Journal of Artificial Intelligence and Data Science (JAIDA)
e-ISSN: 2791-8335
https://dergipark.org.tr/pub/jaida
Vol. 4, No. 2, pp. 104-109, 2024
Research Article
Received: 04/12/2024 Accepted: 20/12/2024

Production of a Cost Effective Microstrip Antenna Operating at 2.4 GHz and 5 GHz

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Abstract
In this study, the aim was to design a microstrip antenna operating in the ISM band using three-dimensional printer technology. The substrate material of the proposed antenna was produced using ABS filament with a 70% infill percentage. The dielectric constant of the produced substrate material was measured experimentally in the laboratory and the Reel-Imaginer graph of the material was extracted. According to the obtained dielectric constant value, the antenna was designed step by step in the simulation environment. Then, the antenna was produced and return loss (S_{11} parameters) were measured using spectrum analyzer. It was observed that the simulation and measurement results were consistent. The measurement results shows that the produced antenna operates at 2.4 GHz and 5 GHz. This study demonstrates the simplicity of antenna production with a low-cost production technique, 3D printing.
Keywords: Microstrip Antenna; 3D printer; ABS filament; 2.4 GHz ;Wifi.

1. Introduction

Nowadays, with the widespread use of wireless communication, interest in applications especially in the WiFi frequency band is increasing. Popular areas such as the Internet of Things and fifth generation communication applications encourage researchers to solve problems that may be encountered in these areas [1,2]. The most commonly preferred antenna type in communication is the microstrip antenna [3]. Their compact structure and flexible design allow them to be used frequently in microwave applications. The biggest disadvantage of traditional microstrip antennas is their production technique. They are often produced in factories and workshops with a device called LPKF. These devices are not the kind of equipment that researchers can easily obtain in terms of cost and size. Another disadvantage of the traditional production method is that the substrate materials are mostly imported from abroad and are costly. In addition, this production technique has certain limitations and the design of complex structures is not possible with these devices [3].

Researchers who are looking for an innovative production technique propose 3D printing technology. With this technology, complex 3D antenna structures can be produced quickly and easily. Due to such advantages, the use of 3D printers in antenna production has attracted great interest from both academic and industrial researchers [4]. In addition, the filament material used as raw material in 3D printers is economically feasible. Researchers have successfully produced various microwave elements such as, slotted array antenna, SIW (substrate integrated waveguide) antennas, dielectric lenses, Ku band horn antenna and folded microstrip antenna using this new production technology [5-10]. In recent years, in addition to mobile phones, many technological devices such as tablets and smart watches have been connected to the internet. As the number of devices that can connect to the internet increases every day, the need for WiFi is also increasing.

All devices that support WiFi technology connect to the local network, via wireless access points. The connection is made at 2.4 GHz or 5 GHz radio frequency depending on the IEEE 802.11 protocol, which is supported by wireless access points and the device. 2.4 GHz offers a wide range of signal, whereas 5 GHz has a shorter range. Researchers have done various studies for the ISM band. A 5 cm x 5 cm microstrip antenna with dual band operation at 2.45/5.8 GHz was designed [11]. In another article, a fractal slot antenna with an operating frequency between 2.5GHz and 4.5GHz was designed [12].

Within the scope of this study, a microstrip antenna was designed and manufactured for the wireless communication frequency band. The study started with determining the dielectric constant of the ABS filament to be used as raw material. The proposed design was produced in 3D printer and the performance of the resulting prototype was measured with spectrum analyzer.

