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Study and Development of a Multi-band Triangular Patch Antenna for 2.45/5.8 GHz WLAN and Wi-Fi Applications

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With the technological expansion in telecommunications and the ongoing scientific research into patch antennas, as well as the many needs in the field of communication, traditional microwave antennas are no longer able to match these requirements. As a result, patch antennas have largely replaced traditional antennas in most applications. This paper descripts the study and design of a multi-bands microstrip triangular array patch antenna covering the Wireless Fidelity (Wi-Fi) bands (802.11a, 802.11ac, 802.11ax, 802.11b, 802.11g, 802.11n) at 2.45 GHz and 5.8 GHz. This array antenna consists of two triangular patches operating separately on the 2.45, and 5.8 GHz bands; the designed patches are grouped into one array function to operate at multiple resonances (2.47, 4.1, 4.9, and 5.94 GHz) with miniaturized size. The suggested low-cost array antenna is designed on a 1.6 mm thick FR4 substrate. The results indicate multiple resonant frequencies defining quad operating bandwidths characterized by a return loss less than –10 dB, which are 50 MHz from 2.44 GHz to 2.49 GHz at 2.47 GHz, 100 MHz from 4.05 GHz to 4.15 GHz at 4.1 GHz, 120 MHz from 4.85 to 4.97 GHz at 4.9 GHz, and 240 MHz from 5.78 GHz to 6.02 GHz for 5.94 GHz operation, respectively. The proposed antenna offers excellent performance for Wi-Fi and Wireless Local Area Network (WLAN) applications. The suggested array antenna model has been performed by using CST MS software.

Keywords: Multi-band, Triangular array antenna, Wi-Fi, WLAN, Gain, Bandwidth.

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1. INTRODUCTION

In comparison to other types of antennas, microstrip antennas are more frequently utilized and chosen due to their low dimensions, light weight, and flat profile arrangements that may be made conformal. Moreover, production costs are modest. Because of these characteristics, they are easily producible in huge numbers. Depending on the radiation design for polarization types, it can handle both circular and linear polarization. Microstrip antennas can also operate at double or even triple frequencies, which is extremely appealing [1]. Nowadays, small, inexpensive antennas are needed for systems of wireless communication like Wi-Fi network or Wi-MAX; as a result, in these systems, microstrip patch antennas are widely employed. Despite these benefits, the fundamental disadvantage of microstrip antennas is their limited bandwidth. Dual band operation antennas are a good option for enlarging the bandwidth. [2].

In the modern era, wireless communications have advanced significantly and quickly, particularly over the past ten years. In the near future, WLAN (Wireless Local Area Networks) will be utilized in personal communication devices to deliver image, video telephony, DMB (Digital Multimedia Broadcasting), voice, and digital conversations may take place at anytime, anywhere in the world.

The necessity for more compact multiband antennas with appropriate frequency bands for IEEE 802.11 standard (Wi-Fi) and mobile IEEE 802.16e-2005 standard (WiMAX) applications has been prompted by significant improvements in various WLAN protocols. Wi-Fi operates in the 2.4 GHz and 5 GHz bands. The mobile WiMAX operational bands are 2.3 GHz, 2.5 GHz, and 3.5 GHz [3]. There have been various dual band antenna proposals for WiFi/WiMax applications. Ref. [4] demonstrated a dual-band inverted-L antenna that operates at 3.5 and 5 GHz. This antenna has a basic shape and a single feed and is intended for mobile WiMAX and Wi-Fi operation. The antenna measured 20×30 mm^2, was supplied by a coaxial connector, and had a ground plane of 60×60 mm^2. Likewise, ref. [5] demonstrated a microstrip patch antenna for WiMAX and Wi-Fi with frequency ranges of 3.5 GHz and 5.2 GHz with a total size of 49×53×1.67 mm^3. Ref. [6] presented a small patch antenna with two U slots for WLAN/WIMAX applications with a 40×47 mm^2 patch dimension. Ref. [7] offered a dual band patch antenna with nine slots. The coaxial feed was used for power feeding, and the substrate was FR4 with a dielectric constant of 4.4 and dimensions of 80×120×3.4 mm^3. For WLAN and WiMAX applications, a human-shaped patch microstrip antenna was presented in [8]. The suggested antenna has a 3.2 mm thick air substrate with a permittivity of 1.0006 and a dimension of 120×100×3.2 mm^3. As moreover, for WLAN, WiMAX, and IMT applications, ref. [9] introduced a horseshoe-shaped stacked microstrip patch antenna. The patch on the antenna was designed like a horseshoe with an overall dimension of 40×50 mm^2 that was positioned on the rigid substrate's top surface. In ref. [10], a tri-band micros strip patch antenna for use with GSM, UMTS, and WiMAX applications was reported. The recom-

