Optimization of Patch E-Shape Array Microstrip Antenna 2.45 GHz Using Double Reflector

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***Abstract*— Microstrip antennas are widely used in telecommunications equipment because they are compact, practical, and easy to adjust. Modifying the patch and the reflector models can improve the microstrip antenna performance. An e-shaped microstrip antenna is one model antenna used for WiFi. In this research, the E-Shaped patch microstrip antenna was optimized by adding and modifying two reflector layers. The first reflector uses a complementary form with the same dimension as the patch. Secondly, the other layer uses Defected Ground Structure (DGS) symmetric "+" shape. This modification can increase the gain and bandwidth of the microstrip antenna. Based on the measurement results, this antenna can work at a center frequency of 2435 MHz with a gain value of 7.139 dB, a VSWR of 1.7, a bandwidth of 60 MHz, and has linear polarization.**

***Keywords*— Microstrip, reflector, E-Shaped patch, DGS, conjugate.**

I. INTRODUCTION

WiFi (Wireless Fidelity) is a wireless technology for communication that operates at 2.4 GHz and 5 GHz [1]. This technology contains 11–13 channels, every 1 MHz wide range for a track. It has Data rates for WiFi ranging from 11 Mbps to 100 Mbps. The volume of data conveyed and the speed of delivery have increased along with human demands, which has sparked a lot of interest in creating supporting devices with wide bandwidth and high gain [2].

The advancement of telecommunications technology has produced numerous breakthroughs in wireless communication systems to improve gain and bandwidth antenna. Modification and development of antenna design is one way to increase antenna bandwidth. Antennas are one of the crucial parts of wireless communication systems. This component acts as a means to transmit and receive electromagnetic waves contained in the free air. Antennas have many types and shapes with various characteristics of each type of antenna. One type of antenna that is popular today is a microstrip antenna with petite and thin dimensions [3]. The array model is one way to get a high-gain microstrip antenna for WiFi applications [4], [5].

Microstrip antennas have low gain and narrow bandwidth, limiting their use. Several studies use proximity-coupled methods to improve the quality of microstrip antennas [6], [7]. But the improvement of gain is not significant. Optimizing the rectangular microstrip antennas on dual-band antennas for WiFi frequency has been done [8], [9]. It can add antenna bandwidth. Antenna patch microstrip for wireless communication has several models, such as square, rectangular, and triangle [10]. The square antenna can be modified to an E-shape form to increase efficiency. E-Shaped antennas have higher gain and directivity than square antennas [11], [12]. E-Shaped antennas have more resonance than square antennas [13].

In addition, adding or modifying the antenna feeder and reflector portion can improve the gain and bandwidth antenna [14]. The reflector can be its conjugate circuit, which has the opposite shape to the original antenna [15]. In addition, the multi-layer antenna consists of DGS (Defected Ground Structures) [16]. Furthermore, the reflector can combine the conjugate and its DGS [17].

Based on these reasons, the idea is to make an E-Shaped Microstrip patch antenna that can work at a frequency of 2.45 GHz, which can implement for WiFi systems with relatively high gain and wide bandwidth. A reflector is needed or with the addition of DGS to obtain high power and wide bandwidth. The antenna structure of the E-Shape antenna consists of two layers. The first reflector uses a complementary design, and the second uses a DGS in the form of plus (+). Antenna feed systems using a power-sharing network on the antenna do not require complicated impedance adjustment techniques to match the impedance of each antenna element to a transmission line from the antenna. So it can be implemented as an antenna WiFi with high gain, wide bandwidth, and a physical form that is easy to apply.

II. ANTENNA DESIGN

A. *Antenna Specification Optimation Antenna*

WiFi antennas use copper (annealed) material as a conductor. Before realizing the antenna, it has simulated using software to know the performance.

TABLE I. ANTENNA SPESIFICATION

Parameter	Description
Frequency	2.45 GHz
Bandwidth	40 MHz
Return Loss (2.45 GHz)	-40.659 dB
VSWR	1.48
Gain	10.83 dB
Radiation Pattern	Directional
Polarization	Co-polarization
Antenna Dimension	172 mm *x* 82 mm

The simulation parameters observed include Return Loss (S_{11}), bandwidth, Voltage Standing Wave Ratio (VSWR), radiation pattern, polarization, bandwidth, and the gain of the antenna design, as shown in Table I.

B. Optimation Antenna

Table II compares antenna optimization with several different forms. There are three models of optimization such as only patch, patch with the conjugate, and patch with double reflector.

