

Efficiency Evaluation and Dual-Band WLAN Protocols in Raspberry Pi-Based Wireless Networks for Medical IoT Communication Systems

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ABSTRACT

Wireless local area network (WLAN) is an innovation that consolidates PC connects with remote correspondence innovation. The 2.4 GHz and 5 GHz recurrence groups in the Industrial Scientific Medical (ISM) band can be utilized in the WLAN condition. On account of the advancement of remote correspondence innovation and the utilization of the recurrence groups without the requirement for approval, the use of WLAN is ending up increasingly broad. As the key piece of the WLAN framework, the radio wire should likewise be adjusted to the advancement of WLAN correspondence innovation. This paper plans two new double recurrence microstrip receiving wires with the utilization of electromagnetic recreation programming High Frequency Structure Simulator (HFSS). The two reception apparatuses receive customary FR4 material as a dielectric substrate, with the upsides of minimal effort and little size. The main receiving wire embraces microstrip line encouraging, and the radio wire radiation fix is made out of a collapsed T-molded emanating dipole which diminishes the reception apparatus size, and two symmetrical rectangular patches situated on the two sides of the T-formed transmitting patch. The second radio wire is a microstrip receiving wire nourished by coaxial line, and the measure of the reception apparatus is lessened by opening a ventured furrow on the two edges of the fix and a collapsed space inside the fix. Reenactment tests demonstrate that the two structured radio wires have a higher addition and a great transmission trademark in the working recurrence extend, which is as per the prerequisites of WLAN correspondence.

KEYWORDS: WLAN, HFSS, microstrip antenna, dual-frequency.

1. INTRODUCTION

In recent years, with the quick advancement of remote correspondence innovation, the WLAN correspondence framework has likewise thrived, and the connected range in the market is progressively wide [1,2]. WLAN correspondence frameworks by and large require two-way sending and getting information in a quick, high-proficiency and solid way, which is reflected in the reception apparatus subsystem. The receiving wire is an essential piece of the remote correspondence framework [3,4]. Current society has gone into the data age, and individuals present higher prerequisites for the radio wire, that is, the reception apparatus not just has a more extensive recurrence band, littler size and is simpler to introduce, yet additionally has high radiation productivity and hostile to obstruction execution and different attributes [5]. In this way, the investigation of multiband and scaled down receiving wires turns into a vital issue in the field of reception apparatuses [6]. Contrasted and the conventional microwave receiving wire, the microstrip reception apparatuses are low profile, little size, ease and light weight, which can fulfill the needs of scaling down. Be that as it may, microstrip radio wires inalienably have restricted data transfer capacity; henceforth, the investigation of double band microstrip reception apparatuses is fundamental.

At present, broad investigations of double band microstrip reception apparatuses connected in WLAN have been done, and a great deal receiving wire types which work in a double band have been advanced, for example, Dipole radio wires [7], Planar Inverted-F reception apparatuses [8], Planar Monopole receiving wires [9] and Quasi-Yagi radio wires [10,11]. These radio wires are basic in structure and low underway cost, which are reasonable for the utilization of WLAN gadgets. The examination of microstrip receiving wires is basically

centered around little scale, broadband, multi polarization, multi band and high increase [12– 14], and so forth. For instance, Heng-Tung Hsu et al. [15] have structured a microstrip radio wire for double band activity, as appeared in Figure 1.

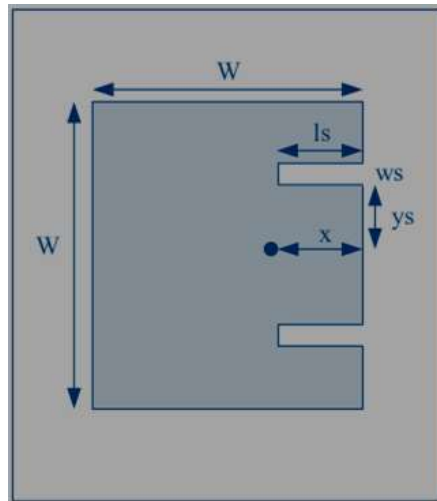


Figure 1. Structure of a microstrip antenna.

This paper primarily thinks about the double recurrence qualities of microstrip radio wires. Two double recurrence microstrip radio wires planned with HFSS, which is fabricated by Ansoft of the United States, can be connected to WLAN. The reproduction results show that the reception apparatus has a tasteful exhibition.