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mended antenna was built on a substrate of 1.6 mm thickness, and an overall dimension of 44×44×1.6 mm^3. The majority of the antennas are built for frequencies ranging from 2 to 5 GHz for Wi-Fi, WiMAX, Bluetooth and GPS applications [11-15].

This work aims to develop and analyze the triangular patch antennas and integrate them into an array for Wi-Fi applications. The first antenna operates at 2.45 GHz frequency, and the second at 5.8 GHz, and the array antenna is the integration of the two antennas before that which allows us to build a single array antenna system having both 2.45 GHz and 5.8 GHz Wi-Fi bands. All the simulation results are achieved by the CST simulator.

2. ANTENNA DESIGNS

In this paper, the design and development of two triangular antennas and integration to form an array antenna to function in the Wi-Fi bands is discussed. The first antenna operates at 2.45 GHz, and the second one operates at 5.8 GHz. The radiation element is designed on a FR-4 substrate with a thickness of h = 1.6 mm, a constant dielectric ε_r = 4.3, and a loss tangent of 0.0197 with dimensions of 85×75×1.6 mm^3.

2.1 Triangular Patch Antenna at 2.45 GHz Frequency

This antenna is proposed for operating at 2.45 GHz operating frequency. It has a triangular form. The patch is depicted on a substrate FR-4 size $W_1 \times L_1$ with a ground plane on the bottom surface of substrate. As seen in Fig. 1, the patch is fed by a 50 Ω microstrip line.

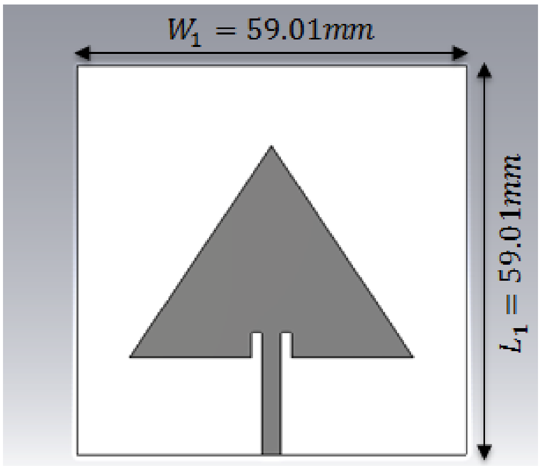


Fig. 1 – Triangular patch antenna at 2.45 GHz frequency.

Fig. 2 depicts the simulated reflection coefficient (S11) of the first triangle antenna. The results of the simulation indicate the correctness of the suggested antenna model. The recommended antenna has an impedance bandwidth of 50 MHz (2.42 – 2.47 GHz) $|S_{11}| < 10\ dB$. Fig. 3 depicts the simulated gain fluctuations. According to the gain curve, the antenna's highest peak gain at 2.4 GHz is 2.02 dBi. Fig. 4 depicts the radiation pattern characteristics of the proposed antenna. Both the E and H planes of the antenna have directional patterns.

2.2 Triangular Patch Antenna at 5.8 GHz Frequency

The second antenna operates at a frequency 5.8 GHz. It also has a triangular form, with the area of this triangle is less than the triangle area of the 2.45 GHz antenna. The patch is placed on the same substrate FR-4 of size $W_2 \times L_2$ with ground on the lower surface of the substrate. As seen in Fig. 5, the patch is feed by a 50Ω microstrip line.

