Dual-wide Band bended cloth Antenna for ISM and WLAN applications

Fatimah Fawzi Hashim*, **Wan Nor Liza Mahadi**, **Tarik Abdul Latef** and **Mohamad Ariff**

Faculty of Electrical Engineering, Universiti of Malaya, Kuala Lumpur 50603, Malaysia.

*Corresponding author: kva190028@siswa.um.edu.my

Abstract: A directional bended microstrip patch antenna was designed for dual-band ISM applications. CST (2014) was used to simulate an antenna with the dimension of 50 x 20 x 1.04 mm and felt substrate with partial copper ground. This antenna was operated at 2.4 GHz and 5.0 GHz with gains of 1.6 dBi and 5.61 dBi and bandwidths of 40% and 75%. The proposed antenna was bended to cater the human body curves. The proposed bended structure gave a high performance in free space, and the results were found identical with the phantom simulation results. This antenna is deemed suitable to be built in clothes for WBNs applications.

Keywords: Dual-band, bended antenna, high gain, ISM, wide-band.

Article History: received 25 May 2021; accepted 12 June 2021; published 28 August 2021.

1. INTRODUCTION

The rapid development in the mobile and wireless communications systems, accompanied with an increasing demand for smaller low-cost and high-performance antennas that can be easily integrated with this small modern device [1], [2]. Microstrip patch antennas have proved to be more beneficial than conventional antennas, such as low profile, easy to fabricate, lightweight, and low production cost. Recently, ISM applications are widely used given the increasing need for small, compact, and high-performance components. Therefore, researchers have been working on developing and improving the performance of wearable antennas to make them more suitable for these devices with the consideration of human body.

The requirement of wider frequency band, smaller size, and easier to fabricate, and a high radiation efficiency and anti-interference performance, and other characteristics [3] it has become essential to work on it and develop it to meet the needs of commonly used applications. Therefore, exploring dual wide band in antennas has become an important issue in the field of antennas [4][5].

The use of dual-band wearable microstrip antennas in WLAN and ISM applications has been recently explored, and numerous dual-band antenna types have been proposed, such as [5], the presented antenna in this paper is operated at 2.4 GHz and 5 GHz and FR4 used as a substrate and deeded by coaxial feeder .[6] One of the main advantages of small-sized antenna is its compatibility with the human body curves, as it is bended. [7] In this study, a 2 x 2 array was used to enhance the performance of patch antenna, and the behaviour of a circularly polarised array at an inclusive range of fold angles and impact of physical reconfiguration were evaluated. [8] The proposed antenna increased the impedance bandwidth from 2.9% (of a standard flat microstrip patch) to 9.0% [9]. Outcomes in this paper demonstrated that the proposed system is a good design choice of microstrip antenna for Bluetooth, Wi-Fi, Wi-MAX, Telemedicine, and UWB applications. Depending on the system results, such as good impedance bandwidth, radiation pattern, directivity, and relatively constant gain over the entire band of frequency comparing with the earlier methods. In another study, the proposed antenna was specifically design for MIMO system at four different frequencies (2.5 GHz, 3.5 GHz, 5.2 GHz, and 7.0 GHz) [10] when compared this work to the recent systems we conclude it is better. This system is designed for WLAN and WiMAX.

This paper is organised as follows: Section 2 introduces the design of bended microstrip patch antenna; Section 3 describes the antenna performance and analysis in free space and the performance of the phantom models; Section 4 concludes the overall study.