The remainder of the paper is sorted out as pursues. In Section 2, the paper presents the related guideline and technique for microstrip reception apparatus plan. A broadband double band printed radio wire for WLAN is structured in Section 3. In Section 4, a double recurrence double band microstrip radio wire is structured, which is utilized to understand the double band activity on the radiation side. Area 5 is the rundown of the paper.

2. DESIGN THEORY

Prologue to Microstrip Antennas

A microstrip radio wire is a resonating radiator, whose radiation field is created by the electromagnetic field of shared inspiration between the upper radiation fix edges of microstrip receiving wire and the establishing plate, and always emanates out electromagnetic waves through the hole between them [16,17]. The parameters of the receiving wire are the proportion of the nature of the reception apparatus. The microstrip reception apparatus structured in this paper will for the most part consider the data transmission and the increase. The data transfer capacity is the recurrence scope of the radio wire when the receiving wire is off the focal point of the working recurrence; in the interim, the reception apparatus' execution parameter is diminished to the passable esteem [18,19]. By and large, the transmission capacity of the microstrip reception apparatus is in 0.7%– 7%. The increase of the receiving wire is the proportion of the radiation control force created by the real structured reception apparatus to the perfect radiation unit at a similar point in space as a similar information control is equivalent.

The Feeding of the Antenna, Efficiency and Dual-Band Technology

The run of the mill structure of printed monopole reception apparatus is appeared in Figure 2. It has focal points of little size, light weight, simple to coordinate and large scale manufacturing [20– 22]. The feed methods for the radio wire are microstrip line encouraging. The assembling procedure of microstrip line is straightforward, simple to coordinate with other dynamic and aloof circuit parts, which is helpful for understanding the scaling down of the circuit framework and improving the level of joining.

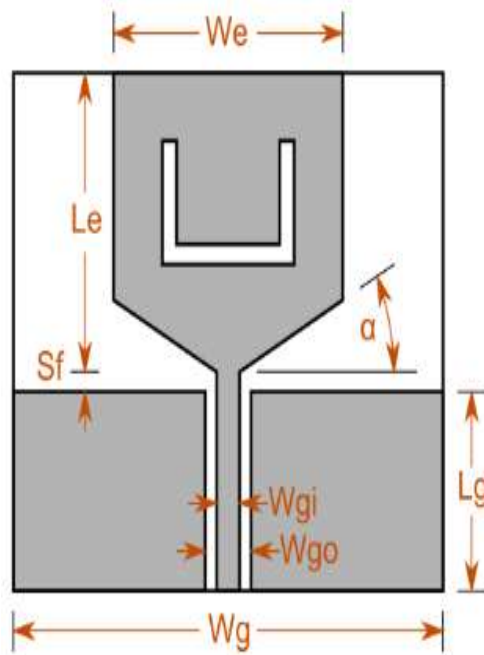


Figure 2. Structure chart of a printed monopole antenna.

When utilizing coaxial feed, the test utilized for nourishing is extended into the resounding cavity to propel the fix receiving wire. The upsides of the coaxial feed is that the encouraging focuses can be chosen at any ideal position of the fix, and the coaxial feeder situated in underneath the ground plane and the fix radio wire situated in the ground floor maintain a strategic distance from the impact of the feeder on the receiving wire radiation.

The transmission capacity and increase of the reception apparatus are firmly identified with the structure and size of the receiving wire. Decreasing the extent of the receiving wire will diminish the productivity of the reception apparatus and tight the transmission capacity. Much of the time, particularly in aviation satellite correspondence and versatile correspondence, because of the restriction of physical space, little radio wires are direly required [23,24]. Along these lines, it is important to lessen the span of the radio wire while improving the execution of the receiving wire.

With the improvement of WLAN innovation and other correspondence advancements, the interest for double recurrence and multi-recurrence radio wires is expanding. In light of this circumstance, the multi-recurrence task strategy for the microstrip radio wire has been contemplated widely. There are two sorts of essential strategies: solid chip technique and multi chip strategy. Solid chip strategy can be isolated into solid multi mode technique and solid stacking technique. Solid multi mode strategy works in various methods of fix all the while, while solid stacking technique receives stacking to shape diverse reverberation frequencies. For solid microstrip fix recieving wire, notwithstanding the utilization of multi mode technique, the heap strategy can likewise be utilized to accomplish multi-recurrence work. Furthermore, low-recurrence proportion of the two working frequencies can be acquired by utilizing the stacking strategy [25]. Generally utilized types of stacking openings incorporate rectangular spaces, U-molded furrows and L-formed depressions. Through the modification of the length and width of the hole, the radio wire can accomplish astounding coordinating qualities and multi-recurrence attributes.

