engineering proceedings

Proceeding Paper

A Novel Wideband Coplanar Waveguide (CPW) Fed Antenna for Energy Harvesting at 2.45 GHz †

Qasim Awais [1,*], Asad Farooq [2], Waqas Ali [3], Reshal Afzal [3] and Adeel Khalid [4]

1 Department of Electrical Engineering, GIFT University, Gujranwala 52250, Pakistan
2 Department of Physics, Beijing Institute of Technology, Beijing 100811, China; asadfarooq03@gmail.com
3 Department of Electrical Engineering, University of Engineering and Technology (UET), Lahore 39161, Pakistan; engr_waqasali@yahoo.com (W.A.); m.reshalafzal@gmail.com (R.A.)
4 Department of Electronics and Computer Science, Fatima Jinnah Women University, Rawalpindi 46000, Pakistan; adeelkhalid@fjwu.edu.pk
* Correspondence: ee.hod@gift.edu.pk; Tel.: +92-3-2138-3833
† Presented at the 1st International Conference on Energy, Power and Environment, Gujrat, Pakistan, 11–12 November 2021.

Abstract: Conversion of electric power from a high voltage to a low voltage causes power losses that also require efficient circuit design techniques to be implemented for durability of a system. Energy harvesting techniques have been implemented to cater to the power demand of low power electronic devices using electromagnetic, electrostatic, and other related technologies. This paper represents the compact design of an antenna system tuned at 2.45 GHz for radio frequency energy harvesting applications. The simulation results achieve a better gain of 5.4 dB along with enhanced radiation patterns. Impedance matching for 50 Ohm is implemented using a high frequency structure simulator (HFSS). The results of the antenna gain, VSWR, and radiation efficiency are compared with the literature. Furthermore, the size of the antenna system has great significance in medical and military related applications; this aspect is also considered in this design and overall, a 20 mm × 37 mm compact antenna is achieved by using mm wave considerations. This antenna design can be embedded in the wireless sensor network (WSN), RFID, and IoT related application to generate the required power required. Mostly, WSN nodes currently use traditional batteries that need to be replaced after some time. As in most cases, WSN nodes are scattered in wide geographical areas, so maintaining the power to these systems becomes challenging. RF energy harvesting provides a solution in these cases where wind, vibration, and solar sources are scarce. The simulated impedance bandwidth is found to range from 1.1 GHz to 5.2 GHz within the acceptable VSWR values.

Keywords: antennas; printed antennas; Wi-Fi; WLAN; 4G; 5G; ultra-wideband; IoT

Citation: Awais, Q.; Farooq, A.; Ali, W.; Afzal, R.; Khalid, A. A Novel Wideband Coplanar Waveguide (CPW) Fed Antenna for Energy Harvesting at 2.45 GHz. *Eng. Proc.* **2021**, *12*, 54. https://doi.org/10.3390/engproc2021012054

Academic Editor: Shahid Iqbal

Published: 10 January 2022

1. Introduction

Antennas are a crucial part of any modern system, e.g., cell phones, laptops, and satellites, etc. It is undoubtedly the major part of any communication system. With the wide deployment of WLAN infrastructure, especially in the urban environment, the requirements of high-speed communication systems for small hand-held connected devices are ever growing. To support this, antenna devices are becoming more compact and smarter in the sense of their working parameters. Energy efficiency and better operational ranges are some of the major characteristics of modern antenna systems [1].

Microstrip antennas started evolving in the 1980s and the antenna array systems were widely adopted in 1990s; however, major miniaturization work started after 2005 when demand for 3G, 4G, and Wi-Fi networks became popular. The latter is a more common practice that is mainly implemented in symmetrical and asymmetrical coplanar waveguide techniques [2].