TABLE II. TYPE OF DIFFERENT ANTENNA MODEL

Antenna	**Frequency Centre (GHz)**	***Gain (dB)***	**VSWR**	***Bandwidth (MHz)***	**S_{11} (dB)**
Type	Different combinations of patch				
patch E-Shape	2,484	6,29	1,13	33	-23,7
patch E-Shape array 1x2	2,472	8,28	1,06	81	-30,268
patch E-Shape array 1x4	2,48	10,8	1,09	85	-26,707
Type	Patch with Conjugate				
patch E-Shape conjugate	2,484	6,3	1,14	33	-23,645
patch E-Shape array 1x2 conjugate	2,47	8,28	1,06	82	-30,38
patch E-Shape array 1x4 conjugate	2,48	10,8	1,04	84	-27,89
Type	Patch with Conjugate and DGS				
Patch E-Shape conjugate with DGS	2,49	6,27	1,14	60	-23,324
Patch E-Shape array 1x2 conjugate with DGS	2,46	8,2	1,05	81	-30,06
patch E-Shape array 1x4 conjugate with DGS	2,45	10,8	1,018	91	-40,659

The maximum optimation is patch E-Shape array 1x4 conjugate with high-gain and wide bandwidth with DGS. It has a gain value of 10.8 dB. The bandwidth value is greater than the others, about 91 MHz, and the most significant S-Parameter value is -40,659 dB.

C. Specification of Substrate and Conductor Material

The substrates used are as follows: Substrate type FR-4 (lossy), Dielectric constant (εr) 4.7, Dielectric thickness (h) 1.6 mm, and Thickness of conductor material (t) 0.035 mm.

In Fig. 1, the dimensions of the designed microstrip antenna have antenna dimensions of 172 mm x 82 mm, which have an E-Shape patch with a width of 28.5 mm and a length of 28.5 mm having a distance between patches d or /4. The microstrip antenna has a feed with the W70Ω having a width of 1.4 mm and a length of λ /8. The W50Ω has a width of 3 mm and a height of λ/40.

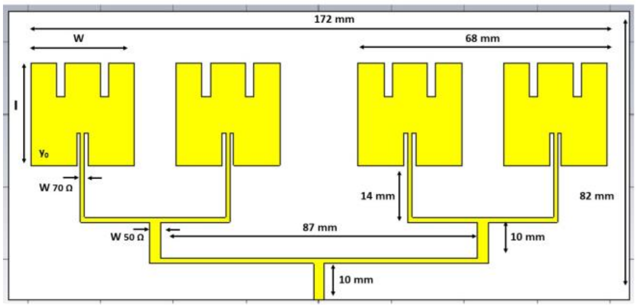

Fig. 1. Patch antenna dimensions.

D. Patch Antenna Optimization Using Complementary

In the first reflector, the concept of this structure is to place the exact dimensions of the patch on the top layer and the slots in the ground layer of the same dielectric substrate to get high gain and wide bandwidth. Based on a reference from research conducted [18], which examined the increase in bandwidth values with the added same DGS slot as the patch in the top layer or complementary as shown in Fig. 2.

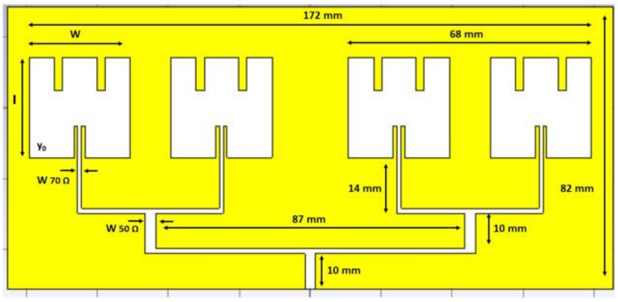

Fig. 2. First reflector (ground).

E. Patch Antenna Optimization Using the DGS Method

The second reflector optimization uses a modified DGS plus "+" and adjustments, as illustrated in Fig. 3. Modification of DGS plus "+" concerning increased bandwidth and radiation on patch antennas to efficient layered for microstrip antenna [19]. Modifying the DGS approach's reflector may increase the gain value and bandwidth.

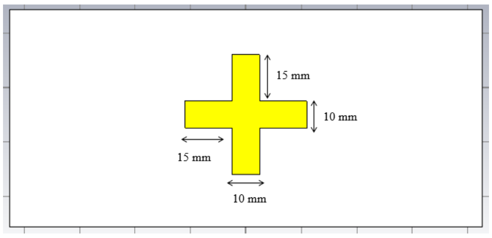

Fig. 3. Second reflector.