3. DESIGN OF MINIATURIZED DUAL-BAND BROADBAND PRINTED ANTENNAS

This part plans a broadband double recurrence printed monopole receiving wire for WLAN, which works in two recurrence groups of 2.4 GHz– 2.52 GHz and 4.5 GHz– 7.5 GHz, covering 2.4 GHz, 5.2 GH and 5.8 GHz, three

working frequencies of WLAN. The addition of 4.4 dB, 4.1 dB and 5 dB are acquired in the most extreme radiation bearing of the three recurrence groups, individuall

Antenna Structure Design

In Figure 3, the structure outline of printed monopole radio wire is displayed. The radio wire is imprinted on the FR4 receiving wire substrate with a relative dielectric steady of 4.4. The span of the substrate is $W_s \times L_s$, the thickness is 1.6 mm. The ground plane of the radio wire is imprinted on the back ground of substrate, whose length and width are spoken to by L_g and W_s , individually. Also, the principle part of the radio wire is imprinted on the facade of the substrate. The reception apparatus is bolstered by a microstrip line with a trademark impedance of 50Ω , and the extent of microstrip line is $W_f \times L_f$. The transmitting component of the receiving wire is made out of two rectangular patches and a T-formed collapsed fix. The length of the rectangular fix is L_2 , and the width is L_3 . The length of the vertical bit of the T-formed is L_4 , the length of level area is L_5 , and the collapsing part is L_6 .

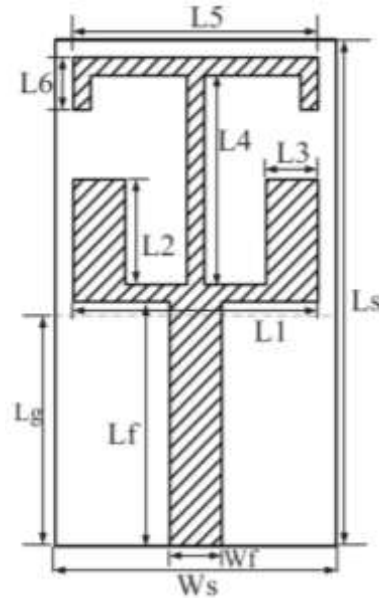


Figure 3. Antenna structure chart.

The Structural Analysis of the Antenna

According to the working principle of the monopole antenna, using the principle of mirror image, the ground plane can be introduced to reduce the length of the half-wave dipole antenna by half, which is equivalent to $1/4$ wavelength of the monopole antenna. Then, the resonant frequency of printed monopole antenna is expressed as:

$$f = \frac{c}{4L\sqrt{\epsilon_r}}$$

where c is the speed of light, L is the resonant path length of the radiator, and ϵ_r is the relative dielectric constant of the dielectric-slab. The antenna adopts a 50Ω microstrip to feed, and the width of the microstrip feeder can be obtained by the following equation:

$$Z_0 = \frac{Z_f}{\sqrt{\epsilon_{eff}} \left(1.393 + \frac{\omega}{h} + \frac{2}{3} \ln \left(\frac{\omega}{h} + 1.444 \right) \right)}$$

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left(1 + 12 \frac{h}{\omega} \right)^{-1/2}$$

In the formula, $Z_f = 376.8 \Omega$ represents free space wave impedance, h represents the height of medium plate, w represents the width of microstrip line, and ϵ_{eff} represents the effective dielectric constant of the dielectric plate.

We run the commercial software Ansoft HFSS to simulate the structure of the antenna. The effects of various parameters on the performance of the antenna are studied in the following.

Changing the scope of L2, which indicates the unit length of rectangular radiation, and keeping different parameters unaltered, the progressions of return misfortune S1 1 with L2 are appeared in Figure 4. It very well may be seen from the assume that L2 for the most part influences the transmission capacity and the full point at a high band. As L2 increases, the full recurrence of 2.4 GHz band moves to one side, the thunderous recurrence at high recurrence fundamentally diminishes, and the coordinating circumstance turns out to be more awful.