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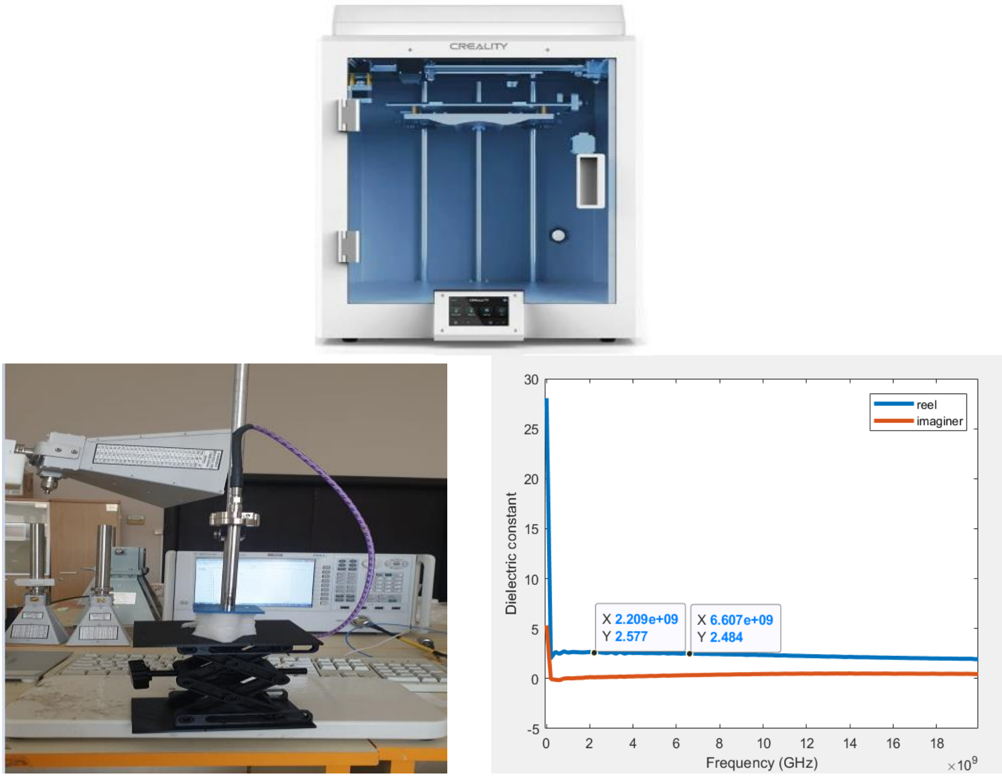
2. Substrate Production Process and Antenna Design

In this section, firstly the fabrication and measurement process of the antenna substrate material will be explained. ABS filament, which is prominent with its durability, was preferred as the substrate material. The recommended substrate was produced using a Creality Cr 5 Pro-H type 3D printer with dimensions of 60 × 60 × 1.6 mm^3. The infill percentage of the filament was set to 70% using the software program of the 3D printer. During the printing phase, the bed temperature of the 3D printer was set to 110 ℃ and the nozzle temperature was set to 240 ℃. The printing process was completed in approximately 50 minutes. After the production process, the measurement setup given in Figure 1(a) was established to determine the dielectric value of the substrate material. The substrate was placed between two conductors and connected to the measurement device. The dielectric values of water and air were used as references during the calibration phase. The graph in Figure 1(b) was obtained by taking measurements at every 100 MHz intervals in the frequency range between 100 MHz and 18 GHz. According to Figure 1(b), the real part of the dielectric constant was measured as ε_r = 2.5 on average, especially between 2 GHz and 6 GHz.



(a) (b)

Figure 1. Images of the Substrate Production Process (a) Measurement set-up (b) Graph of the measured dielectric constant

As a result of the measurements, the dielectric constant of the substrate material was determined. After this stage, the focus was on the antenna design using the simulation software. As a result of the measurements, the dielectric constant of the substrate material was determined. After this stage, the focus was on the antenna design using the simulation program. The steps given in Figure 2(a) were carried out in order to obtain the desired frequency band range. The front and back views of the final design of the antenna are given in Figure 2(b). The final dimensions optimized in the simulation program are summarized in Table 1.

