International Journal of Latest Trends in Engineering and Technology
Vol.(11)Issue(2), pp.023-028
DOI: http://dx.doi.org/10.21172/1.112.05
e-ISSN:2278-621X

A RETURN LOSS IMPROVEMENT OF SLOTTED SQUARE MICROSTRIP INSET-FEED PATCH ANTENNA

Dhurgham Abdulridha Jawad Al-Khaffaf[1], Ali M. Alsahlany[2]

Abstract- A simple square microstrip inset-feed patch antenna with slots for 2.4 GHz of WLAN applications is presented. Our proposed antenna design is a high gain, bandwidth, very low return loss and single band frequency. The antenna is capable to realize return loss (S11) of -45 dB and voltage standing wave ratio (VSWR) equals (1). The antenna can support WLAN applications at 2.4 GHz resonant frequency with bandwidth of 76.278 MHz. The antenna is excited by one port with microstrip inset feed line mechanism. The designed antenna is printed on Flame Retardant 4 (FR-4) substrate with 4.6 dielectric constant. The conducting patch and ground antenna material is copper (annealed). The square microstrip patch antenna has dimensions of 28.45 x 28.45 x 0.035 mm3 of patch plane. The omnidirectional radiation pattern of our antenna is 6.25 dBi. The proposed antenna has been simulated and analyzed through CST microwave studio (MWS) version 2018. The simulation results show that our proposed antenna is considered as a greet solution with an excellent performance to meet the requirements of various modern communication systems.
Keywords –Square microstrip patch antenna, Square patch antenna (SPA), WLAN, Inset feed mechanism, 2.4 GHz antenna, ISM band, CST software, Return loss and Microstrip feed line.

1. INTRODUCTION

Today, The Wireless Local Area Network (WLAN) and Bluetooth are considered one of the most widely used wireless network by users to receive and transmit data. Most of the modern devices such as Mobile, Smartphone, Microwave, laptops, etc. are equipped with the tools required to operate these networks. Scientists and developers are moving towards to start a new revolution in the communication engineering field through connecting and control all electronic and mechanical devices wirelessly [1]. Many researchers show possibility of relying upon these two networks to perform this purpose [1-2]. The WLAN uses 11 channels with frequency range start from 2.4 GHz until 2.484 GHz with bandwidth 20 MHz for each channel [3]. The Bluetooth network works on the Frequency Hopping Spread Spectrum (FHSS) technique and uses a frequency range start from 2.4 and ended at 2.480 GHz [4]. In any wireless communication system, the data transmit and receive in a fast and reliable way depending on the reflection in the antenna subsystem [5]. In the modern communication system, the antenna must be resisted to the interference, works on a large frequency bandwidth, satisfy maximum radiation efficiency, easy to fabricate and has a small size [5]. A microstrip antenna has all needed features that satisfy the above purpose [6]. The microstrip antenna constructs from three main parts: a dielectric medium called substrate having a particular value of dielectric constant surrounded by two sides, the first one is a ground plane and the other is a radiation patch. The simple structure of a microstrip antenna is presented in Fig. 1.

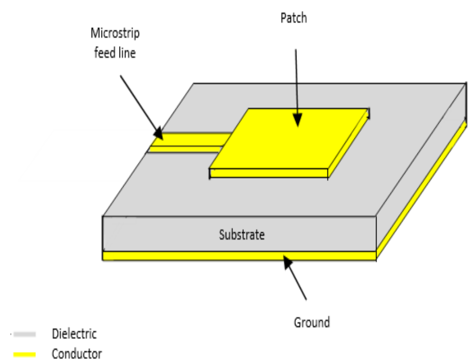

Figure 1: The basic concept of microstrip patch antenna design.

[1,2] Department of Communication Techniques Engineering, Engineering Technical College/Najaf, Al-Furat Al-Awsat Technical University, Najaf, Iraq

The radiation patch constructed from a metal such as gold or copper. The patch dimensions are determining the shape of the antenna and it is smaller comprised to the ground plane and the substrate. There are many geometric shapes of the patch such as; square, circular, elliptical, rectangular and others. The resonant frequency of the microstrip antenna depends on the patch dimensions, dielectric constant and feeding technique [7-8]. The feeding technique means the used method to transmit electromagnetic energy to a patch [9].