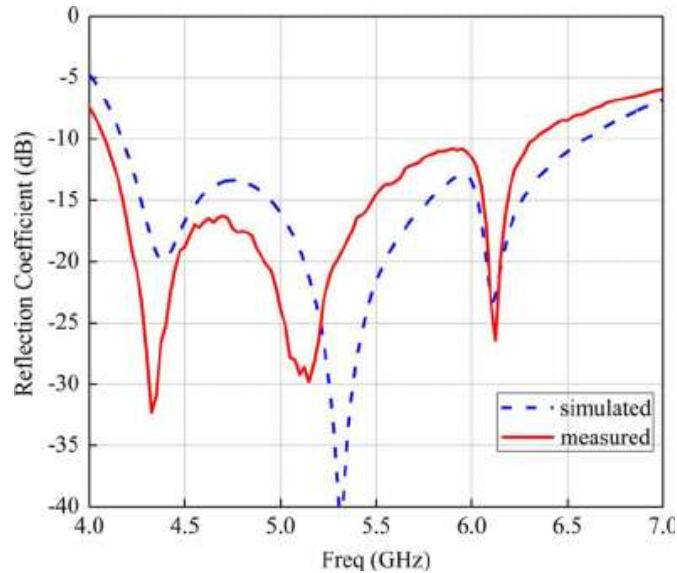


Figure 4. Parameter S_{11} varies with L2.

The width of the rectangular emanating component is L3. Figure 5 represents the aftereffects of S1 1 parameter changes with L3. L3 won't influence the thunderous recurrence of two recurrence groups however will influence the coordinating of the reception apparatus. As L3 increases, the coordinating circumstance turns out to be more awful, and the data transfer capacity is additionally diminished.

The vertical piece of the T-sharped component is L4, and the S1 1 shifts with L4 as appeared in Figure 6. The resounding recurrence of 2.4 GHz band diminishes with the expansion of L4, and the thunderous recurrence of the high recurrence band does not change with the L4. While the L4 increases, the data transfer capacity of the high recurrence band is clearly diminished.

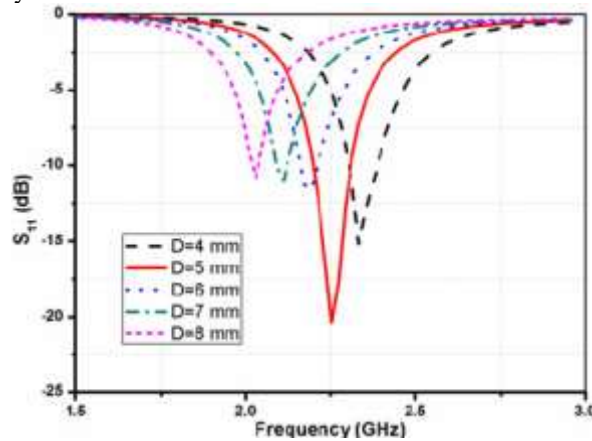


Figure 5. Parameter S_{11} varies with L3.

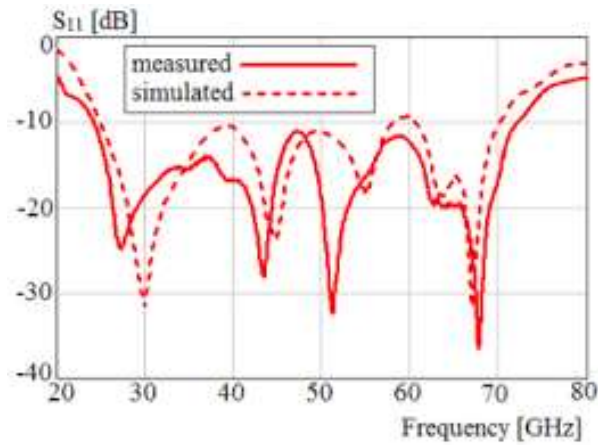


Figure 6. Parameter S_{11} varies with L_4 .

The length of the flat piece of the T-shaped component is L_5 . The estimation of L_5 is changed, and different parameters are consistent, while the progressions of S_{11} with L_5 are appeared in Figure 7. As appeared in the outline, the reverberation recurrence of the low recurrence band diminishes with the expanding of L_5 , and the thunderous recurrence of the high recurrence band does not fluctuate with L_5 .