2. Literature Review

There are well known and widely implemented wireless bands, including IEEE 802.11 (2.4–2.48 GHz) and IEEE 802.15.4 (2.5–2.69 GHz/3.4–3.69 GHz/5.25–5.85 GHz), that need to be matched by any proficient design. Inherently, patch antennas have a low bandwidth and to enhance the bandwidth there are numerous techniques, such as defected ground structure (DGS), complementary slit ring resonators (CSRR), and rounded corners, that are used extensively in the literature [3,4]. A magneto–electric antenna design in [5] shows good radiation patterns on both the E and H planes, better gain, and acceptable radiation patterns due to the rounded corner technique being utilized to enhance the bandwidth characteristics [6]. Similar kinds of design techniques are adopted in our design, which has shown promising results. A wideband antenna in [7,8] has shown greater gain than 1.5 dB at different frequencies of 2 GHz, 3.1 GHz, and 3.4 GHz.

This proposed design works at 2.4 GHz and its bandwidth range is between 1.1 GHz and 5.2 GHz. An excellent voltage standing wave ratio of 0.26 is achieved at the designated frequency. The following Figure 1 shows the basic symmetric co-planar design.

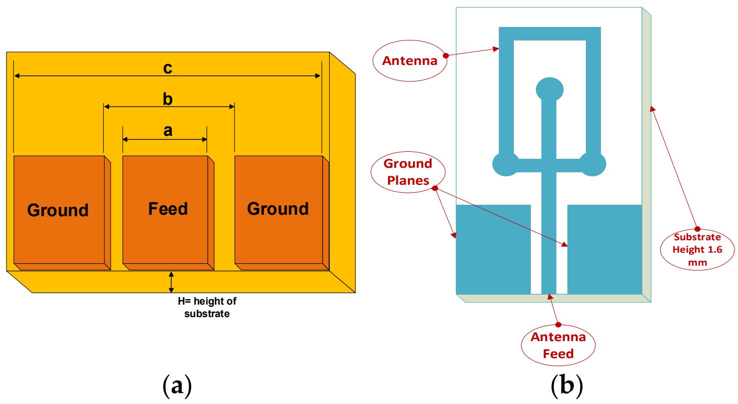


Figure 1. (**a**) Feed line structure; (**b**) the complete antenna design with major components.

3. Antenna Geometry

The feedline length is usually kept very small in order to reduce the reflection of the EM wave's scattering. The width of the feedline is 1.2 mm and the length is optimized at 14 mm. A standard substrate of 1.6 mm is used and the dimensions of parameters b and c are, respectively, 4 mm and 20 mm—as shown in Figure 1a. The complete antenna design is illustrated in Figure 1b. The resonant frequency and the effects of the substrate permittivity are analyzed using following Equations (1) and (2).

$$fr = \frac{C}{4Y_g\sqrt{\varepsilon_{r.eff}}} \tag{1}$$

$$\varepsilon_{r.eff} = \frac{\varepsilon_r + 1}{2} \tag{2}$$

The geometry of the proposed antenna is shown in Figure 2, below, which includes all the calculated and optimized dimensions. The feedline length is 1.3 mm along with 9 mm ground lanes on each side of the feedline. Furthermore, 2 mm wide strips constitute a rectangular shape patch, which has 1.2 mm rounded circles introduced at the three bottom corners. Extensive parametric analysis for the circle radius and for the length of the feedline is carried out at an interval of 0.1 mm.

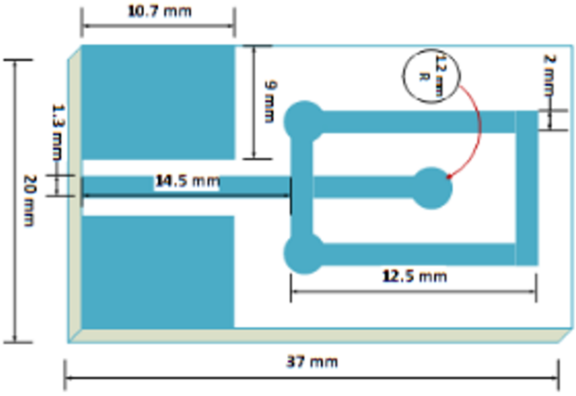


Figure 2. The geometry of the proposed antenna.

