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A Microstrip Antenna Designed Using The Slot-Loaded Algorithm

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ABSTRACT: This study focused on developing a 2.4 GHz broadband microstrip antenna using the SLOT-LOADED algorithm. The design was refined using the ANSOFT HFSS application, including the coaxial feed section. The antenna was tuned to operate at the desired frequency with optimal parameters. Key variables such as resonance frequency, bandwidth, VSWR, gain, and radiation pattern were sequentially investigated. The final design achieved a bandwidth of 320 MHz with a center frequency of 2.4 GHz, meeting simulation requirements. Testing involved a signal generator and spectrum analyzer, with results analyzed using HFSS graphs. The received power level validated the bandwidth, and the test findings were satisfactory. Further analysis is recommended in interference-free environments with more sophisticated equipment.

Keywords: Microstrip Antenna, SLOT-LOADED, ANSOFT HFSS, Coaxial Feed, Bandwidth, Voltage

1. INTRODUCTION

Antennas are the most effective and, in most cases, the only means of transmitting information without the need for wiring and over long distances. Due to the constant growth of wireless communications that demand more and more practical circuits, antennas are at the forefront of achieving efficient transmission of information. Each antenna has different parameters, which judge its behaviours [1]. There are different types of antennas that have unique characteristics to adapt to the different applications that are required today, some applications will demand that the radiated power be extended as much as possible, this means that they should not be directive, and in other cases they will need to be directives to channel the power in a specific direction [2]. This is what makes antennas so functional and important for all types of wireless communication.

A type of antenna that is widely used today are microstrip antennas, which since their appearance have evolved as new technologies advance, since their size can be reduced (by increasing the frequency of operation, smaller antennas can be obtained) and at the same time improve their characteristics [3]. Its use is very important for applications that require compact sizes, for example: aeronautics, satellites, mobile devices, wireless communications in general.

2. BACKGROUND

The concept of the Microstrip Antenna was first proposed to him in 1952. However, it was not until the 1970s that the real study of this type of antenna began. The many advantages of microstrip antennas, such as their low weight, small volume, ease of fabrication, and increased requirements for wireless communications, led to the expansion of designs for various applications today [4]. Although the characteristics of microstrip antennas make them recommended and used in many applications, it is also true that they suffer from a bandwidth limitation in relation to normal microwave antennas [5].

3. FORMULATION OF THE PROBLEM

The design of microstrip antennas that combines compact size with broadband characteristics has become a very important part of the antenna area, since nowadays the technological requirements for different applications demand much more compact and versatile antennas that can be easily attached, without diminishing the characteristics of larger antennas [6]. There are many investigations in the area of microstrip antennas, and through these, it is possible to obtain different methods that allow obtaining good results in terms of improving bandwidth, for this reason it is important to review and study these new techniques, such as the SLOT-LOADED algorithm which will be used in this work. It has shown good results for the improvement of this problem, always taking into account the importance and emphasis that should be given to recent trends and events in this field [7].

4. GENERAL OBJECTIVES

- Design and implement a broadband microstrip antenna for the 2.4 GHz frequency using the slot-loaded algorithm.
- Study the state of the art for a better understanding of basic antenna concepts
- Analyze the various models and design methods of microstrip antennas.
- Design a suitable model for the broadband microstrip antenna.
- Simulate the antenna with the designed parameters.
- Analyze the results to see if the antenna needs to be parameterized.

5. DESIGN OF A BAND MICROSTRIP ANTENNA

5.1. Antenna design

The design of the slot-loaded antenna, including the patch and structure, plays a crucial role in improving bandwidth. A sponge with low dielectric permittivity is used to reduce the interior electric field and potential difference, while the addition of rings increases bandwidth. The antenna utilizes an FR4 epoxy substrate with a permittivity below 5, enhancing radiation efficiency and bandwidth. The materials selected, as outlined in Table 1, are chosen for their favorable characteristics and availability, contributing to the antenna's performance [8].

