5-0.56	2.4-5.2
Anvesh N.) 2017	50×110	0.88-1.69	2.4-7.7
Praveen R., 2018	32×36	2.35-12.9	2.4-12
Supratha C., 2018	48.8×34.3	0.59-3.22	2.4-6.9
Yan D., 2019	1.29×0.36	0.3-1.22	2.4-5.2
Cem Baytory., 2019	20×30	0.59-1.08	2.4-5.2
Pawank K., 2020	56×56	1.3-40	2.4-5.5
Rabnawaz Sarmad., 2020	24×21	0.01-2.2	2.5-5.8
Md. Biplob Hossain, 2021	53×33	0.7-2.2	2.4-5.5
Sarosh A., 2021	40×30	2.04-3.44	2.45-5.8
Sezer K. ,2022	50×50	0.53 -2.2	2.41 - 5.8
Şahin, 2022	29×26	1.4-0.52	2.4 - 5
Thenkumari K., 2023	35×35	0.3-3.06	2-5.8
Ahmed Z. ,2023	30×24.8	0.05-0.20	2.4 - 5.8
Suthasinee L., 2024	48×38	0.27-0.21	2.4-5
Lalbabu P., 2024	60×50	6.02-5.67	2.4-5
Abdel-Ali L., 2025	26.9×20.7	0.76-1.6	2.45 - 5.8
Suggested Antenna	60×50	0.23-0.34	2.4-5

IV. ANTENNA ARAMETERS

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= 4p.U(th,F)/Pin, in which, U(th,F) is the intensity in a given direction, Pin 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=Vmax/Vmin. 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 log10(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.

V. ANALYSIS AND DESIGN EQUATIONS

To develop a rectangular patch antenna of microstrip which is based on the parameters of the dielectric constant (EURr), resonant frequency (fo) 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 l, , *et al*., 2010).

Step:1

Patch width calculation below,

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

Step:2

Dielectric constant calculation,

$$\epsilon_r = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}[1 + 12\frac{w}{h} \quad \ldots\ldots(2)$$

Step:3

Calculate effective length,

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

Step:4

Calculate effective length,

$$\Delta L = 0.412\,h\frac{(\epsilon_{reff} + 0.3)(\frac{W}{h} + 0.264)}{(\epsilon_{reff} + 0.258)(\frac{W}{h} + 0.8)} \ldots.(4)$$

Step:5

Length of the patch,

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

Step:6

Ground plane width calculation,

$$W_g = W + 6h \quad \ldots.(6)$$

Step:7

Ground plane length calculation,

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

Step:8

Antenna Efficiency calculation,

$$\text{Antenna Efficiency} = \frac{P_{radd}}{P_r} \quad \ldots..(8)$$

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

VI. THE ADVANTAGE AND DISADVANTAGE

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

Table 2: The Advantage and the Disadvantage of Patch Antenna

Item	Advantages	Disadvantages
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

VII. 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.

VIII. CONCLUSION

1-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.

2-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.

3-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.

IX. 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:

1-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.

2-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.

References

Afridi , M. A.2015. Microstrip patch antenna−designing at 2.4 GHz frequency. Biol. Chem. Res, 128-132

https://www.ss-pub.org/wp-content/uploads/2015/03/3-BCR-E20140906-02.pdf

Abdel-Ali L., Youssef M., Abdelkebir E., Mohamed T.2025 , .Design of a miniaturized patch antenna for 2.45/5.8 GHz applications Institute of Advanced Engineering and Science (IAES),Vol 14, No 1.

DOI:10.11591/ijaas.v14.i1.pp101-110

Ahmed Z. ,Nur H. , Norun F., Farah N. Mohd I. and Sarah M.2023 .Design of miniaturized antenna for IOT application using metamaterial, Electrical, Computer and Communications Engineering, VOL. 24 NO. 1.

Abdulkawi, W.; Malik, W.; Rehman, S.; Aziz, A.; Sheta, A.; Alkanhal, M. 2021.Design of a Compact Dual-Band MIMO Antenna System with High-Diversity Gain Performance in Both Frequency Bands. Micromachines , 12, 383.
https://doi.org/10.3390/mi12040383

Anvesh N., Gandhi A. S.. A Surveyon 2017.Microstrip Antennas for Portable Wireless Communication System Applications, IEEE.