Initially, the ground planes with the feedline were simulated using an HFSS software package that resulted in a narrow bandwidth ranging from 2.4 GHz to 3.1 GHz. It is worth noting that the middle strip length controlled the overall bandwidth and the rounded corner technique improved the gain of the antenna and the impedance bandwidth. Finally, a better reflection coefficient was achieved ranging from 1.1 GHz to 5.2 GHz, as shown in Figure 3 below. Figure 3a depicts the excellent impedance matching at the designated frequency of 2.45 GHz and similarly Figure 3b proves the concept of rounded corner concept in terms of directing EM energy at the WLAN band. Preciously, 5.4 dB gain is measured and at 3.5 GHz 5G assigned frequency a gain of 2.8 dB is measured. A lumped port excitation was used and the length and width of the lumped port was adjusted by using basic port calculations.

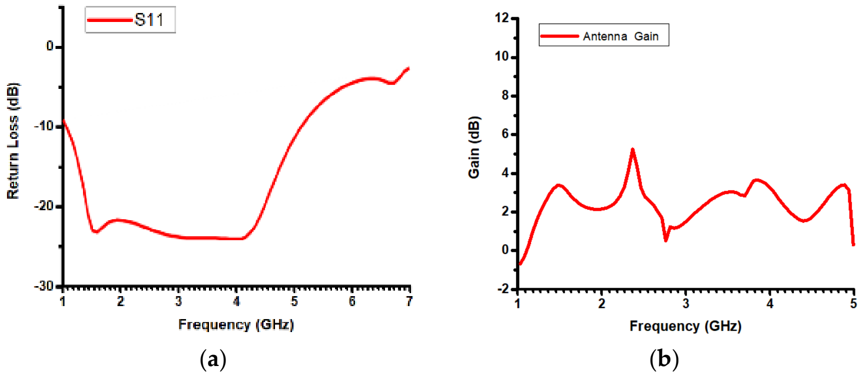


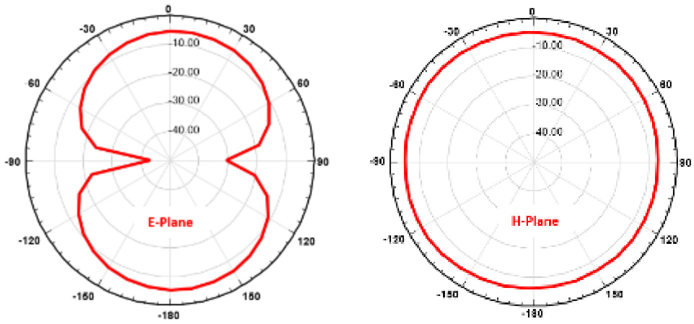
Figure 3. (**a**) S-parameters display; (**b**) Antenna Gain.

3.1. Antenna Gain

The simulated gain of the proposed antenna is shown in Figure 3b. At 2.45 GHz the maximum gain of 5.4 dB is achieved, whereas the overall varying pattern of the gain is observed in the range of 1 GHz to 5 GHz. This result verifies that the proposed design is well suited for WLAN, 4G, WiMAX, and any future 5G applications as it covers all the prominent frequency bands. The maximum gain of 3.5 dB is observed at the 3.5 GHz frequency, which is most likely going to be the designated frequency authorized by PTA.

3.2. Radiation Patterns

The radiation patterns of this novel design for both E and H planes are shown in the following Figure 4. The radiation patterns of the E plane show bidirectional behavior while this antenna performs omnidirectionally on the H plane. After reviewing the gain and radiation pattern characteristics, it is evident from the simulated results that this design is well suited for wireless sensor network and new IoT applications, as well as for traditional scenarios.



(**a**) (**b**)

Figure 4. Radiation pattern of the proposed antenna: (**a**) E plane and (**b**) H plane.