Figure 1: Side view of the antenna

Table 1: Material Specifications

	FR4 EPOXY	SPONGE
Relative permittivity	4.4	Relative permittivity
Substrate thickness	1.6 mm	Substrate thickness

5.2. Simulation

The simulation of the antenna is conducted using the ANSOFT HFSS student version, a program specifically designed for modeling and simulating 3D structures at high frequencies. This software enables the visualization of electromagnetic wave behavior and provides various antenna-specific parameters to evaluate its performance. Additionally, it offers a selection of materials with different characteristics, aiding in the design process.

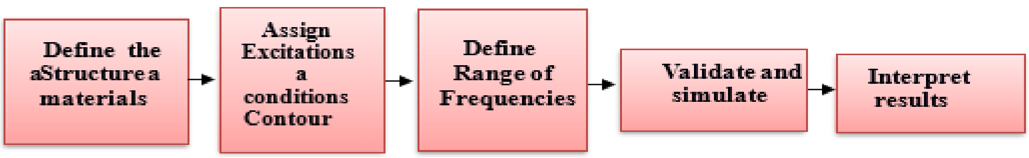


Figure 2: Simulation Process in HFSS

5.3. Structures and Materials

To begin the design, we select the materials for both the design phase and implementation, entering the actual thickness of each material to ensure the design is practical for implementation. The antenna is then structured layer by layer, with a list of materials and their characteristics, such as thickness and position in the x, y, z plane, displayed alongside the design sheet. The patch design is based on the slot-loaded algorithm, with an optimization process carried out to meet the required parameters and define the antenna's dimensions and power port position [9]. The initial design serves as a test, requiring gradual adjustments to width and length until the desired results are achieved.

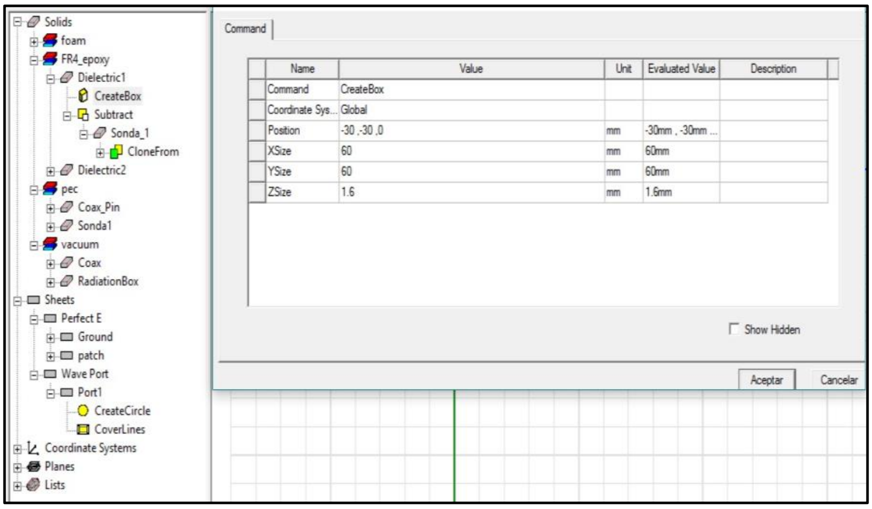


Figure 3: Bill of Materials Schematic in ANSOFT HFSS

5.4. Boundary Conditions

To control the impedance of the patch, a coaxial power point simulating the antenna's feed connector is designed, aiming for simulation results to closely match those of the implemented antenna. The coaxial feed is chosen for its ease of manipulation, especially for centering in the rings, and is a common method in microstrip antennas [10]. The power pin must pierce the substrates and dielectric, soldering directly to the patch. Although this feed type offers limited bandwidth, the antenna configuration partly compensates for this. Boundary conditions are incorporated to define parts of the antenna as perfect electrical conductors, perfect magnetic conductors, impedance elements, or radiation elements. Finite electrical conductors and a radiation surface are defined for the antenna to facilitate wave radiation from the structure.