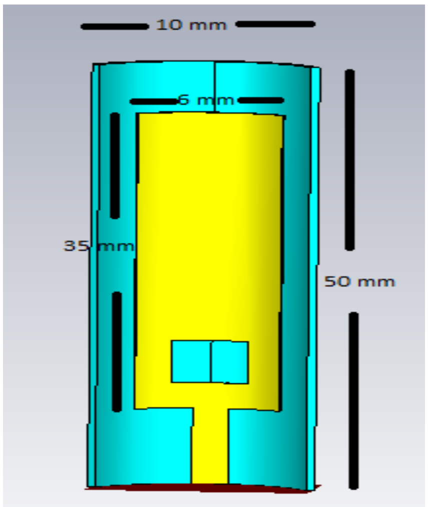
2. DESIGN DESICRIPTION

The antenna structure in this study was basically a felt substrate with a relative dielectric constant of 1.22. The ground plane of the antenna it is partial and attached on the back ground of substrate, all lengths and widths are represented in Table 1. Figure 1 illustrates the front and back views of the proposed bended antenna, which operated at two frequencies: 2.4 GHz and 5.0 GHz. A radiating material was printed on the felt substrate as the antenna patch. A microstrip line was used to feed the antenna with a characteristic impedance of 49 Ω. The radiating element of the antenna was a rectangular patch with a square slot (inside), and this patch was bended at 10°.

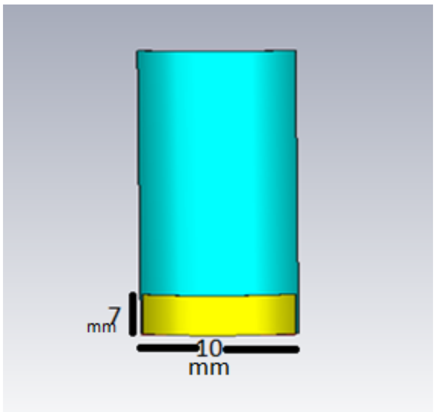
Table 1. Antenna measurements

Antenna structure	Length (mm)	Width (mm)	Hight (mm)
Patch	35	6	0.17
Substrate	50	10	0.7

Ground	7	10	0.17



(a)



(b)

Figure 1. bended patch antenna (a)front view (b)back view

3. ANTENNA PERFORMANCE AND ANALYSIS

3.1 Antenna results and performance in free space

CST (2014) served as a simulation tool for this study to design and obtain the results and performance of the proposed antenna. Table 2 shows the obtained results and performance in free space. Based on the simulation results, the antenna that operated at 2.4 GHz and 5.0 GHz recorded wide bandwidths at both frequencies and high gain, particularly at 5 GHz. Meanwhile, Figure 2 shows the S11 for the bended antenna in free space. The radiation of both frequencies was found omnidirectional, as shown in Figure 3. Based on the obtained results, the proposed antenna was deemed as a high-performance antenna in free space. In other words, it can work well for ISM applications.

Table 2. Results obtained in empty space

Result	At frequency 2.4GHz	At frequency 5GHz
B. W	50%	70%
Gain	2.21dBi	5.1dBi
Return loss	-17.5	-27.31
Efficiency	40%	69%

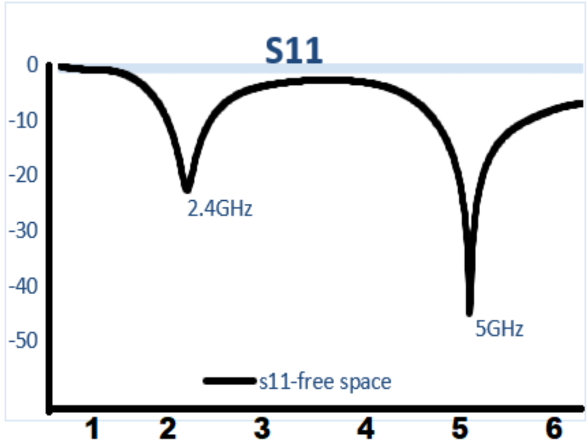
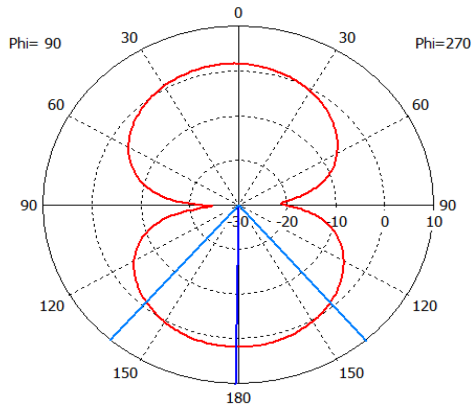
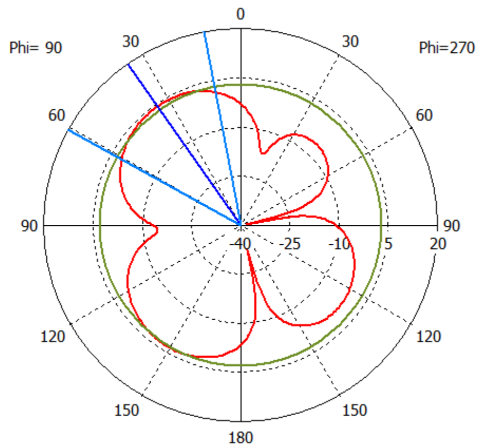