The simulation reflection coefficient (S11) of the second triangular antenna is represented in Fig. 6. The simulation results support the recommended antenna concept. At the resonance frequency of 5.8 GHz, the proposed antenna has good impedance matching with a level of – 23 dB. The simulated gain fluctuations are represented in Fig. 7. The second antenna's highest peak gain is 1 dBi at 5.8 GHz, as indicated by the gain curve. Fig. 8 illustrates the proposed antenna's radiation pattern characteristics. The antenna offers E and H-plane directional patterns.

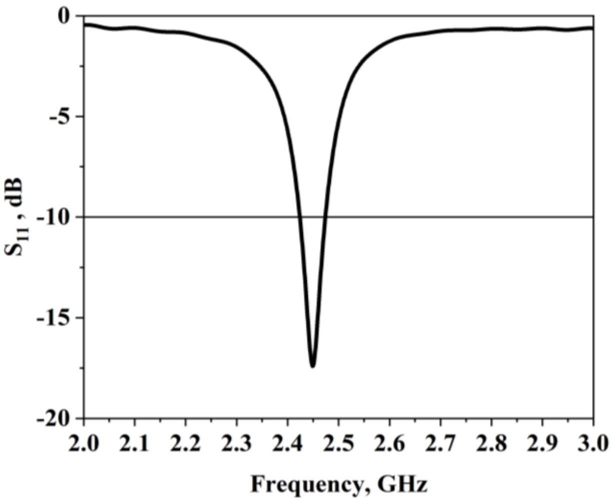


Fig. 2 – The S_{11} of the first triangular antenna at 2.45 GHz

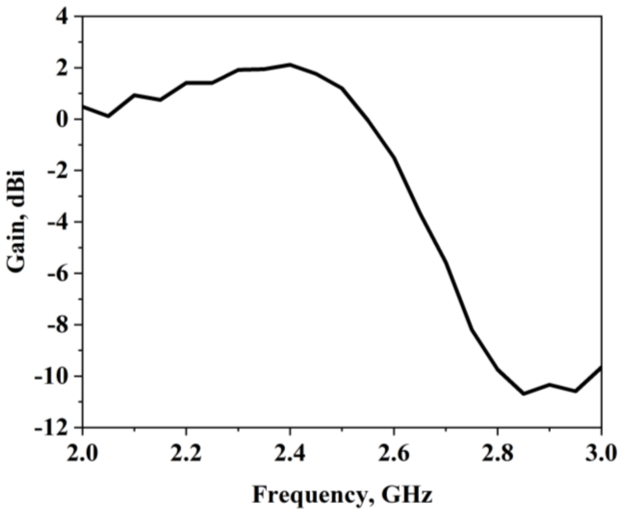
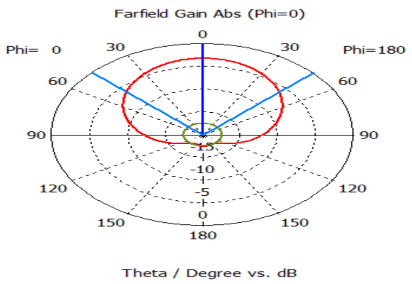


Fig. 3 – The gain of the first antenna at 2.45 GHz



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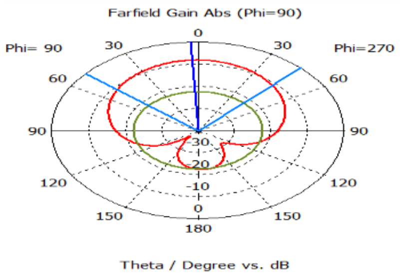

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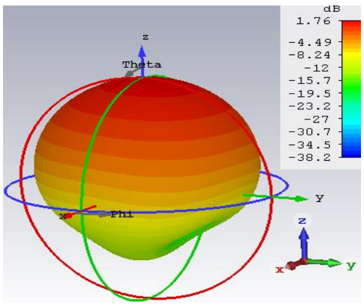

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Fig. 4 – The radiation patterns of the first antenna at 2.45 GHz: (a) H-plane, (b) E-plane, (c) 3D.

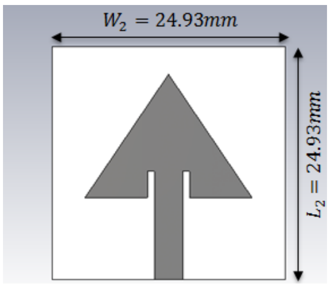


Fig. 5 – Triangular patch antenna at 5.8 GHz frequency.