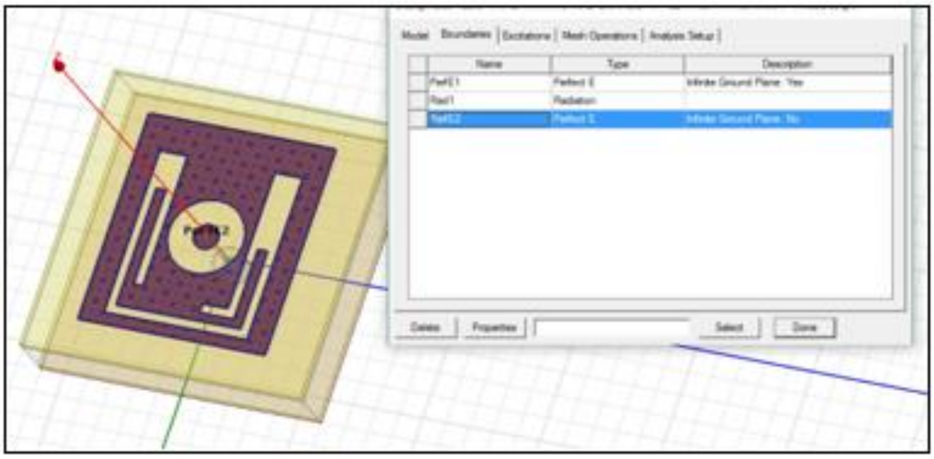


Figure 4: Antenna Boundary Conditions

5.5. Frequency Range

The center frequency is set at 2.4 GHz, and the analysis will cover the frequency range from 2 GHz to 3 GHz. The number of points plotted will be determined, with more points allowing for a clearer visualization of the graph.

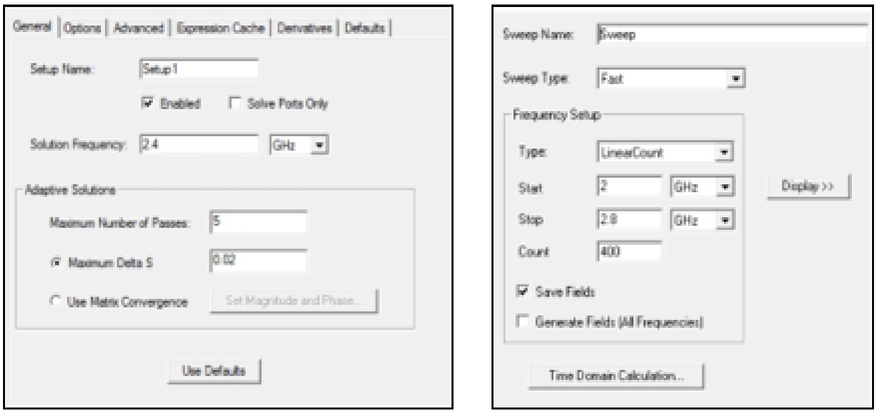
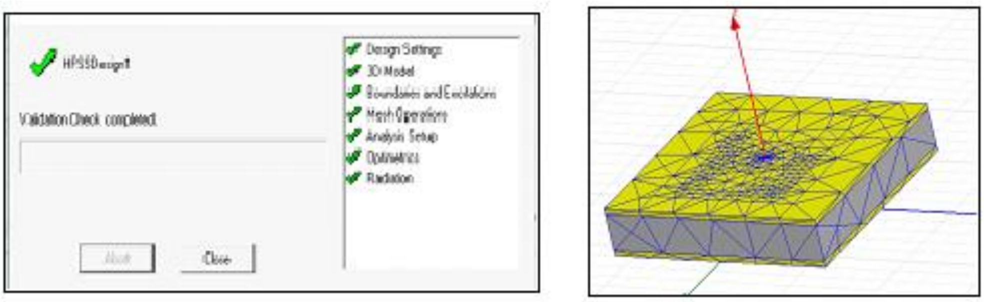


Figure 5: Assignment off frequencies

5.6. Simulation Validation & Meshing

After defining all parameters, we validate the simulation to ensure the antenna's dimensions can be optimized without errors. ANSOFT HFSS employs the finite element method for meshing, dividing the antenna into numerous regions for a more accurate solution, albeit with increased computation time.