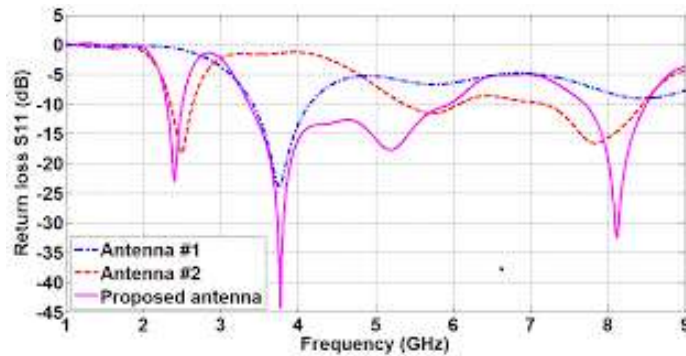


Figure 7. Parameter S_{11} varies with L_5

The folding some portion of the T-shaped unit is L_6 and the progressions of S_{11} with L_6 are appeared in Figure 8. As appeared in the outline, the resounding recurrence of the low recurrence band diminishes with the expanding of L_6 , and the reverberation recurrence of the high recurrence band does not fluctuate with L_6 .

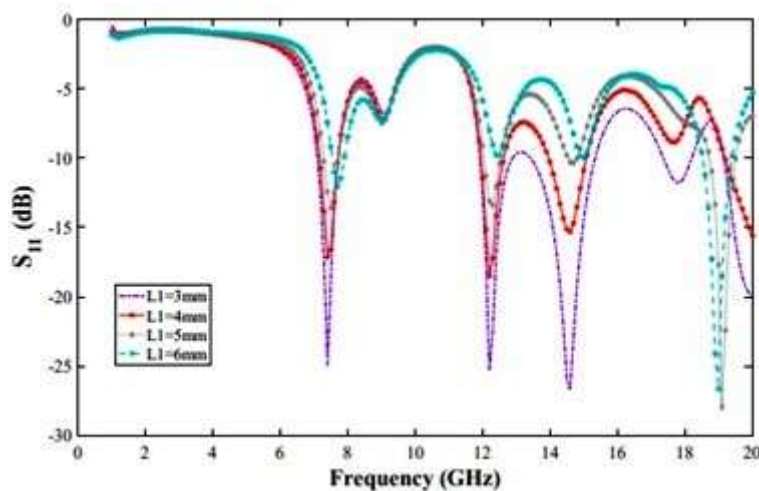


Figure 8. Parameter S_{11} varies with L_6 .

The Results of Antenna Simulation

After optimization, the final parameters of the antenna are shown in Table 1. The overall size of the antenna is 16 mm × 29 mm, the structure is compact, and the horizontal direction of the T-shaped

element is folded down to reduce the antenna size. The miniaturization of the antenna can be applied to the wireless network card and other small devices.

Table 1. The parameters of the optimized antenna

Ws	Ls	Lf	Wf	Lg	L1
16	29	14	3	13	14
L2	L3	L4	L5	L6	H
7	3	12	12	3	1.6

According to the optimized parameters of the antenna, the S_{11} parameter curve of the antenna is shown in Figure 8. The antenna works in the two frequency bands of 4.5 GHz–7.5 GHz and 2.4 GHz–2.52 GHz, the impedance bandwidth reaches 3 GHz and 120 MHz, respectively, covering the 2.4 GHz, 5.2 GHz and 5.8 GHz three operating frequency bands of WLAN. In addition, the working broadband is realized.

4. DESIGN OF DUAL-BAND MICROSTRIP ANTENNA

In this area, the plan of the rectangular double band microstrip receiving wire for WLAN is examined. The impact of various space styles on the radio wire execution is examined. A microstrip radio wire with a ventured depression is planned and improved, and the double band activity is acknowledged by opening a couple of symmetrically collapsed furrows. The receiving wire works in two recurrence groups of 2.4 GHz– 2.46 GHz and 5.16 GHz– 5.4 GHz, and the reception apparatus addition can accomplish 4 dB in a large portion of the working frequencies. The receiving wire fix is a square fix whose length of a side is 25 mm, which guarantees the suitable increase of the reception apparatus while decreasing the volume of the radio wire.

Radio wire Structure Design

The radio wire structure is appeared in Figure 9. The reception apparatus is imprinted on a square FR4 substrate, the thickness and length of which are 1.6 mm and L_s , individually. The emanating component of the radio wire is a square fix, whose measure length is L_0 . The method of encouraging embraces the coaxial nourishing of trademark impedance 50Ω , and the separation from the feed point to the focal point of the fix is x_p . Likewise, the device cut space is opened on the contrary sides of the reception apparatus, the length and width of each progression are every one of the 1 mm, the all out length of the stepping stool formed notch is L_1 , and the all out width is W_1 . We mimic the plan of the receiving wire with the reproduction programming HFSS.