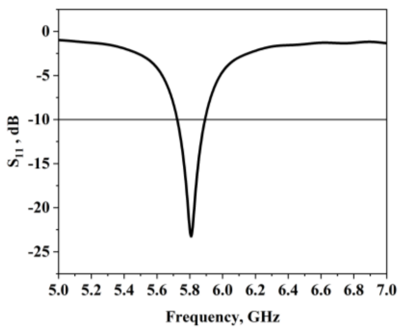


Fig. 6 – The S_{11} of the second antenna at 5.8 GHz

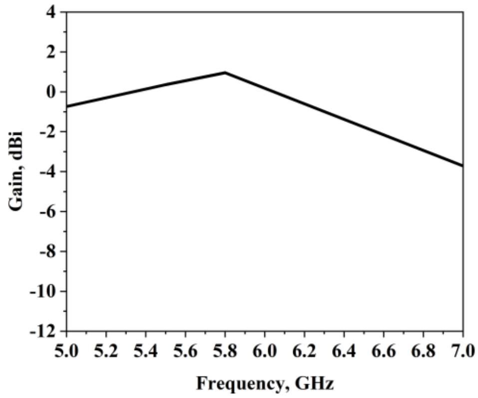
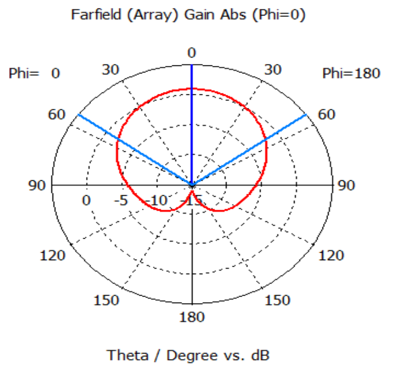


Fig. 7 – The gain of the second antenna at 5.8 GHz



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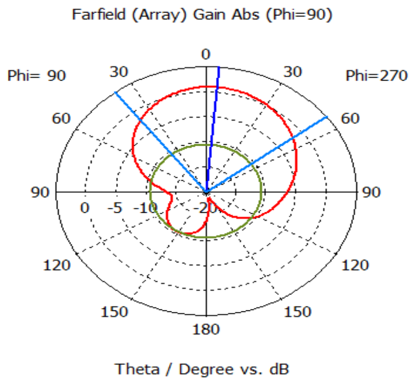

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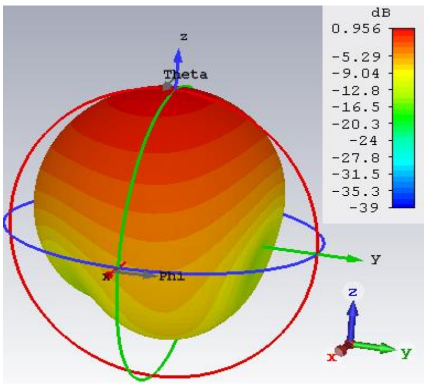

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Fig. 8 – The radiation pattern of the second antenna at 5.8 GHz: (a) H-plane, (b) at the E-plane, (c) 3D.

2.3 Dual Band Patch Array Antenna Powered in Parallel

The third antenna consists of the two antennas discussed in preceding sections. This array antenna operates at quad frequency bands centered at 2.45, 4.1, 4.9, and 5.8 GHz. The array antenna is designed using the optimized dimensions mentioned in single triangular patch elements. The patch array antenna is powered in parallel via a power divider as a T-junction feed by a 50 Ω source. The simulation reflection coefficient (S11) of the antenna array is represented in Fig. 10.

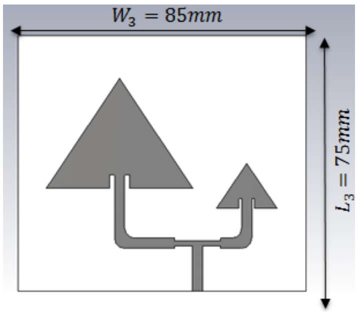


Fig. 9 – Patch array antenna at 2.45 GHz and 5.8 GHz frequency.

