Journal of Electrical Engineering and Computer (JEECOM)
Vol. 6, No. 2 (2024), DOI: 10.33650/jeecom.v4i2
p-ISSN: 2715-0410; e-ISSN: 2715-6427

Design and Construction of a 500–800 MHz Square Spiral Dipole Microstrip Antenna Structure

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Article Info

Article history:

Received Sept 26, 2024
Revised Sept 27, 2024
Accepted October 4, 2024

Keywords:

Microstrip
Antenna
Spiral
Dipole
Radar

ABSTRACT

An antenna can be used to detect an object. The dimensions of the antenna also affect the working frequency, the smaller dimensions, the higher the working frequency and the closer the antenna range to radiate waves. Therefore, a microstrip antenna with a small dimension size is needed, but the antenna radiation distance capability for radar systems still needs to be reduced. A microstrip dipole antenna with a spiral shape, measuring 5 cm, was meticulously designed and fabricated. The square dipole antenna, featuring an optimal design with the arm structure rotated in a clockwise direction, achieved an impressive return loss of -27.54dB with a VSWR of 1.83. The engineering refinement of the antenna design involved the addition of a square shape, which led to a significant and impressive improvement in performance. The second spiral antenna, operating at a frequency of 805MHz with an impressive bandwidth of 57MHz, exhibited a remarkable return loss of -30.83dB and a VSWR of 1.07.

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1. INTRODUCTION

The The development of wireless data communication technology is increasingly rapid, driving the need for efficient and effective antenna devices. Microstrip antennas with specific radiation patterns, such as square spiral shapes, offer attractive solutions for various applications. This study aims to design and analyze the structure of a microstrip antenna with a square spiral shape that operates in the frequency range of 500-800 MHz with a small size.

The choice of this frequency is relevant to various wireless communication standards that are widely used today. Through numerical simulation and theoretical analysis, an optimal antenna design with characteristics that meet the requirements of the intended application is expected to be obtained. The results of this study are expected to contribute to the development of microstrip antenna technology with a square spiral shape and open up opportunities for further applications. The use of dipole antenna this type of antenna is the most frequently used for applications in Radar systems, mainly because of its simple shape [1].

The design process begins with a theoretical approach, changes in physical dimensions and antenna parameters intended as characterizations analyzed in this study. Simulations were carried out using Applied Wave Research (AWR) software to assist the characterization process. Realization and measurements were also carried out to obtain a prototype of a spiral microstrip antenna that meets the specifications of a radar system.

The main limitation of radar is its specific reach location, and antennas are generally optimized only for a specific pulse duration. So, if its works with different pulses, different antennas are needed [2]. Electromagnetic waves transmitted by the transmitting antenna contain data, which is then sent to the receiver. Several types of antennas are commonly used for sending information, one of which is the spiral microstrip antenna [4]

2. METHOD

Explaining There are several stages in designing this antenna, namely determining the specifications to be used and the antenna's dimensions. The results of these calculations are then simulated using the AWR Microwave Office simulator to obtain the expected antenna parameters. The targeted specifications are VSWR < 2 with a working frequency ranging from 500 - 800 MHz with a square spiral shape.

Suppose it does not meet the required antenna parameters. In that case, optimization is done by changing the patch dimensions and the distance between the spiral antenna arms until the expected specifications are met. The microstrip dipole antenna with a square spiral patch is then fabricated and measured using a Vector Network Analyzer (VNA), which then analyzes the effects of changes made to the antenna on the performance of both microstrip antennas.

Each antenna has varying parameters, therefore it is necessary first to determine the antenna requirements used as a spiral microstrip antenna. The type of substrate used in this design is FR-4 (epoxy) with a substrate thickness of 1.6mm. The spiral antenna design begins by changing the shape of the conventional microstrip dipole antenna into a spiral, with the length of the antenna arm following the length of the previous dipole antenna[3]. The spiral antenna can be designed in various shapes, as seen in Figure 1.

