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Research Article

Triple-Band Patch Antenna Design with Machine Learning Algorithms

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Abstract **–** Wireless communication is crucial in many fields, such as engineering, transportation, inventory tracking, industrial automation, IoT, and mobile communication, due to advancing technology. Antennas are essential for signal transmission and reception in wireless communication, playing a vital role in ensuring the effective operation and efficiency of these technologies. Antenna design is essential for achieving objectives such as enhancing efficiency, improving communication quality, and extending communication range in communication systems. Machine learning algorithms can serve as powerful tools for optimizing the antenna design process and achieving more accurate results. This study presents the design of an antenna that operates in three bands and can be used in wireless communication technology with the support of machine learning. The antenna was designed using an FR-4 substrate with a dielectric constant of 4.4, a loss tangent of 0.02, and a thickness of 1.6 mm. Copper was used for the patch and ground sections. The antenna provides three impedance bandwidths: 856.81 MHz with a bandwidth of 158.27 MHz, 1298.4 MHz with a bandwidth of 38.5 MHz, and 2164.8 GHz with a bandwidth of 958.5 MHz. The geometric parameters of the antenna were input into the ML model. The data set comprises 1024 samples and the output data represents the magnitude of the reflection parameter (S11). Twelve regression algorithms were applied and compared, with the Random Forests algorithm producing the best result.

Keywords – Antenna Design, Machine Learning, Triple-Band, Microstrip Patch, Wideband, Communication.

I. INTRODUCTION

Advancements in communication technologies are increasing the effectiveness and reliability of wireless communication systems, where the design and optimization of wireless components are crucial in determining their performance. The use of wideband technology is gaining importance as it enhances the versatility of communication systems by providing flexibility in diverse fields of wireless applications, ranging from microwave filters [1], rectennas [2], mmwave photonic transmitter modules [3], and microwave antennas [4,5].

In addition, the antenna has potential applications in RFID (Radio-Frequency Identification) technologies, as demonstrated by its use in such systems [6]. The second band, which ranges from 1277.1 MHz to 1315.6

MHz, is part of the L band and is important for various applications, including GPS, remote sensing, and mobile communication [7]. The third band covers a frequency range of 1748.8 MHz to 2707.3 MHz. This frequency range is frequently utilized in applications that require high bandwidth, such as satellite communication, radar, radio broadcasting, and base station communication. The antenna is compatible with modern communication technologies, including popular wireless communication standards such as 2.4 GHz Wi-Fi and IoT (Internet of Things) [8]. Its wide frequency range provides flexibility and enables communication in multiple frequency bands across various application areas [9]. The use of Machine Learning algorithms has the potential to speed up the antenna design process, reduce simulation times, and enhance the overall system performance [10,11]. To this end, regression models were established based on the simulation results dataset. Error rates and R2 scores were calculated, and the models were compared.

This study focuses on the design and characterisation of wideband antennas with emphasis on their bandwidths and frequency ranges using machine learning algorithms to achieve these objectives. The primary objective of the antenna is to provide effective performance over a wide frequency range with a wide bandwidth and low reflection parameter. This paper examines in detail the geometric structure of the antenna, principles of frequency band compatibility, simulation and analysis methods, performance evaluation and application areas.

II. MATERIALS AND METHOD

A. Antenna Design

This study presents a microstrip antenna design that operates in three bands. The antenna dimensions are 116x116x1.6 mm3 and consist of three layers: ground, patch, and substrate. Copper with a thickness of 0.035 mm is used for the ground material, while FR-4 material with a dielectric constant of 4.4, a loss tangent of 0.02, and a thickness of 1.6 mm is selected for the substrate layer. The patch layer also uses copper with a thickness of 0.035 mm. Modifications have been implemented to ensure that the antenna operates at the desired frequencies.

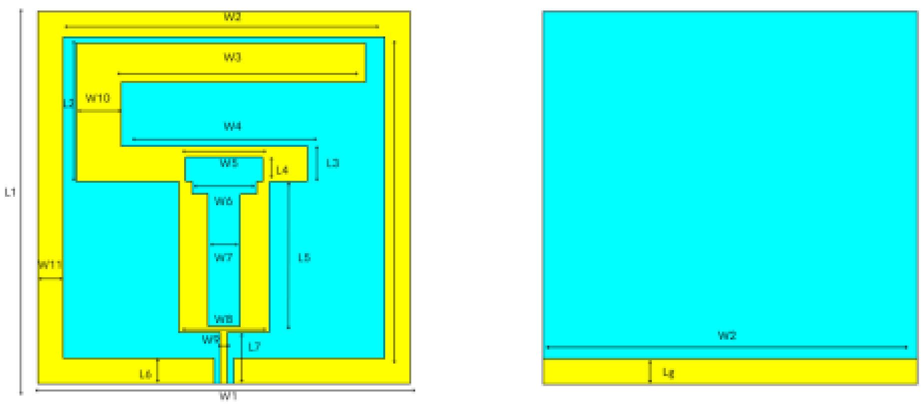

Figure 1. Front and back view of antenna

Many geometric parameters can be determined on the proposed antenna, thus increasing the number of input parameters for ML algorithms. The operating frequency and bandwidth of the antenna can be modified by changing the dimensions of the patch and the ground surface of the antenna.