The suggested antenna model's validity is supported by the results of the simulation. At three resonance frequencies of 2.47, 4.1, 4.9 and 5.8 GHz, the proposed antenna has good impedance matching at return loss levels of 13.74, 21.3, 10.5 and 16.44 dB, respectively. The simulated gain variations are shown in Fig. 11. The gain curve indicates that the antenna's maximum peak gain at 5.6 GHz is 4.19 dBi. In Fig. 12, the proposed array antenna's radiation pattern characteristics are displayed. At the E and H planes, the antenna offers directional patterns.

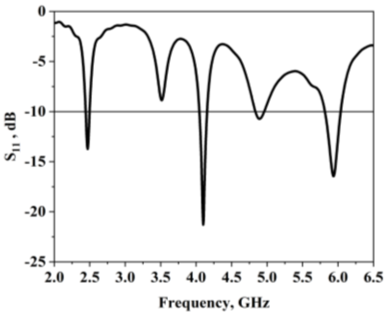


Fig. 10 – S11 of the proposed two-element array antenna

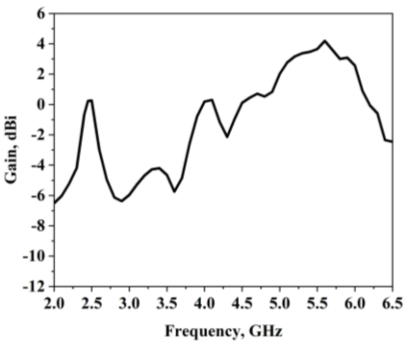
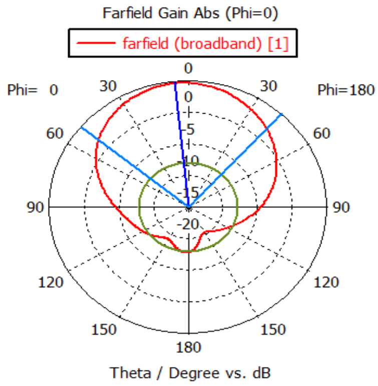


Fig. 11 – The gain of the proposed two-element array antenna.



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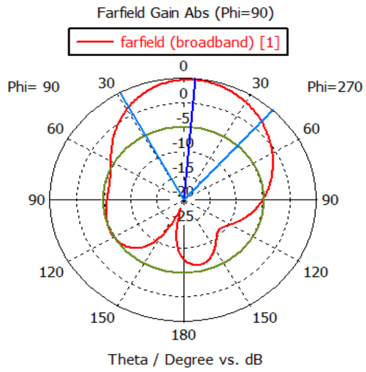

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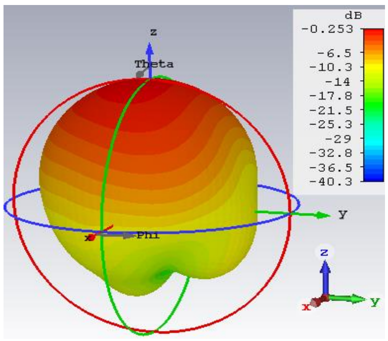

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Fig. 12 – Proposed array antenna's radiation patterns: (a) H-plane (2D), (b) E-plane (2D), (c) 3D

3. CONCLUSION

This paper presents the study and design of a multiband triangular microstrip patch antenna for Wi-Fi and Wi-MAX applications. First and foremost, we designed two single element triangular antennas that operate independently at 2.45GHz and 5.8GHz. The two previously designed antennas are then combined to form an array antenna which is excited with parallel-fed antenna. As a result, the constructed array antenna operates at multiple frequencies: 2.47 GHz, 4.1 GHz, 4.9 GHz and 5.94 GHz, which includes Wi-Fi bands. The simulation results demonstrate that the reflection coefficient is less than −10dB for all bands of frequencies, and the suggested design produces an omnidirectional radiation pattern with good gain.