There are many authors have been designed a microstrip antenna works on the resonant frequency 2.4 MHz. As in [10-11], the authors designed a rectangular microstrip antenna using different substrate material. The study in [10] used the hydrocarbon ceramic laminate (RO4350B) substrate with dielectric constant 3.66, while e.g. in [11] using the Flame Retardant 4 (RF4) with 4.4 of the relative permittivity. The minimum values of return loss obtained was -28.15 dB and -14.42 dB for RO4350B and RF4, respectively. Also, M. Karthick [12] proposed a novel design of a rectangular microstrip antenna with patch dimensions 29.2 x 29.2 x 1.6 mm3 with FR-4 material of substrate and dielectric constant 4.8, in this novel design, the obtained return loss value was -39.008 dB with 22 MHz of bandwidth. In all references mentioned above the electromagnetic energy was fed to the radiation patch using the inset feed technique. S. Singh1 et al. [13] designed a microstrip antenna using a different feed technique by HFSS simulator. They used prop (coaxial feed) as a feeding technique. In this technique, the core of the coaxial connector soldered to the patch after extended through the substrate, while the shield conductor is joined to the ground plane. The simulated results shown that the return loss obtained was -12.0505 dB. The lower return loss value -40 dB is achieved by designing a slotted rectangular patch antenna proposed by A. Sarma et al. [3].

This research presents a new and simple design of square microstrip patch antenna with dual slots on each edges and inset feed line mechanism. The antenna design has patch dimensions of 28.45 x 28.45 x 0.035 mm3 with two slits on each one of its edges. The conducting and dielectric materials of the antenna are the copper (annealed) and RF4 material, respectively. Since ISM band can serve the most of wireless communication systems, the antenna is designed to operate on the resonant frequency of 2.4 GHz. This optimized model of microstrip patch antenna achieves satisfactory performance with very low return loss, good gain and bandwidth.

The rest of the paper is organized as follows. Section II debates the analytical analysis and design of the proposed antenna. Section III discusses the mathematical constraints of antenna design. The simulation results and discussion are presented in section IV. Finally, section V summarizes the main point of this paper.

2. ANTENNA DESIGN CONSIDERATIONS

In this section, we will focus on the antenna materials parameters of ground, substrate and patch. The antenna materials should be precisely chosen with regarding the antenna size, cost and performance. According to Sami et al. [14], the patch parameters is wisely chosen such as feed line position and mechanism, thickness and length. The desired band can be determined by shorting pin position, which modifies the field distribution and excites inductive loading to the patch in turns will change its resonant frequency. Some researchers as in [15] investigates that cutting slots or notch parallel on the radiating edges can add reactive load to adjust the equivalent circuit of the loaded patch in order to alter the dual frequencies. In our scheme, we adjust the slots to affect the resonant frequency, return loss,gain, directivity, etc. As a reported in [16-17, 18], there are some restrictions in microstrip antenna design such as the patch length limitations , where $\lambda 0$ indicates the free-space wavelength, and the thickness should be very thin ( ). Moreover, the height of substrate is usually limited to ( ), and the substrate should have a dielectric constant within the range ( ). The low loss tangent of substrate can reduce the dielectric power loses in the antenna. So, all these criteria have been considered in our proposed antenna design as discussed in following section.

3. DESIGN OF THE PROPOSED ANTENNA

Figure 2 shows the geometric shape of the proposed square microstrip inset-feed patch antenna with slots. The antenna constructed from three layers, one placed above the others. The first layer is the ground plane. This layer is placed on the bottom and made from copper (annealed) material with identical dimensions to the substrate except the thickness, which is 0.035 mm. The second one is the substrate, printed on RF4 material, which has a dielectric constant (permittivity) = 4.6. The volume of the square shaped of substrate is 56.9 x 56.9 x 1.6 mm3, which represents the length, width and height, respectively. Finally, the main and most important layer of the antenna is the patch, which is the radiating part.