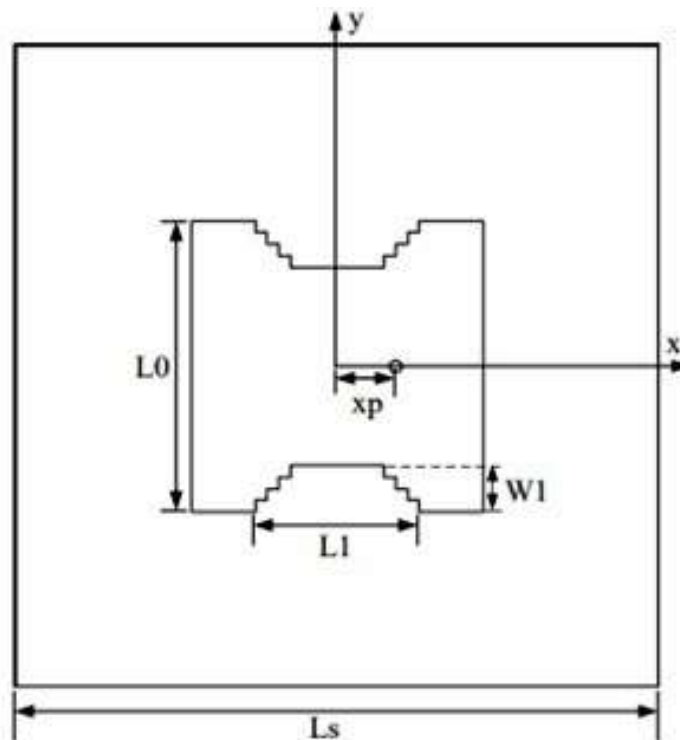


Figure 9. Antenna structure.

Improved Dual-Band Microstrip Antenna

So as to arrange of the third recurrence point, we presently improve the receiving wire structure appeared in Figure 11. We open two symmetrical collapsing shape spaces based on the above receiving wire, the improved radio wire structure as appeared in Figure 12. The length of opened level segment is L_2 , the length of collapsible segments is L_3 , and the length of vertical segment is W_2 . In Figure 12, the length of dielectric section is $L_s = 55$ mm, the length of square fix of reception apparatus is $L_0 = 25$ mm, and the extent of stepping stool molded furrow is $L_1 = 14$ mm, $W_1 = 4$ mm. The measure of the collapsing groove is $L_2 = 8$ mm, $W_2 = 4.5$ mm, $L_3 = 7$ mm, and the separation from the fix focus to the feed point is $x_p = 4.5$ mm. As indicated by the parameters of the improved radio wire, the reenactment results are as per the following.

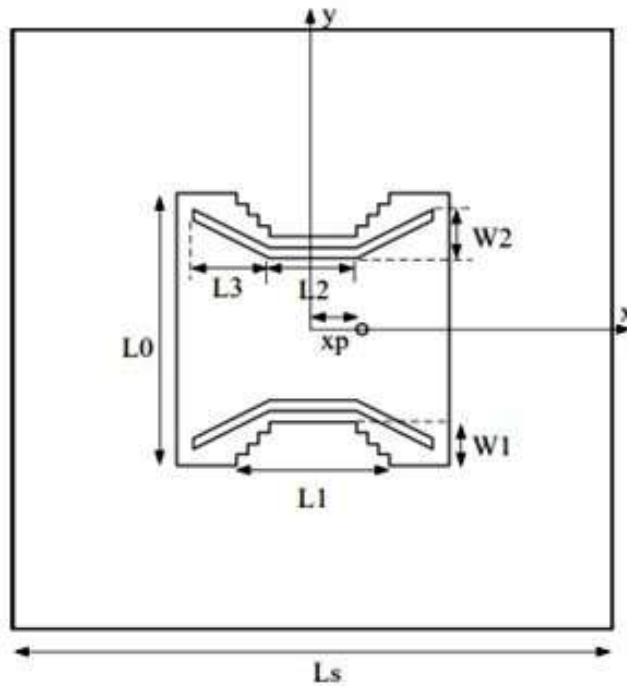


Figure 11. Improved antenna structure.