DOI:10.1109/ICACCI.2017.8126165

BAYTÖRE, C., GÖÇEN, C., PALANDÖKEN, M., Kaya, A., & ZORAL, E. Y. 2019 .Compact metal-plate slotted WLAN-WIMAX antenna design with USB Wi-Fi adapter application. Turkish Journal of Electrical Engineering & Computer Sciences, 27(6), 4403-4417.
https://journals.tubitak.gov.tr/elektrik/vol27/iss6/26/

Chen, S.; Dong, D.; Liao, Z.; Cai, Q.; Liu, G.2014, Compact wideband and dual-band antenna for TD-LTE and WLAN applications. Electron. Lett, 50, 1111–1112.

https://ietresearch.onlinelibrary.wiley.com/doi/10.1049/el.2014.1576

Chung, M.-A. 2018.A miniaturized triple band monopole antenna with a coupled branch strip for bandwidth enhancement for IoT applications. Microw. Opt. Technol.Lett,60,23362342.
https://onlinelibrary.wiley.com/doi/10.1002/mop.31351

Chung, M.-A. 2018.A miniaturized triple band monopole antenna with a coupled branch strip for bandwidth enhancement for IoT applications. Microw. Opt. Technol.Lett,60,23362342.
https://onlinelibrary.wiley.com/doi/10.1002/mop.31351

Cem Baytory, Cem, Cem Gocen ,Merih Palandoken 2019. Compact metal-plate slotted WL Compact metal-plate slotted WLAN-WIM AN-WIMAX antenna design with AX antenna design with USB Wi-Fi adapter application, Turkish Journal of Electrical Engineering

DOI10.3906/elk-1904-122

Gokcen Demirbas , Ekrem A. .2022 . Design and Interpretation of Microstrip Patch Antenna Operating at 2.4GHz for Wireless WI-FI Application. European Journal of Science and Technology Special Issue 34, pp. 672-675.

https://dergipark.org.tr/en/download/article/file/2295211#:~:text=Rambe%20et%2

0al%2C%20the%20gain,13.75%20dB%20%5B17%5D.

Goswami P**.K.;** Goswami, G. Truncated .2020 . T parasite staircase fractal U-slot antenna for multiple advance internets of things applications. Microw. Opt. Technol. Lett,62,830838.

https://onlinelibrary.wiley.com/doi/10.1002/mop.32082

Haydar K. , Ahmet Y. TEŞNEL , N. Berna TEŞNELİ. 2013. 3.3 Ghz Microstrip Antenna Design and Analysis for Different Feeding Methods. SAU J. Sci. Vol 17, No 1, p. 119-124.

https://kutuphane.dogus.edu.tr/mvt/pdf.php

Imran K, Md. Ahasan K., and Avijit H., 2017.A Simple Multiband Patch Antenna for Application in Wireless Communication, International Conference on Electrical, Computer and Communication Engineering (ECCE), IEEE.

DOI:10.1109/ECACE.2017.7912978.

Imran K, Md. Ahasan K., and Avijit H., 2017.A Simple Multiband Patch Antenna for Application in Wireless Communication, International Conference on Electrical, Computer and Communication Engineering (ECCE), IEEE.

DOI:10.1109/ECACE.2017.7912978.

Jha, K.R.; Bukhari, B.; Singh, C.; Mishra, G.; Sharma, S.K. 2018, Compact Planar Multistandard MIMO Antenna for IoT Applications. IEEE Trans. Antennas Propag,66,33273336.

DOI: 10.1109/TAP.2018.2829533

Kim, M. K., Kim, K., Suh, Y. H., & Park, I. (2000, July). A T-shaped microstrip-line-fed wide slot antenna. In IEEE Antennas and Propagation Society International Symposium. Transmitting Waves of Progress to the Next Millennium. Digest. Held in conjunction with: USNC/URSI National Radio Science Meeting (C IEEE, 2000, Vol. 3, pp.1500-1503.

https://doi.org/10.1002/mop.21041

Karmokar, D. K., Morshed, K. M., Numan-Al-Mobin, A. M.,& Kabir, A. E. .2010 High gain multiband loaded inverted-F antennas for mobile WiMAX, Wi-Fi, bluetooth and WLAN operation. International Journal of Engineering (IJE),4(3),219232.
https://www.researchgate.net/publication/45692673_High_Gain_Multiband_Loaded_Inverted-F_Antennas_for_Mobile_WiMAX_Wi-Fi_Bluetooth_and_WLAN_Operation

Kumar, N.; Khanna, R. 2020.A compact multi-band multi-input multi-output antenna for 4G/5G and IoT devices using theory of characteristic modes. Int. J. RF Microw.Comput.AidedEng,30,e22012.
https://onlinelibrary.wiley.com/doi/10.1002/mmce.22012

Lalbabu P., Harish M. , and Ahmed Al-Gburi.2024 , Dual Band Rectenna for Electromagnetic Energy Harvesting at 2.4 GHz and 5 GHz Frequencies, PIERB Vol. 108 pp. 75-88.

DOI:10.2528/PIERB24072102

Lee, H.; Ren, D.; Choi, J.H.2018. Dual-Band and Polarization-Flexible CRLH Substrate-Integrated Waveguide Resonant Antenna. IEEE Antennas Wirel. Propag.Lett,17,14691472.

https://ieeexplore.ieee.org/document/8392428

Mao, Y.; Guo, S.; Chen, M.2018. Compact dual-band monopole antenna

with defected ground plane for Internet of things. IET Microw. Antennas Propag, 12,13321338.

https://ietresearch.onlinelibrary.wiley.com/doi/10.1049/iet-map.2017.0860

Md. Biplob Hossain and Md. Faruque Hossain 2022.Design and Performance Analysis of a Triple- band Rectangular Slot Microstrip Patch Antenna for Wi-Fi, Wi-MAX and Satellite Applications

Md.Biplob Hossain and Md. Faruque Hossain .