REFERENCES

1. R.H. Thaher, Z.S. Jamil, *TELKOMNIKA (Telecommunication Computing Electronics and Control)* **16** No 6, 2864 (2018).
2. S. Maci, G.B. Gentili, *IEEE Anten. Propag. Magazine* **39** No 6, 13 (1997).
3. L. Pazin, N. Telzhensky, Y. Leviatan, *IEEE Antenn. Wireless Propag. Lett.* **7**, 197 (2008).
4. S.S. Alam, A.S.K. Khan, L. Saha, M.H. Pavel, T. Rahman, *Int. J. Comput. Sci. Eng. Surv.* **2** No 2, 22 (2011).
5. A.A. Yassin, R.A. Saeed, R.A. Mokhtar, *International Conference on Computer and Communication Engineering IEEE*, 228 (2014).
6. P. Bhagat, P. Jain, *SSRG International Journal of Electronics and Communication Engineering* **1**, 7 (2014).
7. G.V. Kumari, P.V. Chowdary, K. Madhulatha, M.D. Kumar, K.A. Sagar, *International Journal of Advanced Research in Computer and Communication Engineering* **4** No 3, 414 (2015).

Y.P. Lakshmi, M.U. Rao, B.S. Babu, *International Journal of Innovative Research of Research in Electrical, Electronics, Instrumentation and Control Engineering* **3**, 3 (2015).

9. E. Sidhu, A. Kumar, A. Singh, *An International Journal of Engineering Sciences* **17**, 525 (2016).
10. M.T. Guneser, Cihatseker, *Proceedings of 65th ISERD International Conference* (*Saudi Arabia*: 2017).
11. H. Wang, M. Zheng, *IEEE Antenn. Wireless Propag. Lett.* **10**, 569 (2011).
12. J.H. Yoon, G.S. Kil, *Microwave Opt. Technol. Lett.* **54** No 7, 1559 (2012).
13. J.S. Lim, C.S. Kim, D. Ahn, Y.C. Jeong, S. Nam, *IEEE Trans. Microwave Theory Tech.* **53** No 8, 2539 (2005).
14. X. Gao, H. Zhong, Z. Zhang, Z. Feng, M.F. Iskander, *IEEE Antenn. Wireless Propag. Lett.* **9**, 83 (2010).
15. A. Mehdipour, A.R. Sebak, C.W. Trueman, *IEEE Antennas and Propagation Society International Symposium,* 1 (2019).

Дослідження та розробка багатодіапазонної трикутної патч-антени для додатків WLAN і Wi-Fi 2,45/5,8 ГГц

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З технологічним розвитком телекомунікацій і триваючими науковими дослідженнями патч-антен, а також багатьма потребами в галузі зв'язку традиційні мікрохвильові антени більше не можуть відповідати цим вимогам. Як наслідок, патч-антени значною мірою замінили традиційні антени в більшості застосувань. У роботі описано дослідження та проектування багатодіапазонної мікросмужкової трикутної антенної решітки, що охоплює діапазони Wireless Fidelity (Wi-Fi) (802.11a, 802.11ac, 802.11ax, 802.11b, 802.11g, 802.11n) на 2,45 ГГц і 5,8 ГГц. Антенна решітка складається з двох трикутних ділянок, що працюють окремо в діапазонах 2,45 і 5,8 ГГц; розроблені патчі згруповані в одну функцію масиву для роботи на кількох резонансах (2,47, 4,1, 4,9 і 5,94 ГГц) з мініатюрним розміром. Пропонована дешева антенна решітка розроблена на підкладці FR4 товщиною 1,6 мм. Результати вказують на численні резонансні частоти, що визначають чотири робочі смуги пропускання, що характеризуються зворотними втратами менше -10 дБ, які становлять 50 МГц від 2,44 ГГц до 2,49 ГГц при 2,47 ГГц, 100 МГц від 4,05 ГГц до 4,15 ГГц при 4,1 ГГц, 120 МГц від 4,85–4,97 ГГц при 4,9 ГГц і 240 МГц від 5,78 ГГц до 6,02 ГГц для роботи на 5,94 ГГц відповідно. Антена забезпечує високу продуктивність для додатків Wi-Fi та бездротової локальної мережі (WLAN). Запропонована модель антенної решітки виконана за допомогою програмного забезпечення CST MS.

Ключові слова: Багатодіапазонний, Трикутна антенна решітка, Wi-Fi, WLAN, Підсилення, Пропускна здатність.