Figure 2. S11 in free space



(a)



(b)

Figure 3. Radiation pattern (a) 2.4GHz (b) 5GHz

3.2 Antenna results and performance on body (arm and chest models)

This section presents the results of the designed wearable bended antenna in terms of its behavior when it was applied to a human body. For this study, the arm and chest multi-layer models (tissues) were simulated to mimic the human body. With diameter of 80 mm and length of 150 mm, the arm model was mimicked by cylindrical, while the chest model was mimicked by cubic, as shown in Figure 4 [11-13]. Both models consisted of four layers with typical thickness, permittivity, density, conductivity, and mass, which are tabulated in Table 3 [11, 12].

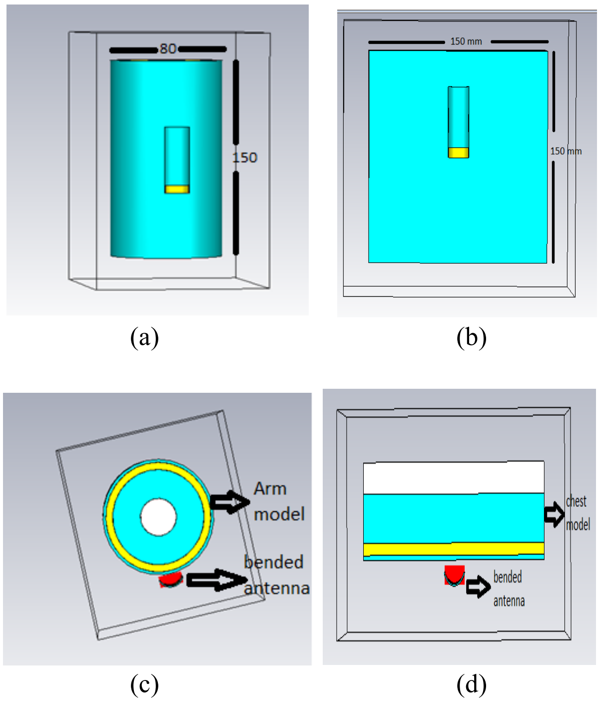


Figure 4. Arm and chest models (a) front view of arm model (b) front view of chest model (c) top view of arm model (d) top view of chest model

Table 3. Properties of multilayer body tissues

Property	Fat	Muscle	Bone	Skin
Density	900	1006	1008	1001
permittivity	5.27	52.67	18.49	37.95
conductivity	0.11	1.77	0.82	1.49
thickness	5	20	13	2

The bended antenna was then placed at 10 mm away from the arm and chest models. Although both operated frequencies were shifted to the right, the shifting was still within the acceptable range. Figure 5 shows the S11 after applying the arm and chest models. Both cases depicted almost similar performance outcomes with the case of free space. The comparison of the antenna results and performance clearly revealed the ability of the antenna to maintain its wide bandwidth and high gain despite the changes in the radiation pattern. Figure 6 illustrates the antenna radiation pattern in the phantom models. The antenna radiation pattern in the phantom models also remained stable to a satisfactory degree. The obtained antenna results and performance in both outdoor tests and on body (the arm and chest models) reaffirmed the suitability of the antenna for applications related to the human body. However, the SAR absorption coefficient must be taken into account and further minimized to ensure its workability in reality.