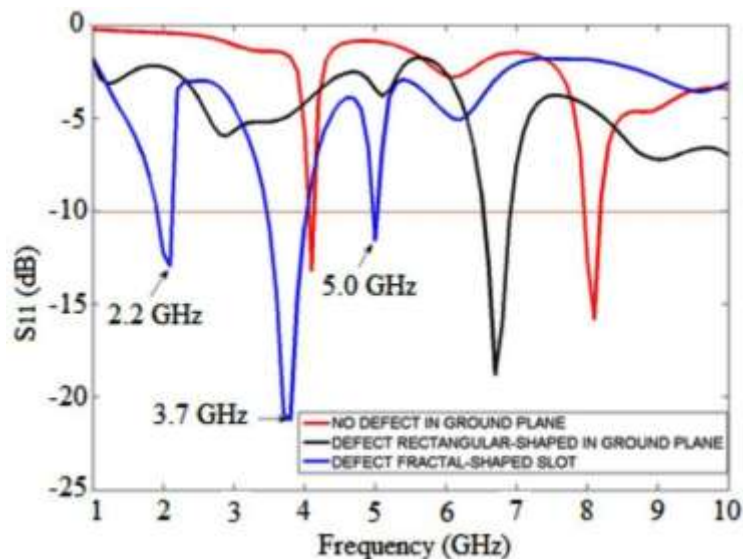


Figure 12. The gain of the improved antenna (a) 2.2 GHz; (b) 5 GHz.

5. CONCLUSION

In this paper, two double band reception apparatuses as indicated by the interest of WLAN for multi recurrence correspondence are structured. One of them is a double band printed monopole radio wire, which works in two recurrence groups of 2.4 GHz– 2.52 GHz and 4.5 GHz– 7.5 GHz, and the impedance data transfer capacity

achieves 120 MHz and 3 GHz, separately, covering 2.4 GHz, 5.2 GHz and 5.8 GHz three working recurrence groups of WLAN. Moreover, the addition of the radio wire is more prominent than 4 dB, and the volume of this reception apparatus is just $16 \times 29 \times 1.6 \text{ mm}^3$, executing the scaling down of the receiving wire. The second radio wire is a double band small scale strip receiving wire, which works in two recurrence groups of 2.4 GHz–2.46 GHz and 5.16 GHz–5.4 GHz, and understands the scaling down and double band activity by receiving the opening innovation. The two structured reception apparatuses have a higher increase and a great transmission

trademark in the working band, which is as per the necessities of WLAN correspondence under increasingly convoluted conditions.