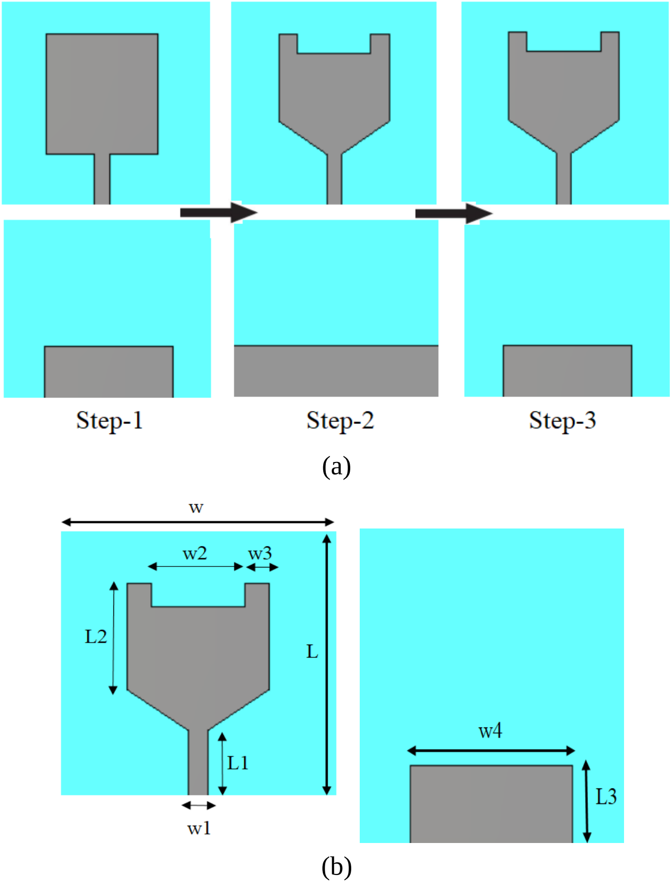


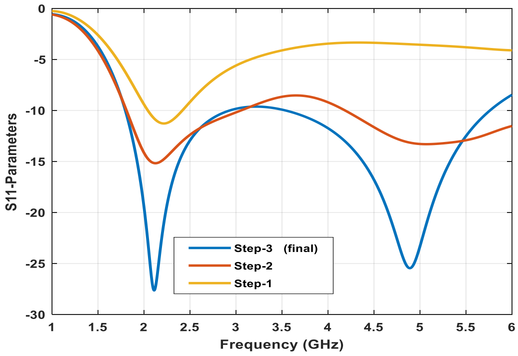
Figure 2. Images of the Proposed Microstrip Antenna (a) Design steps (b) Layout of the design

Table 1. *Optimized dimensions of the final antenna (mm)*

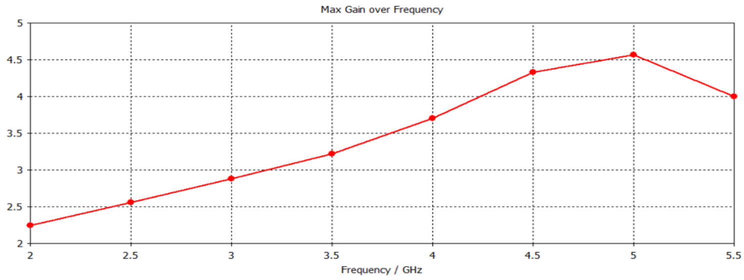
W	60	**L**	60
W1	4	**L1**	15
W2	20	**L2**	23.6
W3	5	**L3**	15
W4	35		

3. Simulation and Measurement Results

In this section, firstly the simulation results of the designed antenna will be analyzed. In Figure 3(a), the return loss (S_{11}-parameters) graph obtained in the design phase of the antenna is given comparatively. In the first phase, the antenna resonates only at 2.4 GHz. In the second phase, a second resonance is produced at 5 GHz and the bandwidth increases. In the final design, the antenna provides the desired bandwidth between 1.8 GHz and 5.8 GHz. In Figure 3(b), the maximum gain over frequency graph of the antenna is given. The antenna gives a gain of 2.5 dBi at 2.4 GHz and 4.5 dBi at 5 GHz. The radiation loss of the antenna at 2.4 GHz and 5 GHz is given in Figures 4(a) and 4(b), respectively.