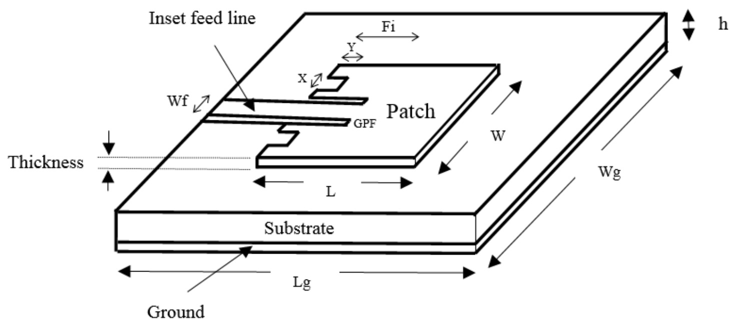

Figure 2: A schematic diagram of the slotted square microstrip inset feed patch antenna geometry with parameters and its values.

The patch is also made from the copper (annealed) and has a square geometric shape. The entire side length of the square patch is 28.45 mm, and the thickness is 0.035 mm. The width and length of square patch antenna can be calculated by the following equations, as a described in [12, 16-18].

$$W_p = \frac{c}{2f\sqrt{\frac{\varepsilon_r+1}{2}}} \quad (1)$$

$$L_p = \frac{c}{2f\sqrt{\varepsilon_{reff}}} - 2\Delta L \quad (2)$$

where is the dielectric constant (relative permittivity) of the substrate, f is the operating frequency, denotes the effective dielectric constant and c is the light speed in vacuum. The effective length of the patch (Leff) is the actual length (L) of the patch plus the extended distance , where and are given via:

$$\Delta L = 0.412h \frac{(\varepsilon_{reff} + 0.3)\left(\frac{W_p}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W_p}{h} + 0.8\right)} \quad (3)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + \frac{12h}{W_p}\right]^{-\frac{1}{2}} \quad (4)$$

The ground and substrate layer dimensions are calculated by Equations. (5) and (6) below.

$$L_g = 2W_p \quad (5)$$

$$W_g = 2W_p \quad (6)$$

For square shape microstrip patch antenna (SMSA), the width is same as length for both patch, substrate and ground elements. According to John et al. [8], the width of the strip line (Ws) is calculated via Eq. (7).

$$\frac{W_s}{h} = \begin{cases} \frac{8e^A}{e^{2A} - 2}, & for\frac{W_s}{h} \leq 2 \\ \frac{2}{\pi}\left[B - 1 - \ln(2B - 1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}\left\{\ln(B - 1) + 0.39 - \frac{0.61}{\varepsilon_r}\right\}\right], & for\frac{W_s}{h} > 2 \end{cases} \quad (7)$$

where A and B are given by:

$$A = \frac{z_0}{60}\sqrt{\frac{\varepsilon_r + 1}{2}} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1}\left(\frac{0.0253}{\varepsilon_r}\right) \quad (8)$$

$$B = \frac{377\pi}{2 \times z_0 \times \sqrt{\varepsilon_r}} \quad (9)$$

where denotes the characteristics, the length of strip (l) is

$$l = \frac{\lambda_g}{4} \quad (10)$$

where λg is the wavelength in dielectric layer, which can be calculated by:

$$\lambda_g = \frac{c/f}{\sqrt{\varepsilon_{reff}}} = \frac{\lambda_0}{\sqrt{\varepsilon_{reff}}} \quad (11)$$

In this work, central feed line is used for microstrip antenna. This will give an excellent performance and a match with the patch. The used feeding technique is the contacting mechanism which is simple to model and easy to fabricate due to the patch is directly excited to the conducting strip. A such manner, the microstrip line may be placed at any position and the impedance matching will be easy. According to John et al. [8], the inset feed line length of microstrip patch antenna is calculated by the following formula.

$$l = 10^4 (0.001699\,\varepsilon_r^7 + 0.13671\,\varepsilon_r^6 - 6.1783\,\varepsilon_r^5 + 93.187\,\varepsilon_r^4 - 682.69\varepsilon_r^3 + 2561.9\varepsilon_r^2 - 4031\,\varepsilon_r + 6697)\,\frac{L}{2} \quad (12)$$

There are two slots on each one of the patch edges. The gap between patch and feed line (GPF) has a 1 mm width and 8 mm of feed inset depth the patch (Fi). The second slot has x and y dimensions which are equals 3 mm and 1.5 mm, respectively. The patch has above slots on each the right and left sides of the line feed. In this proposed design, the patch is excited to radiate the electromagnetic energy by using the inset-feed technique through the microstrip rectangular feed. The rectangular feed has been built from the same material used to build the patch. The antenna feeds by positive y-direction. It has a l= 14.225 mm of length and Wf = 1.137 mm of width, and the thickness is 0.035 mm. The proposed antenna design simulated by using CST software. The next section presents the simulation results and analysis of our proposed antenna design.