(a) Simulation Validation (b) Approximation Mesh

Figure 6: Simulation Validation & Approximation Mesh

Table 2: Summary of Simulated Microstrip Antenna Parameters

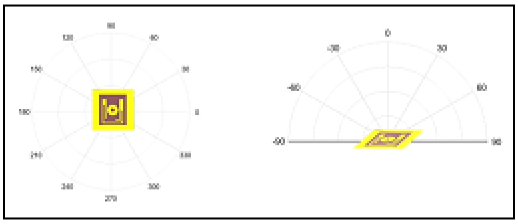
FREQUENCY 2.4 GHZ	
Parameter	Value
Reflection Parameter	-27.77 dB
ROE	1.08 dB
Gain	3.23 dB
Bandwidth	340 MHZ
Radiation Efficiency	84.65 %
Radiation Pattern	Directional

6. ANALYSIS OF RESULTS

6.1. Measurements

The results will show the power received by the microstrip antenna as a function of the angular position of another antenna. Radiation patterns will be graphed by sampling at constant angle intervals, with 20-second pauses to stabilize the signal for more accurate results. Using polar coordinates φ (azimuth angle) and θ (elevation angle), the data will be entered into MATLAB to generate polar and Cartesian graphs to compare with simulated results.

- In the φ direction (azimuth angle) on the x-axis, which ranges from 0º to 360º, the antenna radiation pattern will be represented at 0º and 90º (Figure 7(a)).
- In the θ direction (elevation angle), it will be represented from 0° to 180° (Figure 7(b)).



(a) (b)

Figure 7: Schematics Used for Measurements

6.2. First Measurement

Measurements were conducted at 2.4 GHz, with the azimuth angle (φ) at 0º and the elevation angle (θ) ranging from 0º to 180º in roughly 10º intervals. Initially, a monopole antenna verified the microstrip antenna's correct operation and resonance at the specified frequency, followed by testing another microstrip antenna with identical characteristics.

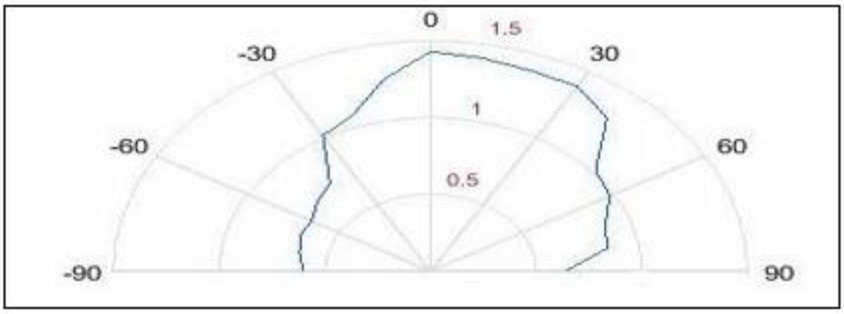


Figure 8: Radiation pattern of the microstrip antenna with frequency of 2.4 GHz for 0º Phi

In MATLAB, a directional radiation lobe is displayed in the z-direction with a beamwidth of around 65º, mirroring the simulation results. The spectrum analyzer provided measurements, all of which were normalized to facilitate graphing in MATLAB.

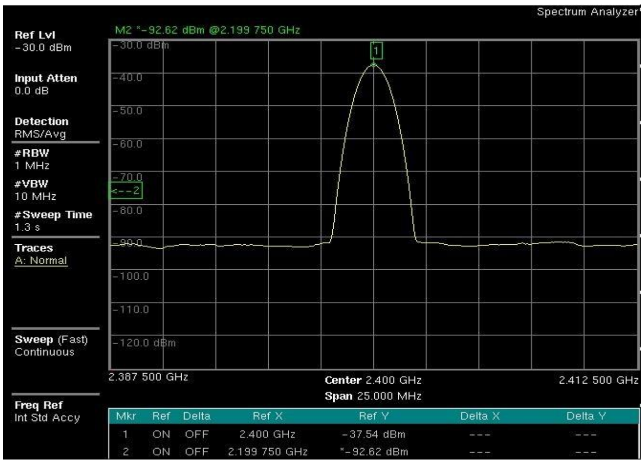


Figure 9 : Measurement for the 2.4 GHz frequency

6.3. Second Measurement

The procedure is repeated as in the first measurement, but this time measurements are taken in the direction φ at 90º and in the direction θ with the same interval as before. The resulting radiation pattern is depicted in Figure 10.