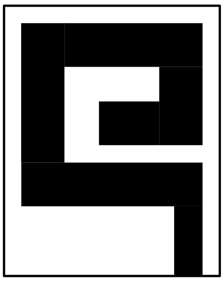

Figure 1. Spiral microstrip antenna design

It is a simple spiral shape with an arm shape that rotates clockwise. The modeling of the dipole microstrip antenna is inspired by the spiral shape of the research entitled "Low-profile and Small-sized Spiral-shaped Microstrip Line Antenna with Multi-band Operation in UHF Frequency Band."[5].

Antenna parameters measured in this study are return loss, VSWR, and bandwidth. Characterization is carried out on the antenna feeder dimensions, and the dimensions of the dipole patch antenna are changed into a spiral shape, resulting in minimum return loss and VSWR values. The results obtained from the measurements will be compared with those obtained from the design using the Microwave Office AWR.

Figure 2. Antenna Measurement Configuration Using VNA

Spiral Antenna measurement using VNA is done to compare simulation results and fabrication results. The results of the previous antenna dimension calculations are then simulated and optimized until the antenna return loss value is below -10. After obtaining the arm length of the dipole antenna, its shape is characterized as a spiral. Furthermore, the spiral antenna is then optimized based on the reference shape that already exists in previous studies. The results compared are the return loss and VSWR values , and the compared parameter values will be analyzed.

3. RESULTS AND DISCUSSION

In This research was conducted by determining the specifications and dimensions of the antenna. The results of the calculations were then simulated using the AWR Microwave Office simulator to obtain the expected antenna parameters. The targeted specifications are VSWR <2 with a working frequency ranging from 500 to 800 MHz and a square spiral shape. Suppose it does not meet the targeted specifications. Optimization is carried out by changing the patch dimensions and the distance between the spiral antenna arms until the required specifications are met.

The final stage of the antenna is printed and measured using a Vector Network Analyzer (VNA), and the effects of changes made to the antenna on the performance of the microstrip antenna are analyzed. Each antenna has varying parameters. Therefore, it is necessary first to determine the needs of the antenna used as a spiral microstrip antenna. The type of substrate used in this design is FR-4 (epoxy), with a substrate thickness of 1.6 mm. This type of substrate is widely produced, has good quality, and is affordable. The basic formula used to calculate the length of the antenna patch can be seen in the following equation (1) and (2) below [3]:

$$\lambda = \frac{300}{f} \tag{1}$$

For the length of the antenna arm is calculated using the following equation,

$$L = 0{,}5 \; x \; K \; x \; \lambda \tag{2}$$

Where f is the desired working frequency λ, is the wavelength in air, L is the total length of the dipole antenna and K is the velocity factor. The research variables of this antenna are expected to have a Working Frequency Value Specification of 500-800 MHz with VSWR <2, Return Loss <-10 dB, and Circular Polarization and Gain ≥ 3 dB. Due to the discontinuity between the transmission line and the input impedance of the load on the antenna, the return loss value is obtained. The return loss calculation can be seen in Equation (3) [10]

$$Return\ loss = 20 log_{10}|\Gamma| \tag{3}$$

An antenna works with good function and usually has a return loss value below -9.54 dB [11]. This is because the reflection signal has a manageable value with the signal sent, or the transmission channel becomes mismatched.

3.1. Spiral Antenna 1

The first antenna design only features a single type of square spiral patch. The antenna patch has a spiral shape and rotates clockwise, as shown in Figure 3 below.

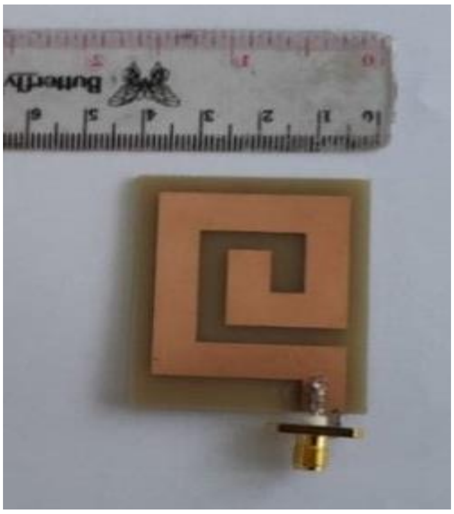

Figure 3. The first square spiral microstrip antenna design.