4. SIMULATION RESULTS AND DISCUSSION

The antenna architecture is successfully designed via using CST microwave studio software version 2018 as shown in Fig. 3, and various tests is done to gather the data for analyzing and calculating results. The simulation is focused on the return loss, gain, directivity, VSWR, surface current, bandwidth and radiation pattern.

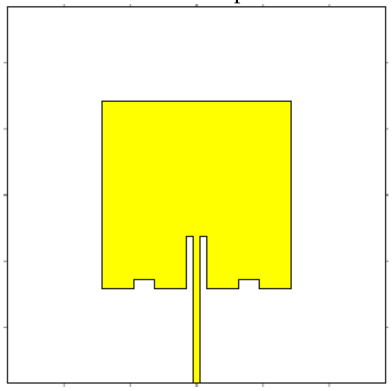

Figure 3: CST simulation setup of slotted square microstrip inset feed patch antenna design using CST software with copper (annealed) material for patch plane.

To investigate the efficiency of the proposed slotted square antenna there many parameters such as Return loss (S11), the Voltage Standing Wave Ratio (VSWR), and far-field directivity and gain must be discussed. The ratio of the reflected power from the proposed antenna to transmit power which mean the S11 which is a function of frequency as shown in Fig. 4. It is clearly seen that there is an efficient matching between the transmitter and the proposed antenna where the S11 obtained is -45 dB at resonant frequency 2.4 GHz. The minimum amount of return loss indicates that the antenna has a low of lost power to be returned as reflected form the load.

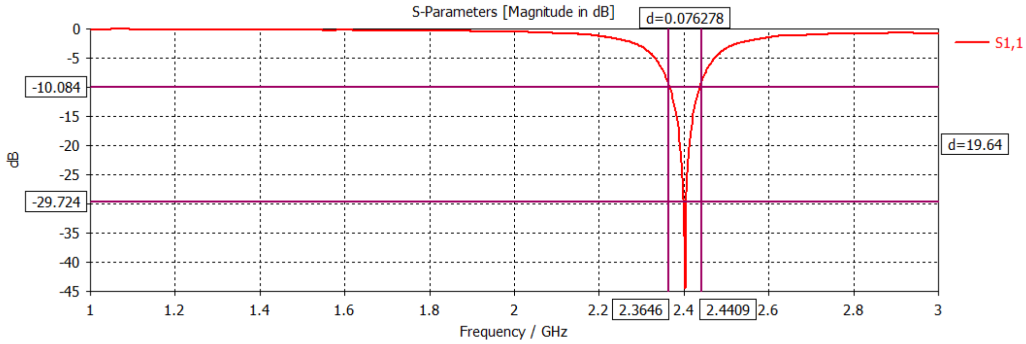

Figure 4: Return loss (S11) of the proposed a square microstrip inset feed patch antenna with demonstration of the bandwidth.

The supporting antenna bandwidth is 76.278 MHz at -10 dB from 2.3646 GHz to 2.4409 GHz. The VSWR describes the performance of antenna adaptation to the transmission line, the perfect match is unity as agreed with our simulation results of the VSWR. The curve in Fig. 5 shows the VSWR values as a function of frequency range. At the resonant frequency the VSWR is recorded to be 1.0119, which is considered a typical value.

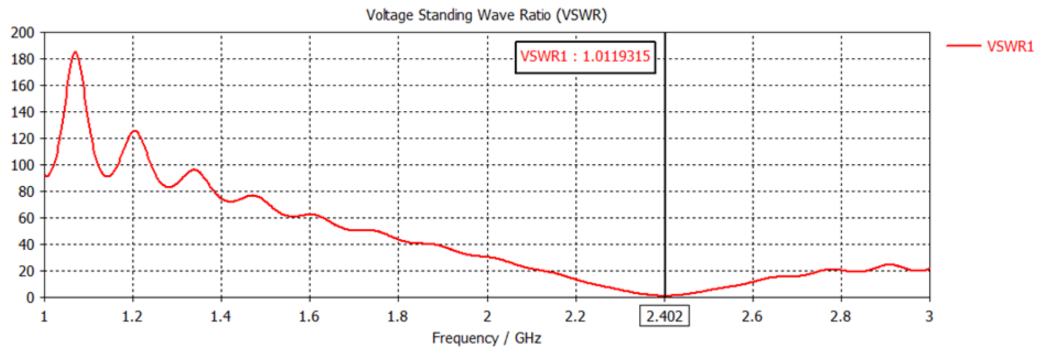

Figure 5: Shows the VSWR of proposed square microstrip inset feed patch antenna.