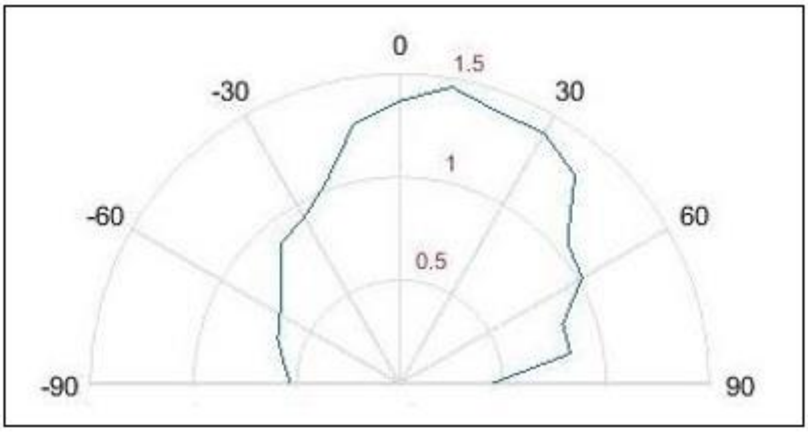


Figure 10: Radiation pattern of the microstrip antenna with a frequency of 2.4 GHz for 90º Phi.

6.4. Third Measurement

The measurement is taken in the φ direction on the x-axis and y-axis, ranging from 0º to 360º with intervals of 15º.

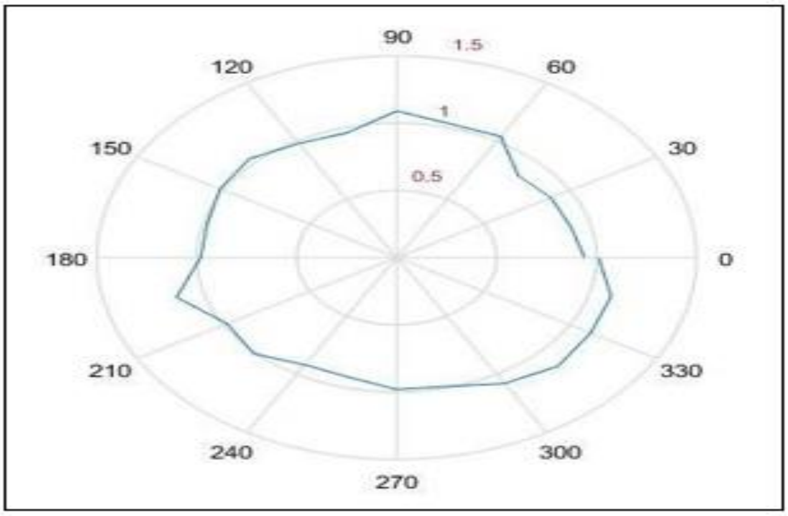


Figure 11: Radiation pattern with frequency of 2.4 GHz on the x-axis, y

Figure 11 presents a top view of the microstrip antenna's radiation pattern, showing a low power level in this direction due to the radiation lobe being oriented in the Z direction, indicating that it is not an omnidirectional antenna. Contrary to the simulation results, the radiation lobe appears more circular in shape.

6.5. Fourth Measurement

To evaluate the antenna's operational frequency spectrum or bandwidth, measurements were taken of the power level received or reflected in the direction of maximum radiation. Another microstrip antenna was utilized for this measurement. Table 3 served as a reference for indicating the power level received by the microstrip antenna.

Table 3: Interpreting Signal Power Level Values

Values	**Interpretation**
0	Ideal signal, difficult to achieve in practice
-40 to -60	Ideal signal with stable transfer rates
-60	Good link, 80% stable connection
-70	Normal to low link, may suffer from interference issues
-80	Minimum Acceptable Signal

A frequency sweep was conducted from 2.2 GHz to 2.75 GHz, adjusting the frequency both up and down. This range yielded the best power levels, with the signal generator transmitting a stable signal at -10 dBm. Figure 15 illustrates the power reflected by the antenna at frequencies ranging from 2.25 GHz to 2.7 GHz, indicating that the antenna operates with a stable bandwidth of 450 MHz.