The results of the Return Loss and VSWR measurements of the first spiral antenna fabrication that has been characterized can be seen in Figures 4 and 5 below.

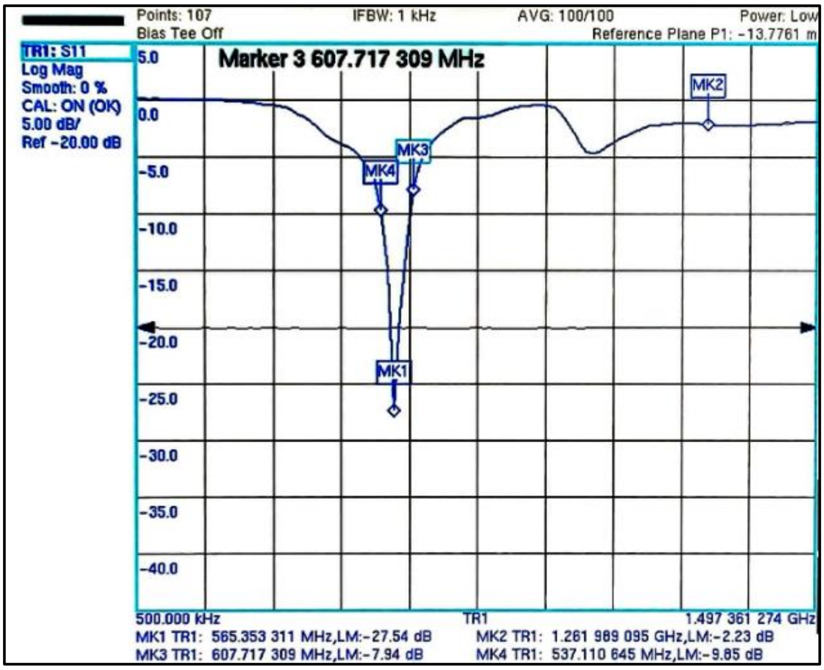

Figure 4. The results of the measurements from the second spiral microstrip antenna show that Return loss value of -27.54dB.

The microstrip antenna has a larger substrate dimension than the initial fabrication design, with a size of 40x50 mm. It features a spiral arm length of 168mm and a spiral arm width of 7mm. The measurement graph indicates a Return Loss value of -27.54dB, and a bandwidth of 72MHz.

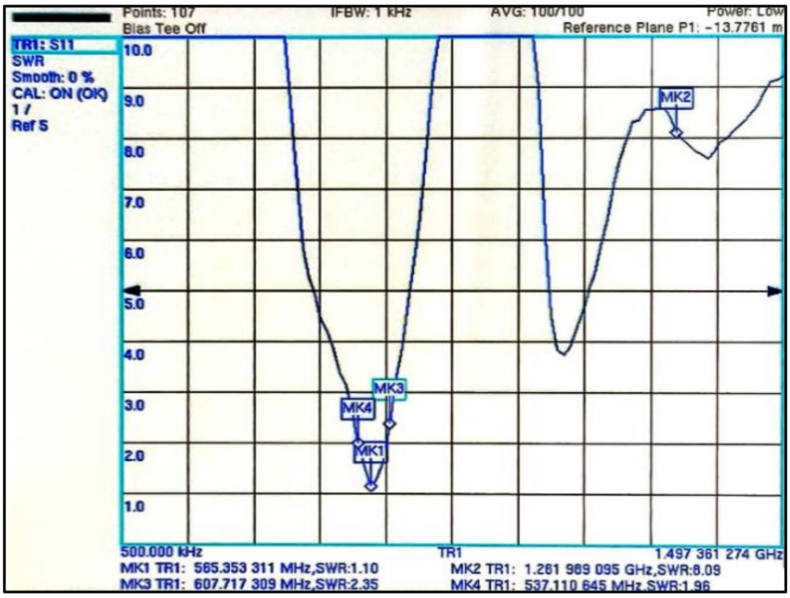

Figure 5. The results of the measurements from the second spiral microstrip antenna show that VSWR of 1.10.