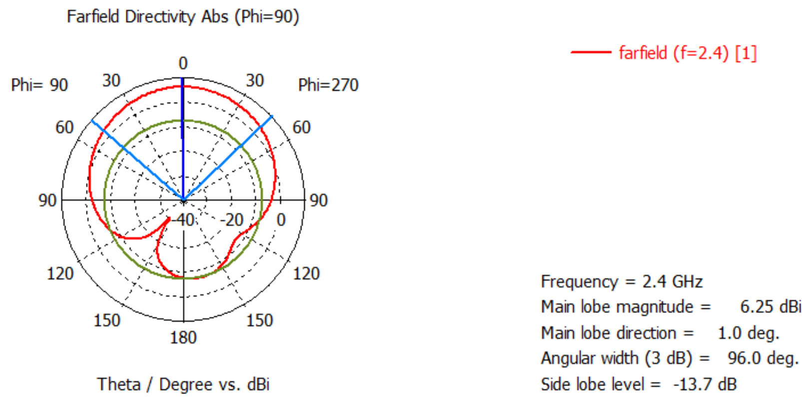

Figure 6: Radiation pattern of the proposed square microstrip antenna.

The far-field directivity (radiation pattern) propagated from the proposed antenna at 2,4 GHz in its coverage area to a specific direction is shown in Fig. 6. The simulation results show that the main lobe magnitude of the directivity is 6.25 dBi and the angular width (3 dB) is 96 degrees. The main lobe has a 1 degree of direction. Also, it is clearly seen that the proposed antenna has an omnidirectional radiation pattern. This pattern is suitable for WLAN and Bluetooth applications. Figure 7 describes the distribution of the current surface of our proposed antenna at 2.4 GHz.

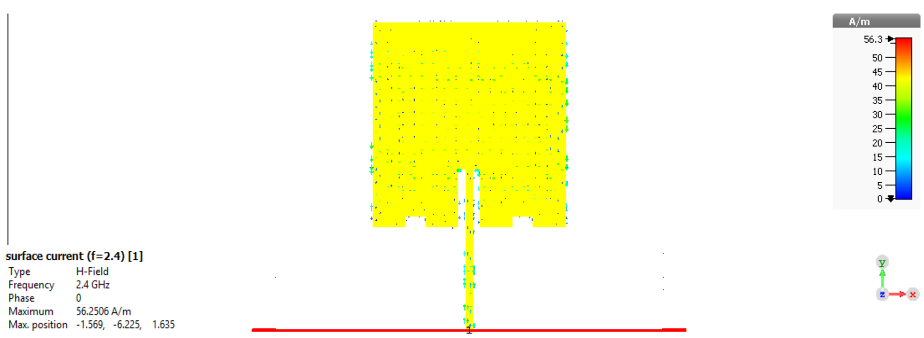

Figure 7: Surface current of the proposed square microstrip antenna.

5. CONCLUSION

This article has been investigated a new slotted square microstrip inset feed patch antenna for most commonly applications such as WLAN system via using CST software. A reliable performance is achieved in terms of gain, directivity, return loss and bandwidth. Our proposed antenna scheme has perfectly matched for WLAN systems such as IEEE 802.11b/g/n and Bluetooth. Moreover, the antenna uses a cost-effective material of substrate such as FR-4, which has a very low price. Therefore, the proposed antenna can be easily manufactured with low cost and optimum performance. The proposed antenna has a good gain and bandwidth, also, it has an excellent reflection coefficient and typical voltage standing wave ratio. More work could be achieved in the future in respect of antenna fabrication and testing its performance and compares the simulation and fabrication results. In addition, it can extend the work to do array antenna design such as 2x2 and 4x4 array antenna.

6. REFERENCES

[1] Ranjan, R., et al., “The Next Grand Challenges: Integrating the Internet of Things and Data Science,”IEEE Cloud Computing, vol. 5, pp. 12-26,2018.