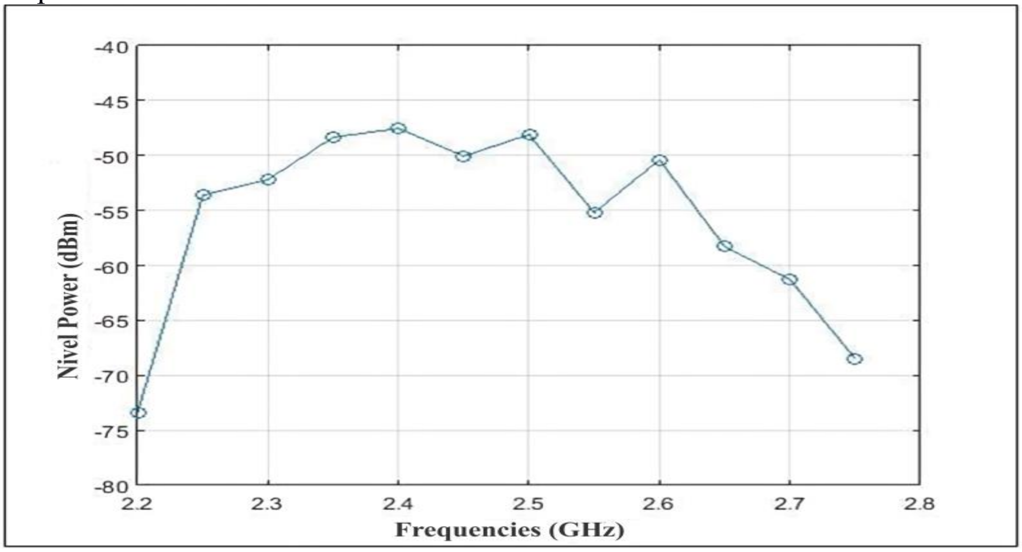
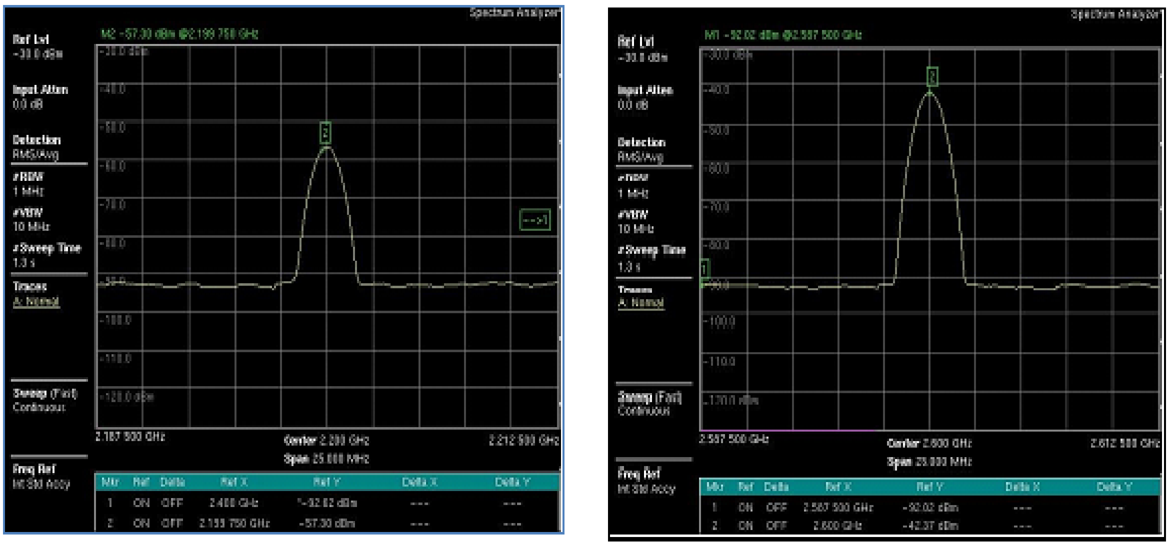