The measurement graph indicates a VSWR of 1.10, and a bandwidth of 72 MHz at a frequency of 565 MHz this shows that the antenna can work well.

3.2. Spiral Antenna 2

The second antenna has a ground located next to the patch antenna. This causes the patch antenna to be longer than the first antenna design, and the shape of the patch antenna rotates counterclockwise. The fabrication results of the second antenna are illustrated in the following figure 6.

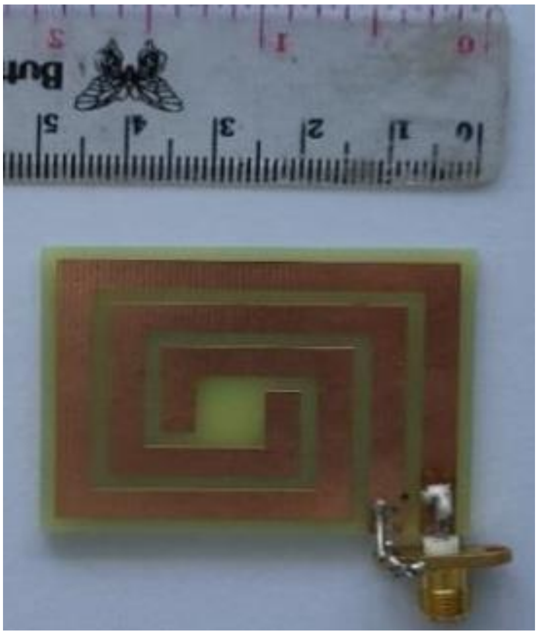

Figure 6. The Second Square Spiral Microstrip Antenna Design.

The results of the Return Loss measurements of the second spiral microstrip antenna fabrication can be seen in Figure 7 below.

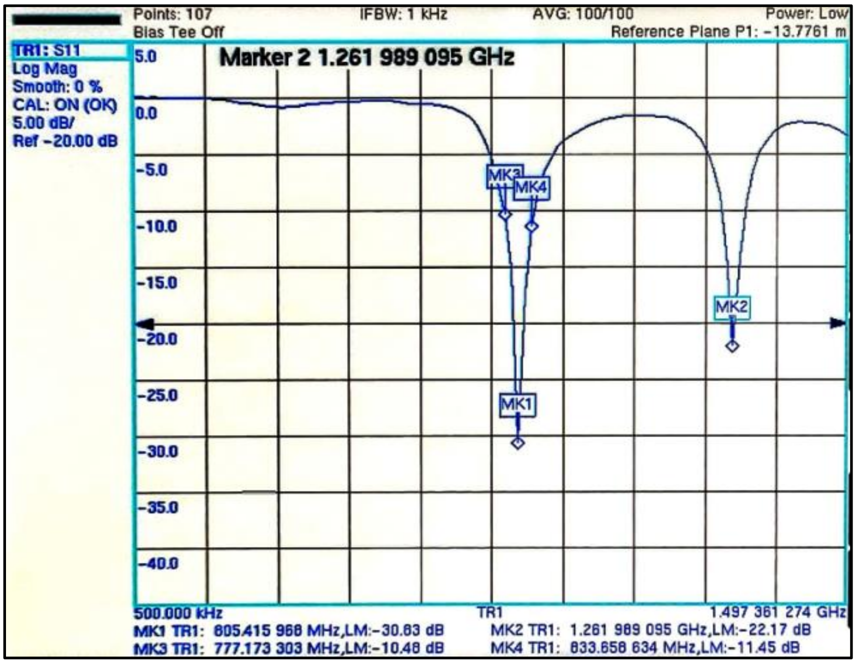

Figure 7. The results of the measurements from the second spiral microstrip antenna show that Return loss value of -30.83.

Upon reviewing the measurement graph of the second spiral microstrip antenna, it is evident that it demonstrates a return loss value of -30.83 dB at a frequency of 805 MHz.