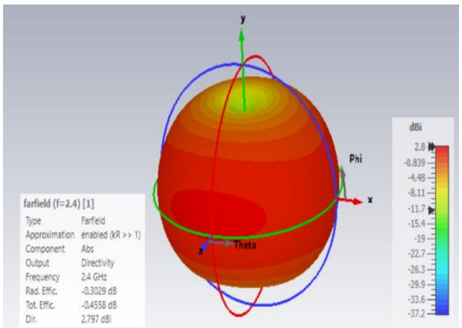


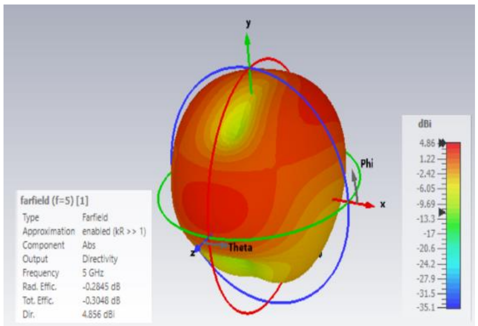
(a)



(b)

Figure 3. Simulation results (a) Return loss (S_{11}), (b) Max. Gain over frequency

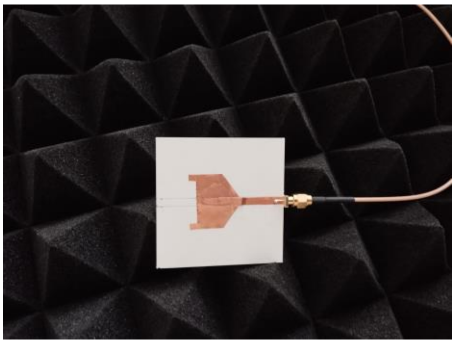




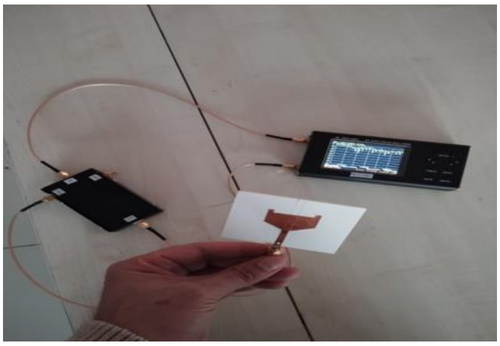
(a) (b)

Figure 4. Simulated 3D radiation pattern (a) at 2.4 GHz (b) 5 GHz

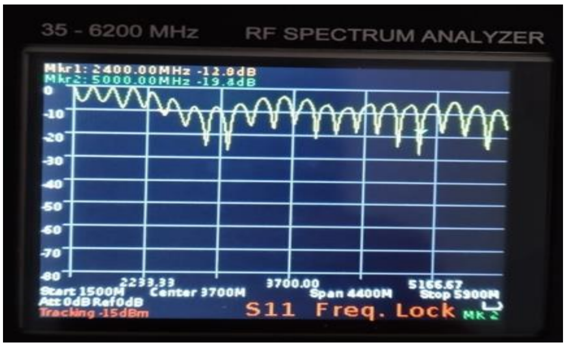
Once the desired efficiency was obtained from the simulation results, the production and measurement phase of the antenna was started. 35 micron thick adhesive copper tape was used for the conductive parts of the antenna. The measurements of the produced antenna were made with the ARINST SSA-TG R2 spectrum analyser device. This device is an easy portable panoramic spectrum analyzer (RF multimeter) designed to display signal spectrums in the frequency range from 35 to 6200 MHz. One of the features of this device is the presence of an internal tracking generator, which makes it possible to measure Standing Wave Ratio (SWR) and return loss of the antenna. The picture of the manufactured antenna is given in Figure 5(a). The measurement setup using the Radio Frequency (RF) bridge and spectrum analyzer is given in Figure 5(b). The measurement results obtained from the spectrum analyzer are given in Figure 5(c). The tracking input attenuation value on the device is set to -10 dB and the generator power value is set to -15 dBm. Before the antenna measurement, the spectrum analyzer was calibrated. For this purpose, open, short and load (50 Ω) were connected to the Device Under Test (DUT) port, respectively. As seen on the measurement screen, -12 dB return loss was obtained at 2.4 GHz and -19.4 dB at 5 GHz.