REFERENCES

- [1] Park, H.; Ghovanloo, M. Wireless Communication of Intraoral Devices and Its Optimal Frequency Selection. *IEEE Trans. Microw. Theory Tech.* 2014, 62, 3205–3215.
- [2] Ngan, T.L.; Wong, E.T.H.; Ng, K.L.S.; Jeor, P.K.S.; Lo, G.G. The Enhanced Workflow and Efficiency of the Wireless Local Area Network (WLAN)-Based Direct Digital Radiography (DDR) Portable Radiography. *J. Digit. Imaging* 2015, 28, 302–308.
- [3] Joseph, W.; Pareit, D.; Vermeeren, G.; Naudts, D.; Verloock, L.; Martens, L.; Moerman, I. Determination of the duty cycle of WLAN for realistic radio frequency electromagnetic field exposure assessment. *Progr. Biophys. Mol. Biol.* 2013, 111, 30–36.
- [4] Ziegler, V.; Schulte, B.; Sabater, J.; Bovelli, S.; Kunisch, J.; Maulwurf, K.; Grass, E. Broadband 57–64 GHz WLAN communication system integrated into an aircraft cabin. *IEEE Trans. Microw. Theory Tech.* 2012, 60, 4209–4219.
- [5] Aruna Rai Vadde, Ravali Sada Shiva rao. Peripheral Interface Controller (PIC) Based on Brown-Out Reset of Zigbee Technology *Global Journal of Engineering Science and Research* 2015, 60–67
- [6] Mehdipour, A.; Denidni, T.; Sebak, A.R. Multi-band miniaturized antenna loaded by ZOR and CSRR metamaterial structures with monopolar radiation pattern. *IEEE Trans. Antennas Propag.* 2014, 62, 555–562.
- [7] Khodabakhshi, H.; Cheldavi, A. Irradiation of a six-layered spherical model of human head in the near field of a half-wave dipole antenna. *IEEE Trans. Microw. Theory Tech.* 2010, 58, 680–690.
- [8] Islam, M.S.; Esselle, K.P.; Bull, D.; Pilowsky, P.M. Converting a wireless biotelemetry system to an implantable system through antenna redesign. *IEEE Trans. Microw. Theory Tech.* 2014, 62, 1890–1897.
- [9] Lee, E.; Hall, P.; Gardner, P. Novel Compact Wideband or Multi-Band Planar Monopole Antenna. In *Proceedings of the IEEE Antennas and Propagation Society International Symposium, Salt Lake City, UT, USA, 16–21 July 2000*; pp. 624–627.
- [10] Shi, J.; Wu, X.; Chen, Z. N.; Qing, X.; Lin, L.; Chen, J.; Bao, Z.H. A Compact Differential Filtering Quasi-Yagi Antenna with High Frequency Selectivity and Low Cross Polarization Levels. *IEEE Antennas Wirel. Propag. Lett.* 2015, 14, 1573–1576.
- [11] Lu, H.D.; Si, L.M.; Liu, Y. Compact planar microstrip-fed quasi-Yagi antenna. *Electron. Lett.* 2012, 48, 140–141.
- [12] Fujimoto, T.; Yoshitake, Y. Stacked microstrip antenna fed by an L-probe for quadruple band operation. *IET Microw. Antennas Propag.* 2014, 9, 360–368.
- [13] Wu, P.; Liu, J.R.; Xue, Q. Wideband Excitation Technology of TE₂₀ Mode Substrate Integrated Waveguide (SIW) and Its Applications. *IEEE Trans. Microw. Theory Tech.* 2015, 63, 1863–1874.
- [14] Liu, Y.; Hao, Y.; Wang, H.; Li, K.; Gong, S. Low RCS Microstrip Patch Antenna Using Frequency Selective Surface and Microstrip Resonator. *IEEE Antennas Wirel. Propag. Lett.* 2015, 14, 1290–1293.
- [15] Hsu, H.; Kuo, F.; Lu, P. Design of Wifi/WiMAX dual-band E-shaped patch antennas through cavity model approach. *Microw. Opt. Technol. Lett.* 2010, 52, 471–474.
- [16] Ali, M.T.; Dzulkefli, N.; Abdullah, R.; Omar, S. Design and analysis of microstrip Yagi antenna for Wi-Fi application. In *Proceedings of the 2012 IEEE Asia-Pacific Conference on Applied Electromagnetics, Melaka, Malaysia, 11–13 December 2012*; pp. 283–286.
- [17] Pereira, J.P.P.; da Silva, J.P.; de Andrade, H.D. A new design and analysis of a hexagonal PBG microstrip antenna. *Microw. Opt. Technol. Lett.* 2015, 57, 2147–2151.
- [18] Parmanand, S.; Swastik, G. Bandwidth and gain enhancement in microstrip antenna array for 8 GHz frequency applications. In *Proceedings of the 2014 Students Conference on Engineering and Systems, Allahabad, India, 28–30 May 2014*; pp. 1–6.

- [19] Yang, Z.X.; Yang, H.C.; Hong, J.S.; Li, Y. Bandwidth enhancement of a polarization-reconfigurable patch antenna with stair-slots on the ground. *IEEE Antennas Wirel. Propag. Lett.* 2014, 13, 579–582.
- [20] Souza, R.D.; Gupta, R.K. Printed dual band WLAN antenna. In *Proceedings of the IEEE International Conference Electro/Information Technology, Bhubaneswar, India, 18–21 December 2006*; pp. 539–543.
- [21] Peng, C.M.; Chen, I.F. Modeling printed monopole antenna with coplanar ground-plane by gaussian filter model analysis. *Int. J. Appl. Electromagn. Mech.* 2011, 36, 243–251.
- [22] Yu, Y.; Hui, H.T. Design of a mutual coupling compensation network for a small receiving monopole array. *IEEE Trans. Microw. Theory Tech.* 2011, 59, 2241–2245.
- [23] Zhu, H.L.; Cheung, S.W.; Yuk, T.I. Miniaturization of patch antenna using metasurface. *Microw. Opt. Technol. Lett.* 2015, 57, 2050–2056.
- [24] Sharma, S.; Daya, K.S.; Sharma, S.; Batoo, K.M.; Singh, M. Sol-gel auto combustion processed soft Z-type hexanoferrites for microwave antenna miniaturization. *Ceram. Int.* 2015, 41, 7109–7114.
- [25] Kundu, A.; Chakraborty, U.; Bhattacharjee, A.K. Design of compact dual-band co-axially fed microstrip antenna for 2.4/5.2/5.8 GHz WLAN applications. *J. Electromagn. Waves Appl.* 2015, 29, 1535–1546.