Table 1. Parameters of antenna

Parameters	**Values(mm)**	**Parameters**	**Values(mm)**	**Parameters**	**Values(mm)**
L1	116	L7	16	W5	24
L2	43	Lg	8	W6	20
L3	11	W1	116	W7	10
L4	7.5	W2	100	W8	28
L5	47	W3	76	W9	2.4
L6	8	W4	58	W10	14

B. Machine Learning Algorithms

The geometric parameters changed in the proposed antenna are determined as W2, W7, L4, L5 and L7. A data set consisting of 1024 simulation results was prepared and regression was performed using various machine learning methods. 20% of the data set was used as the test set and 80% as the training set. Machine learning algorithms used five different parameters of the antenna as input to estimate a single S11 magnitude value. The results showed high R2 scores and low error rates. Machine learning techniques were used to design the antenna geometry to achieve the best results and achieve the desired results.

III. RESULTS

The antenna's input reflection coefficients (S11 values) are: -25.6 dB at 857 MHz, -21.653 dB at 1298 MHz, -19.7 dB at 1998.4 MHz, -28.573 dB at 2167 MHz, and -19.328 dB at 2664 MHz. The simulation results indicate that the antenna has bandwidths of 158.27 MHz (816.14 MHz – 974.41 MHz), 38.5 MHz (1277.1 MHz - 1315.6 MHz), and 958.5 MHz (1748.8 MHz – 2707.3 MHz). Table 3 summarises the farfield parameters at 868 MHz, 1.3 GHz, 1.8 GHz, 2.1 GHz, 2.4 GHz, and 2.6 GHz.

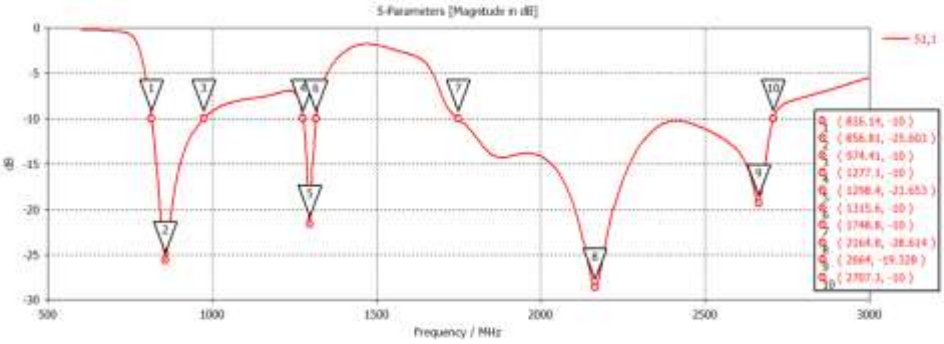

Figure 2. S11 Graph of antenna

Table 2. Gain, S11(dB) and S11(Magnitude) values.

Frequency (GHz)	Gain (dBi)	S11 (dB)	S11 (Magnitude)
0.868 GHz	3.08 dBi	-22.5 dB	0.075
1.3 GHz	2.42 dBi	-21.12 dB	0.088
1.8 GHz	3.77 dBi	-11.86 dB	0.252
2.1 GHz	6.15 dBi	-19.8 dB	0.105
2.4 GHz	6.08 dBi	-10.32 dB	0.304
2.6 GHz	4.87 dBi	-14.1 dB	0.205

A total of 1024 simulations were conducted to evaluate the effects of altering the geometric dimensions of the antenna, specifically its length and width. The results were analysed using various machine learning techniques, and 15 different regression models were constructed based on these simulation outcomes. These models yielded low error rates and high R2 scores. The results demonstrate the success of machine learning algorithms in predicting changes to antenna geometry. The Random Forest algorithm produced the highest R2 score of 0.9942 and an MSE value of 0.0003. The R2 scores and MSE values for all algorithms are presented below.