(a)



(b)



(c)

Figure 5. Images of the measurement (a) Prototype of the antenna (b) Measurement set-up (c) Display of spectrum analyzer

4. Conclusion

One of the important hardware parts of wireless communication is the antenna. It is clear that with the development of infrastructures such as the Internet of Things, the importance of next-generation antenna production techniques and studies on improving antenna performance will increase. For this purpose, the subject of the study was determined and a microstrip antenna was produced using three-dimensional printer. It was observed that the measurement results and simulation results were consistent. According the measurement results the fabricated antenna is suitable for use in 2.4 GHz and 5 GHz applications. This study has shown that 3D printers can play an alternative role in antenna production. At the same time, this study has proven that ABS filaments can be used without any problems in ISM band applications.

Declaration of Interest

The authors declare that there is no conflict of interest.

Author Contributions

Conceptualization, BD; methodology, BD ; data generation, BD; investigation, BD; designing BD; writing—original draft preparation, BD; writing—review and editing, BD; visualization, BD; supervision, BD; project administration, BD.

Acknowledge

This study is supported by Kafkas University Scientefic Research Project within the scope of project number 2022-FM-72.

References

[1] Balanis, C.A., Antenna Theory: Analysis and Design. John Wiley & Sons, New Jersey, A.B.D., 2005.

[2] Garg, R., Bhartia, P., Bahl, I., ve Ittipiboon, A., “Microstrip Antenna Design Handbook”. Artech House, Boston, A.B.D., 2001.

[3] D. Cao, Y. Li and J. Wang, “A Millimeter-Wave Spoof Surface Plasmon Polaritons-Fed Microstrip Patch Antenna Array”, in IEEE Transactions on Antennas and Propagation, vol. 68, no. 9, pp. 6811-6815, 2020.

[4] Olan-Nuñez KN, Murphy-Arteaga RS, “Dual- band antenna on 3D-printed substrate for 2.4/5.8 GHz ISM-band applications.” Electronics, 12(11):2368,2023.

[5] Bjorgaard J, Hoyack M, Huber E, Mirzaee M, Chang YH, Noghanian S., “Design and fabrication of antennas using 3d printing”. Progress In Electromagnetics Research C, 84:119-134, 2018.

[6] Zhang, S., Arya, R.K., Pandey, S., et al., “3D printed planar graded index lenses”, Microw. Antennas Propagation., 1411-1419, 2016.

[7] B. Dokmetas and G. O. Arican, “Design of Dual-Band SIW Antenna for Millimeter-Wave Communication”, 31st Telecommunications Forum (TELFOR), Belgrade, Serbia, pp. 1-4, 2023.

[8] Ghazali M.I.M., Karuppuswami S., Kaur, A, “3D printed air substrates for the design and fabrication of RF components”, Trans. Compon. Packag. Manuf. Technol., 982-989, 2017.

[9] Jun S., Sanz-Izquierdo B., Heirons J., “Circular polarised antenna fabricated with low-cost 3D and inkjet printing equipment”, Electronic. Letters., 370-371, 2017.

[10] Belen MA., Güneş F, Mahouti P, Belen A, “UWB Gain Enhancement of Horn Antennas Using Miniaturized Frequency Selective Surface”, Applied Computational Electromagnetics Society Journal, 997-1002, 2018.

[11] B. Dokmetas, G. O. Arican and B. A. Yilmaz, “A Folded Pyramid-Shaped Microstrip Antenna with Improved Bandwidth”, IEEE International Symposium on Antennas and Propagation and INC/USNC-URSI Radio Science Meeting (AP-S/INC-USNC-URSI), Firenze, Italy, pp. 1273-1274, 2024.

[12] Malakooti S.-A., Hayati, M., Fahimi, V.,Afzali, B., “Generalized dual-band branch-line coupler with arbitrary power division ratios.” International Journal of Microwave and Wireless Technologies, 1-9, 2015.

[13] Krishna, D.D., Gopikrishna, M., Anandan, C., Mohanan, P., Vasudevan, K., “CPW-fed Koch fractal slot antenna for WLAN/WiMAX applications.” IEEE Antennas and Wireless Propagation Letters, 7, 389-392, 2008.