4. Conclusions

In this article, a novel rectangular shape antenna design for 2.45 GHz applications is proposed and simulated. The antenna has a middle strip that can control the resonant frequency along with the length of antenna. Additionally, the rounded corners technique is employed to further enhance the overall impedance bandwidth and gain of the antenna. Ultra-wide bandwidth ranging from 1.1 GHz to 5.2 GHz was achieved along with excellent voltage standing wave ratio (VSWR) values. The radiation patterns of this design suggest that it is suitable for both omnidirectional and bidirectional patterns. The gain of the antenna at 2.45 GHz is found to be 5.4 dB, which is comparable to the available designs in the literature and also shows an excellent impedance value, which matches with the minute variances at 2.8 GHz and 4.6 GHz in terms of the antenna gain. Finally, it is concluded that this novel design is well suitable for current as well as future high bandwidth applications.

Author Contributions: Conceptualization and methodology of this manuscript was perceived by Q.A. and W.A., software simulation and validation is carried out by the R.A. and A.F. The formal analysis is completed by Q.A., A.K. and R.A. However, the original draft writing is prepared by Q.A. and A.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research work is self-funded and does not incur huge costs. However, GIFT University, Gujranwala has provided the necessary resources.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Rehman, S.U.; Haider, W.A.; Khalid, K.; Farooq, O.; Mahmood, U. Design and Comparative Analysis of 2.45 GHz Rectangular microstrip Patch Antenna. In Proceedings of the 2020 International Conference on Engineering and Emerging Technologies (ICEET), Lahore, Pakistan, 22–23 February 2020; pp. 1–5. [CrossRef]
2. Çelik, F.T.; Karaçuha, K. A Reconfigurable Binomial Weighted Phased Array Antenna Design for Wi-Fi Band. In Proceedings of the 2020 28th Signal Processing and Communications Applications Conference (SIU), Gaziantep, Turkey, 5–7 October 2020; pp. 1–4. [CrossRef]
3. Awais, Q.; Jin, Y.; Chattha, H.T.; Jamil, M.; Qiang, H.; Khawaja, B.A. A Compact Rectenna System with High Conversion Efficiency for Wireless Energy Harvesting. *IEEE Access* **2018**, *6*, 35857–35866. [CrossRef]
4. World Population Clock: 7.9 Billion People (2021)—Worldometer. Available online: https://www.census.gov/popclock/ (accessed on 11 October 2021).
5. Bi, K.; Wang, L.; Yu, J.; Zhu, W.; Wang, Z.; Gao, S. Design of 2.45 GHz High-gain Antenna that Based on Air-ground Ad-hoc Network. In Proceedings of the 2021 7th International Symposium on Mechatronics and Industrial Informatics (ISMII), Zhuhai, China, 22–24 January 2021; pp. 5–10. [CrossRef]

6. Chen, C.-C.; Huang, Z.-W.; Jheng, K.-H.; Lin, Z.-D.; Sim, C.-Y.-D.; Chen, H.-D. Coplanar Antenna Design for GNSS and WiFi Applications. In Proceedings of the 2020 International Workshop on Electromagnetics: Applications and Student Innovation Competition (iWEM), Makung, Taiwan, 26–28 August 2020; pp. 1–2. [CrossRef]
7. Patil, V.; Sapkale, P.; Saxena, A.; Mali, S. Design and Performance Evaluation of a Planar Bi-Quad Antenna Operating at 2.4 GHz. In Proceedings of the 2021 2nd International Conference for Emerging Technology (INCET), Belagavi, India, 21–23 May 2021; pp. 1–4. [CrossRef]
8. Awais, Q.; Chattha, H.T.; Jamil, M.; Jin, Y.; Tahir, F.A.; Rehman, M.U. A Novel Dual Ultrawideband CPW-Fed Printed Antenna for Internet of Things (IoT) Applications. *Wirel. Commun. Mob. Comput.* **2018**, *2018*, 2179571. [CrossRef]