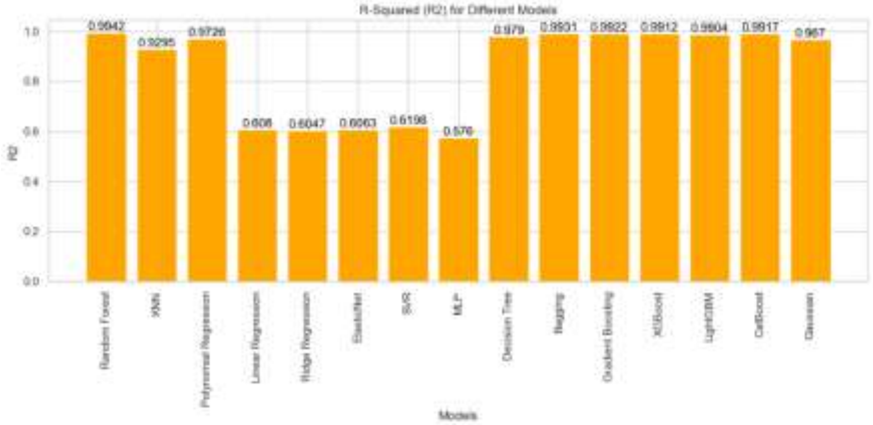

Figure 3. R2 scores for different machine learning algorithms

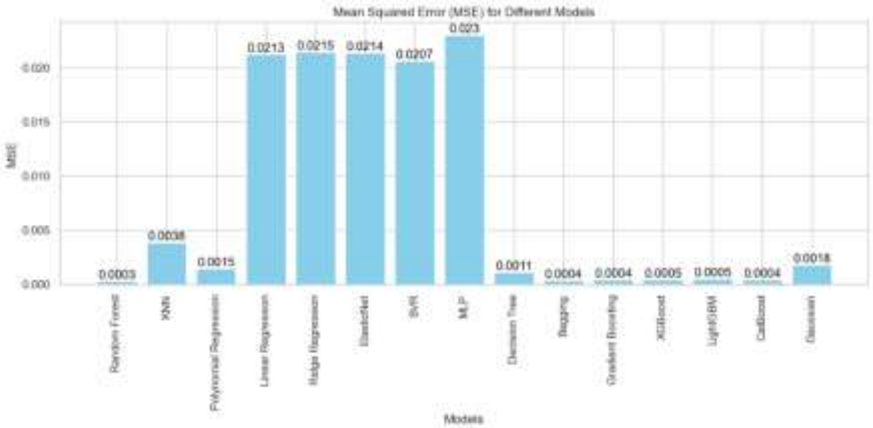

Figure 4. MSE values for different machine learning algorithms

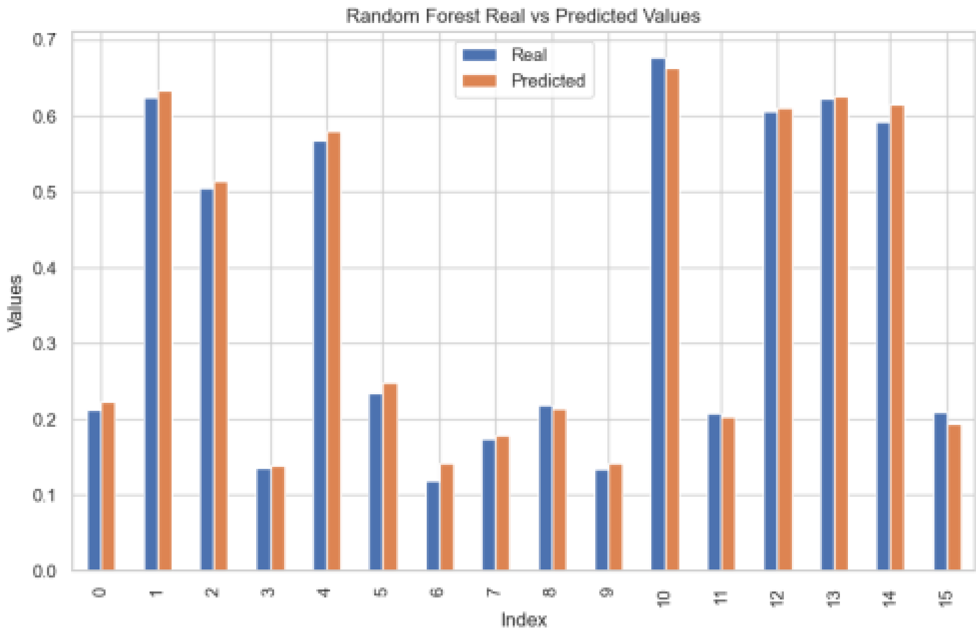

Figure 5. Random Forest algorithm actual / predicted graph

IV. DISCUSSION

This study focuses on designing and characterizing wideband antennas. The designed antenna successfully achieved wide bandwidths at various frequency bands, highlighting its suitability for modern wireless communication technologies and ensuring its versatility for a wide range of applications. The antenna is versatile and has the potential for use in various industrial applications, covering wide bandwidths for applications such as RFID systems, GPS, Wi-Fi, IoT, and other wireless communication standards. Additionally, it achieves high gain. High gain amplifies signal power and increases transmission distance, enhancing the effectiveness and reliability of the antenna in communication systems. The designed antenna can also be produced in compact dimensions, making it suitable for portable devices or limited spaces, thus increasing application flexibility and facilitating easy integration into various systems. The designed antenna could be widely adopted in commercial applications due to its cost-effective production. Cost-effectiveness provides an advantage in large-scale antenna production and offers an economical solution for industrial applications. This study incorporates machine learning techniques into the design process of wideband antennas, optimizing parameters such as bandwidth and gain. Machine learning algorithms, including neural networks and regression models, provide insights into complex relationships between antenna geometry and performance metrics. This approach enables rapid prototyping, iterative refinement, and the development of cost-effective antennas suitable for diverse industrial applications.

V. CONCLUSION

This paper presents the design of a low-cost, high-gain antenna capable of operating in various frequency bands, including 816.14 MHz – 974.41 MHz, 1277.1 MHz - 1315.6 MHz, and 1748.8 MHz – 2707.3 MHz. These frequencies are commonly used in applications such as UHF RFID, GPS, GSM, UMTS, WLAN, and LTE. The study involved making various parametric changes to achieve optimal results, and the desired values were successfully obtained. In conclusion, the designed antenna provides a practical solution for various wireless communication applications. This study not only successfully designed and characterized the antenna but also integrated machine learning techniques into the design process. Machine learning played a crucial role in enhancing the antenna's efficiency and versatility through iterative refinement and analysis of simulation results.