[2] Ferro, E., & Potorti, F.,“Bluetooth and Wi-Fi wireless protocols: a survey and a comparison,”IEEE Wireless Communications, vol. 12, pp. 12-2,2005.

[3] Sarma, A., Sarmah, K., & Sarma, K. K., “Low return loss slotted rectangular microstrip patch antenna at 2.4 GHz,”In Signal Processing and Integrated Networks (SPIN), 2015 2nd International Conference on IEEE., pp. 35-39. 2015.

[4] Tiwari, N., Nagwanshi, D. N., & Dwivedi, S.,“Design of U-Shape microstrip patch antenna for Bluetooth application at 2.4 GHz,”International Journal of Innovation and Scientific Research, vol. 6, pp. 92-96,2014.

[5] Yang, J., Wang, H., Lv, Z., & Wang, H, “Design of miniaturized dual-band microstrip antenna for WLAN application”. Sensors, vol. 16, pp. 1-15,2016.

[6] Abdullah-Al-Mamun, M., Datto, S., & Rahman, M. S., “December. Performance Analysis of Rectangular, Circular and Elliptical Shape Microstrip Patch Antenna using Coaxial Probe Feed,” In 2017 2nd International Conference on Electrical & Electronic Engineering (ICEEE),2017.

[7] Afridi, M. A., “Microstrip patch antenna− designing at 2.4 GHz frequency,”Biological and chemical research, pp. 128-132, 2015.

[8] John, M., Ayyappan, M., Manoj, B., & Rodrigues, S., “Bandwidth enhancement of microstrip patch antenna for 5.8 GHz by optimized feed offset,” In Communication and Signal Processing (ICCSP), 2016 International Conference on IEEE., 2186-2189, 2016.

[9] Sudarsan, A., & Prabhu, A., “Design and Development of Microstrip Patch Antenna,”International Journal of Antennas (JANT),vol. 3, pp. 1-12, 2017.

[10] Ahmed, K. F., & Abdullah, R. H, “Design and Simulation of Microstrip Patch Antenna for Wireless Applications,”Kurdistan Journal of Applied Research, vol. 2, pp. 365-368, 2017.

[11] Jadhav, S., & Veeresh, P. M.,“Design and Implementation of Rectangular Microstrip Patch Antenna for 2.4 Ghz Wireless Applications,”Imperial Journal of Interdisciplinary Research, vol. 3, pp. 325-328,2016.

[12] Karthick, M., “Design of 2.4 GHz patch antennae for WLAN applications,”In Computing, Communication and Information Systems (NCCCIS), 2015 IEEE Seventh National Conference on IEEE. pp.4-1 ,2015.

[13] Shera Prabjyot Singh, et al., “Design and Fabrication of Microstrip Patch Antenna at 2.4 Ghz for WLAN Application using HFSS,” pp. 1-6,2016.

[14] Sami, G., Mohanna, M. and Rabeh, M.L., “Tri-band microstrip antenna design for wireless communication applications,”NRIAG Journal of Astronomy and Geophysics, vol. 2, pp.39-44,2013.

[15] Mishra, A., Singh, P., Yadav, N.P., Ansari, J.A. and Vishvakarma, B.R., “Compact shorted microstrip patch antenna for dual band operation,”Progress In Electromagnetics Research, vol. 9, pp.171-182,2009.

[16] Yadav, M.B., Singh, B. and Melkeri, V.S., “April. Design of rectangular microstrip patch antenna with DGS at 2.45 GHz”In Electronics, Communication and Aerospace Technology (ICECA), 2017 International conference ofIEEE,vol. 1, pp. 367-370,2017.

[17] Altaf, A., Mahmood, K., Munir, M. and Kiani, S.H., “A High Gain MIMO Antenna for Fixed Satellite and Radar Applications,”(IJACSA) International Journal of Advanced Computer Science and Applications, vol. 9, pp. 248-251. 2018.

[18] Mounsef, A., Tabakh, I., El Bakkali, M., El Gholb, Y. and El Idrissi, N.E.A., “Design and simulation of a dual band microstrip patch antenna for an emergency medical service system,”In Wireless Networks and Mobile Communications (WINCOM), 2017 International ConferenceonIEEE, pp. 1-4, 2017.