DIO: 10.24425/ijet.2022.139870

Neha P., Manish S., Krishnkant N.,2014 .Review of Microstrip Patch Antenna for WLAN and WiMAX Application, Int. Journal of Engineering Research and Applications, ISSN : 2248-9622, Vol. 4, Issue 1(Version 1), pp.168-171

https://www.ijera.com/papers/Vol4_issue1/Version%201/AC4101168171.pdf

Oahidul I., Mohammad F,2023. IoT Application using a Rectangular 2.4 GHz Microstrip Patch Antenna, 2023 International Conference for Advancement in Technology (ICONAT).

DOI:10.1109/ICONAT57137.2023.10080448

Praveen R. , KM S., Rajan.A., 2018. Circular Shaped Microstrip patch Antenna for Bluetooth/Wi-Fi/UWB/X-band Applications, IEEE.

DOI: 10.1109/PEEIC.2018.8665602

PAWAN K., SHABANA U. 2020.Design and Implementation of Quad-Element Super-Wideband MIMO Antenna for IoT Applications, IEEE Access,PP(99):1-1

DOI: 10.1109/ACCESS.2020.3045534

[1]

Rachmansyah, A. I., & Mutiara, A. B. 2011 .Designing and manufacturing microstrip antenna for wireless communication at 2.4 GHz. International Journal of Computer and Electrical Engineering, 3(5), 670-675

DOI:10.7763/IJCEE.2011.V3.401

Rabnawaz Sarmad Uqaili1, Junaid Ahmed Uqaili1, Sidrish Zahra2, Faraz Bashir Soomro3, Ali Akbar. Study on 2020.Dual-band Microstrip Rectangular Patch Antenna for Wi-Fi, Vol. 16. https://doi.org/10.46604/peti.2020.6266

Supratha C, Robinson S. 2018.Design and Analysis of Microstrip Patch Antenna for WLAN Application, IEEE,

DOI: 10.1109/ICCTCT.2018.8550979

Sarosh A., Adnan G., Niamat H., 2021.Compact Dual-Band Antenna with Paired L-Shape Slots for On-and Off-BodyWireless Communication, , 21(23), 7953.

https://doi.org/10.3390/s21237953

Sezer K., Adnan K. 2022. Dual-Band Microstrip Patch Antenna Design for Wi-Fi Applications, European Journal of Science and Technology.

DOI:10.31590/ejosat.1084147

Şahin, D.A. & Kaya, A.2022, 2.4 GHz and 5 GHz Dual Band Wi-Fi Antenna Design for IoT Based Smart Media Application.

DOI:10.31590/ejosat.1144355

Suthasinee L., Nattakarn S., Wararak N., Chuwong P.2024 , Adual-band rectangular shape incorporated into circular patch antenna for 2.4/5 GHz wireless local area network applications,TELKOMNIKA Telecommunication Computing Electronics and Control, 23(1):22.

DOI:10.12928/TELKOMNIKA.v23i1.26519

Thenkumari K., Sakthidasan K. and Mathana J.2023 , Design and Implementation of Frequency Reconfigurable Antenna for Wi-Fi Applications, Engineered Science, Vol. 23.

https://dx.doi.org/10.30919/es8d876

Thaher, R. H., & Jamil, Z. S.2018. Design of Dual Band Microstrip Antenna for Wi-Fi and WiMax Applications. TELKOMNlKA16(6),28642870.

DOI:10.12928/TELKOMNIKA.v16i6.10016

Wang, M.; Yang, L.; Shi, Y. 2020.A Dual-port Microstrip Rectenna for Wireless Energy Harvest at LTE Band. AEU Int. J. Electron.Commun,126, 153451
https://www.sciencedirect.com/science/article/abs/pii/S1434841120309912?via%3Dihub

Wang, W., Ma, C., Zhang, X., Shen, J., Hanagata, N., Huangfu, J., & Xu, M.. 2019.High-performance printable 2.4 GHz graphene-based antenna using water-transferring technology. Science and technology of advancedmaterials, 20(1),870875.

DOI:10.1080/14686996.2019.1653741

Yan D., IEEE Student Member, and Yu Jian Cheng, IEEE Senior Member 2020. A Tri-band Shared-Aperture Antenna for 2.4/5.2-GHz Wi-Fi Application with MIMO Function and 60-GHz Wi-Gig Application with Beam-Scanning Function, Vol. 68 Issue: 3, 1973 - 1981.

DOI: 10.1109/TAP.2019.2948571