Figure 12: Frequency Sweep

Figure 13(a) displays the spectrum analyzer's measurement at 2.2 GHz, while Figure 13(b) shows the measurement at 2.6 GHz. The spectrum analyzer's bandwidth is limited to a maximum value of 10 MHz by the equipment itself. These measurements confirm that the antenna radiates at the desired frequency with higher power levels compared to other frequencies



(a) Measurement at the 2.2 GHz frequency (b) Measurement at the 2.6 GHz frequency

Figure 13: (a) Measurement at the 2.2 GHz frequency (b) Measurement at the 2.6 GHz frequency

7. CONCLUSIONS

Interpreting results required knowledge of antenna fundamentals. The SLOT-LOADED algorithm was used to design a microstrip antenna with a resonant frequency of 2.4 GHz, proving its adaptability to high frequencies. The simulation showed an SWR value of 1.08 dB at 2.4 GHz, indicating effective coupling, and return losses of -27.77 dB with a bandwidth of 340 MHz. The radiation pattern was directional in the z-direction with a gain of 3.22 dB, confirmed by laboratory measurements. The SLOT-LOADED algorithm achieved a bandwidth of approximately 14%, higher than the typical 5–8% for microstrip antennas. Construction was simplified using accessible materials and a low budget. ANSOFT DESIGNER software proved comprehensive for antenna design. This work contributes to future studies aiming for design improvements and the use of materials that enhance antenna performance. The gain of 3.24 dB in the simulation was satisfactory, focusing on bandwidth improvement. SWR measurements indicated impedance coupling at different frequencies, providing a more accurate bandwidth measurement in the simulation, with values between one and two, deeming the antenna suitable for radiation emission.

8. REFERENCE

[1]. Ibrahim, A. A., & Ali, W. A. (2022). High isolation 4-element ACS-fed MIMO antenna with band notched feature for UWB communications. International Journal of Microwave and Wireless Technologies, 14(1), 54-64.

[2]. Chen, Y., & Wang, C. F. (2015). Characteristic modes: Theory and applications in antenna engineering. John Wiley & Sons.

[3]. Lee, K. F., Luk, K. M., & Lai, H. W. (2017). Microstrip patch antennas. World Scientific.

[4]. Kumar, A., Gupta, N., & Gautam, P. C. (2016). Gain and bandwidth enhancement techniques in microstrip patch antennas-a review. International Journal of Computer Applications, 148(7).

[5]. Sharma, V. (2020). Microstrip antenna-inception, progress and current-state of the art review. Recent Advances in Electrical & Electronic Engineering (Formerly Recent Patents on Electrical & Electronic Engineering), 13(6), 769-794.

[6]. Balanis, C. A. (2016). Antenna theory: analysis and design. John wiley & sons.

[7]. Ahmad, I., Tan, W., Ali, Q., & Sun, H. (2022). Latest performance improvement strategies and techniques used in 5G antenna designing technology, a comprehensive study. Micromachines, 13(5), 717.

[8]. Baudh, R. K., Kumar, M., Prasad, R. K., & Sahu, S. (2020). Design and Analysis of Slot loaded C-shaped Trapezoidal Microstrip antenna. In International Conference on Intelligent Computing and Smart Communication 2019: Proceedings of ICSC 2019 (pp. 533-544). Springer Singapore.

[9]. Zerrad, F. E., Taouzari, M., Makroum, E. M., Islam, M. T., Özkaner, V., Abdulkarim, Y. I., & Karaaslan, M. (2022). Multilayered metamaterials array antenna based on artificial magnetic conductor's structure for the application diagnostic breast cancer detection with microwave imaging. Medical Engineering & Physics, 99, 103737.

[10]. Banerjee, U., Karmakar, A., & Saha, A. (2020). A review on circularly polarized antennas, trends and advances. International Journal of Microwave and Wireless Technologies, 12(9), 922-943.

[11]. Verma, R. K., & Srivastava, D. K. (2019). Design, optimization and comparative analysis of T-shape slot loaded microstrip patch antenna using PSO. Photonic Network Communications, 38, 343-355.