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REFERENCES

[1] Palandöken, M., Sondas, A. (2014). Compact Metamaterial Based Bandstop Filter. Microwave Journal, 57(10).

[2] Palandoken, M., Gocen, C. (2019). A modified Hilbert fractal resonator based rectenna design for GSM900 band RF energy harvesting applications. International Journal of RF and Microwave Computer-Aided Engineering, 29(1), e21643.

[3] Rymanov, V., Palandöken, M., Lutzmann, S., Bouhlal, B., Tekin, T., & Stöhr, A. (2012, September). Integrated photonic 71–76 GHz transmitter module employing high linearity double mushroom-type 1.55 μm waveguide photodiodes. In 2012 IEEE International Topical Meeting on Microwave Photonics (pp. 253-256).

[4] Al-Gburi, A. A., Zakaria, Z., Palandoken, M., Ibrahim, I. M., Althuwayb, A. A., Ahmad, S., & Al-Bawri, S. S. (2022). Super compact UWB monopole antenna for small IoT devices. Comput. Mater. Contin, 73, 2785-2799.

[5] Belen, A., Güneş, F., Mahouti, P., & Palandöken, M. (2020). A novel design of high performance multilayered cylindrical dielectric lens antenna using 3D printing technology. International Journal of RF and Microwave Computer-Aided Engineering, 30(1), e21988.

[6] Wang, B. (2015). A compact antenna design for UHF RFID applications. Progress In Electromagnetics Research Letters, 53, 83-88.

[7] Irsigler, M., Hein, G. W., & Schmitz-Peiffer, A. (2004). Use of C-Band frequencies for satellite navigation: benefits and drawbacks. GPS Solutions, 8, 119-139.

[8] Al-Hraishawi, H., Chougrani, H., Kisseleff, S., Lagunas, E., & Chatzinotas, S. (2022). A survey on nongeostationary satellite systems: The communication perspective. IEEE Communications Surveys & Tutorials, 25(1), 101-132.

[9] Balanis, C. A. (2016). Antenna theory: analysis and design. John wiley & sons.
[10] Ranjan, P., Yadav, S., Gupta, H., & Bage, A. (2023). Design and Development of Machine Learning Assisted Cylindrical Dielectric Resonator Antenna.
[11] Mahouti, M., Kuskonmaz, N., Mahouti, P., Belen, M. A., & Palandoken, M. (2020). Artificial neural network application for novel 3D printed nonuniform ceramic reflectarray antenna. International journal of numerical modelling: electronic networks, devices and fields, 33(6), e2746.