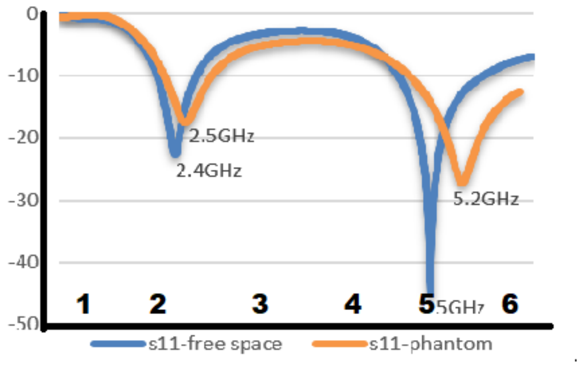
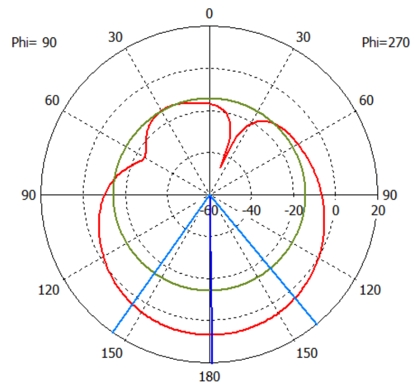
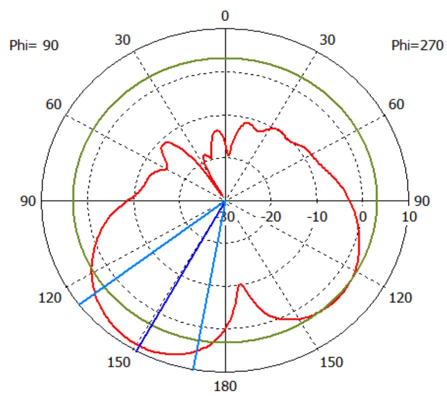


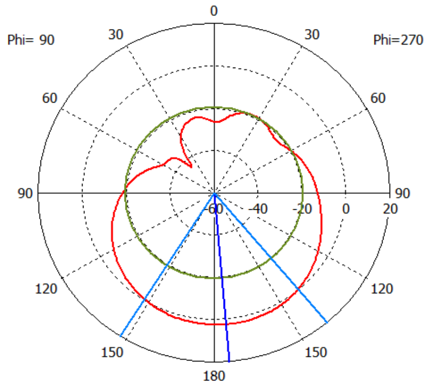
Figure 5. S11 in free space and phantom models



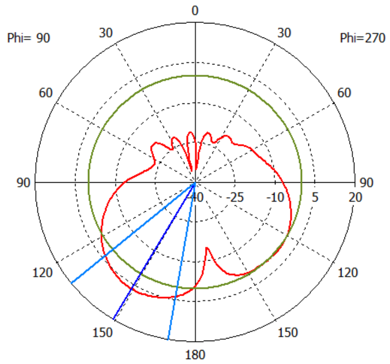
(a)



(b)



(c)



(d)

Figure 6. Antenna radiation pattern in phantom models (a) 2.4 GHz arm model (b) 5 GHz arm model (c) 2.4 GHz chest model (d) 5GHz chest model

4. CONCLUSION

In this study, a dual-band bended patch antenna was specifically designed for the purpose of applications related to the human body. The obtained simulation results showed that the proposed antenna has wide bandwidths at both operated frequencies and recorded high gain at the upper frequency band. In other words, it is capable to cover the operating bandwidths of ISM applications. Apart from its wide bandwidth feature, the proposed antenna also has high peak gains at both frequency bands. Furthermore, the proposed antenna is small and compact. With all these elements combined, this antenna is qualified to efficiently function in real life. Moreover, its bended shape and felt substrate are among the qualifying specifications for the real-world applications, especially for human-based applications.