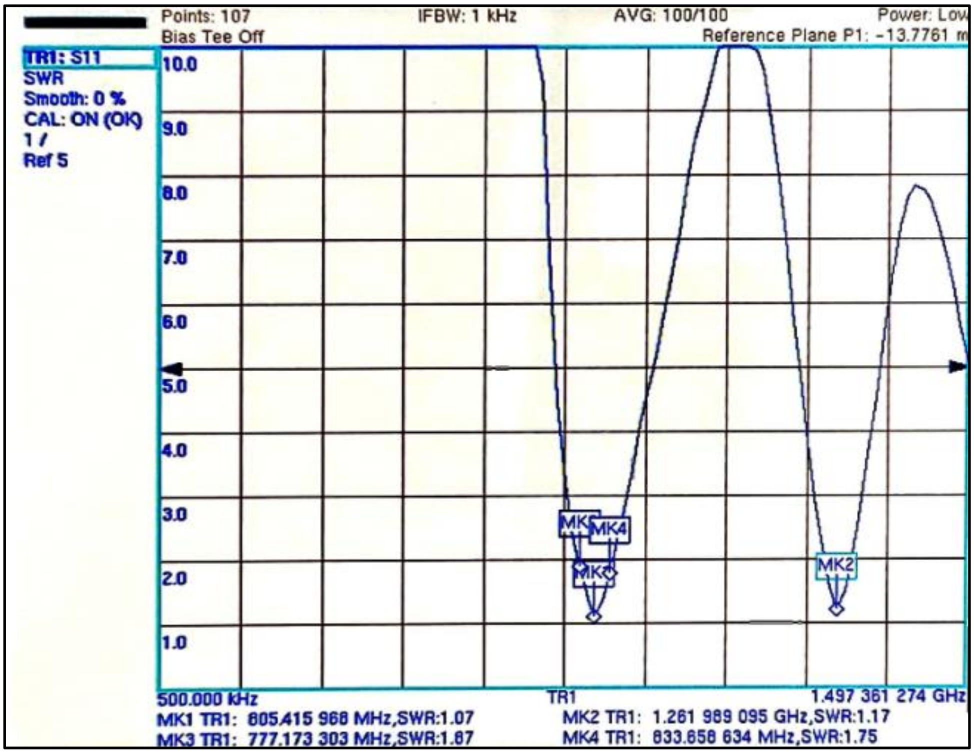

Figure 8. The results of the measurements from the second spiral microstrip antenna show that VSWR of 1.07.

A high-quality antenna will display a VSWR value below 2, indicating satisfactory performance. The image in Figure 6 depicts the measured results of the second spiral antenna that has been produced. VSWR of 1.07, and a bandwidth of 57 MHz.

Table 1 Antenna Measurement Gain Comparison

Antena	*Return Loss* minimum	VSWR minimum	Dimension
Spiral 1	-27,54 dB	1,10	40x50mm
Spiral 2	-30,83 dB	1,07	40x50mm

4. CONCLUSION

From the results of testing and analysis of antenna parameter calculations, a microstrip spiral antenna 1 was produced where the shape of the arm structure was rotated clockwise. The optimal gain resulted in a VSWR of 1.83, a return loss of -27.54 dB, and a bandwidth of 72 MHz at a frequency of 565 MHz. Optimal gain was obtained by characterizing the changes in the length of the spiral arm and the dimensions of the substrate.

The placement of the ground plane position and changes in the direction of rotation of the antenna arm on spiral 2 affect the substrate's size and the antenna's working frequency. The optimal gain was obtained better using the same antenna substrate size, where the VSWR was 1.07, the return loss was -30.83 dB, and the bandwidth was 57 MHz at 805 MHz. Adding ground to the second antenna resulted in significant changes in the measurement of the return loss value. However, the bandwidth and working frequency of the antenna also changed.

ACKNOWLEDGEMENTS

Thank you to the lecturers, who have provided invaluable assistance and guidance, as well as family and friends, who have always supported and motivated me during the process of writing this journal. Without the support and assistance of all parties, I would not have been able to complete this journal properly.

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