REFERENCES

[1] LI, R., DEJEAN, G., TENTZERIS, M. M., LASKAR, J. "Development and Analysis of a Folded Shorted- Patch Antenna with Reduced Size,"IEEE Transactions on Antennas and Propagation, vol. 52, no. 2, p. 555 - 562.2004.

[2] GUPTA, K. C., GARG, R., BAHL, I., BHARTIA, P. "Microstrip Lines and Slotlines," 2nd ed. Norwood: Artech House, 1996.

[3] Wang, Z.; Lee, L.Z.; Psychoudakis, D.; Volakis, J.L. "Embroidered multiband body-worn antenna for GSM/PCS/WLAN communications," IEEE Trans.Antennas Propag. 2014, 62, 3321–3329.

[4] 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.

[5] Yang, J., Wang, H., Lv, Z., & Wang, H. "Design of Miniaturized Dual-Band Microstrip Antenna for WLAN Application," Sensors.2016, 983. doi:10.3390/s16070983.

[6] Li, R., De Jean, G., Tentzeris, M. M., & Laskar, J. "Development and Analysis of a Folded Shorted-Patch Antenna with Reduced Size," IEEE Transactions on Antennas and Propagation.2004, 52(2), 555–562, doi:10.1109.

[7] Espinal, F., Huff, G., Sessions, D., Pallampati, S., Fuchi, K., Seiler, S., Gillman, A. " A Circularly-Polarised Origami-Inspired Folding Patch Antenna Sub-Array. IET Microwaves," Antennas & Propagation. 2020,doi:10.1049/iet- map.2019.0181.

[8] G. Muntoni et al. "A Curved 3-D Printed Microstrip Patch Antenna Layout for Bandwidth Enhancement and Size Reduction," IEEE Antennas and Wireless Propagation Letters ,vol. 19, no. 7, pp. 1118-1122, doi: 10.1109/LAWP.2020.2990944.

[9] Singh, A., Mehra, R.M. & Pandey, V.K. "Design and Optimization of Microstrip Patch Antenna for UWB Applications Using Moth–Flame Optimization Algorithm," Wireless Pers Commun,2020, 112, 2485–2502.

[10] K. Vasu Babu, B. Anuradha."Design of multi-band minkowski MIMO antenna to reduce the mutual coupling,"Journal of King Saud University - Engineering Sciences,Volume,2020,ISSN 1018-3639.

[11] Z. H. Jiang, D. E. Brocker, P. E. Sieber, and D. H. Werner. "A compact, low-pro_le metasurface-enabled antenna for wearable medical bodyarea network devices,'" IEEE Trans. Antennas Propag.2014,vol. 62, no. 8, pp. 4021_4030.

[12] A. Y. I. Ashyap, Z. Zainal Abidin, S. H. Dahlan, H. A. Majid, M. R. Kamarudin, A. Alomainy, R. A. Abd-Alhameed, J. S. Kosha, and J. M. Noras."Highly ef_cient wearable CPW antenna enabled by EBGFSS structure for medical body area network applications,'" IEEE Access.2018,vol. 6, pp. 77529_77541.

[13] A. Y. I. Ashyap, Z. Zainal Abidin, S. H. Dahlan, H. A. Majid, and G. Saleh."Metamaterial inspired fabric antenna for wearable applications,'" Int. J. RF Microw. Comput. -Aided Eng.2019, vol. 29, no. 3, Art. no. e21640.