The simulation results observed from the final results include Return Loss (S_{11}), bandwidth, Voltage Standing Wave Ratio (VSWR), radiation pattern, polarization, bandwidth, and the magnitude of the gain of the antenna design.

III. MEASUREMENT AND ANALYSIS OF ANTENNA PARAMETERS

Measurements using a vector network analyzer, as shown in Fig. 4. Antenna performance measurements include S Parameter, Gain, and Radiation Pattern testing. The S-parameter test determines several parameters, such as bandwidth and returns loss (S_{11}), S_{21}, and VSWR).

Antenna gain testing using Vector Network Analyzer (VNA) in ports one and two. Installing the intended antenna on port one and a monopole antenna on port 2 is the test procedure through radiation pattern testing, the form of the antenna beam pattern in both the horizontal and vertical planes.

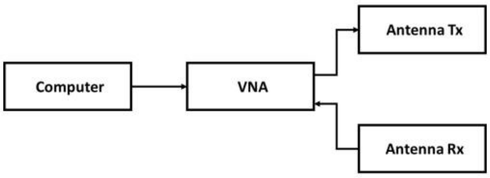

Fig. 4. S-Parameter measurement.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

Figure 5 shows the result of antenna manufacturing. The antenna uses two substrates consisting of one single layer substrate and one double layer substrate for the feed channel and ground. The use of these two substrates follows the double reflector technique, which utilizes two substrates separated by an air aperture between the two substrates. The connector used in the supply is an SMA Female connector with an impedance of 50 ohms at the end of the antenna supply line.

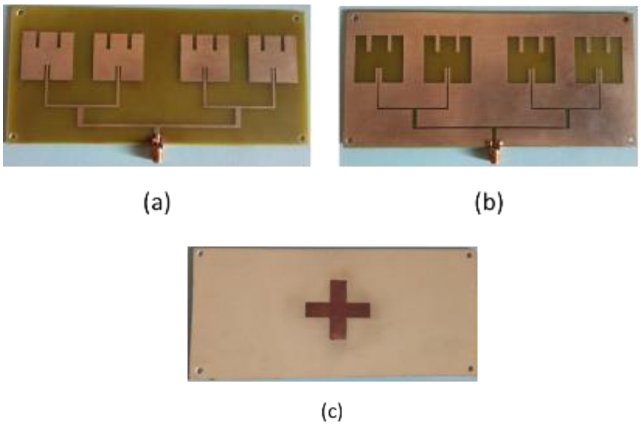

Fig. 5. Antenna fabrication results, (a) top view, (b) first reflector, (c) second reflector.

A. S-Parameter Test Results

From Fig. 6, the return loss value in the simulation at the center frequency of 2450 MHz is -40,659 dB, and the results of the antenna design can work well at a frequency of 2435 MHz of -30.117 dB. This value indicates that the designed antenna can still work well at a frequency of 2435 MHz, following the standard category of both antennas, which has $S_{11} < -10$ dB and VSWR meets the requirements of $1 \leq \text{VSWR} < 2$.

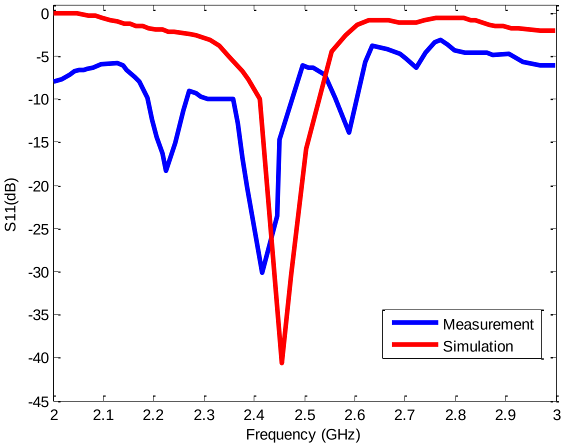

Fig. 6. S_{11} Test Results

The value obtained in this S-Parameter measurement has a different value compared to the simulation results. The simulation process produces S_{11} of 40.659 dB, VSWR of 1.48, and a bandwidth of 40 MHz in the frequency range of 2440 MHz to 2480 MHZ. The attenuation of the cable and connector and the frequency shift make the value difference between simulation and fabrication. In addition, the influence of air in the gap between the substrates is due to the antenna performance.

B. VSWR

The measurement results show an excellent VSWR value in the frequency range of 2410 MHz to 2470 GHz. Based on measurement results, the bandwidth of the designed antenna is 60 MHz, as illustrated in Fig. 7.

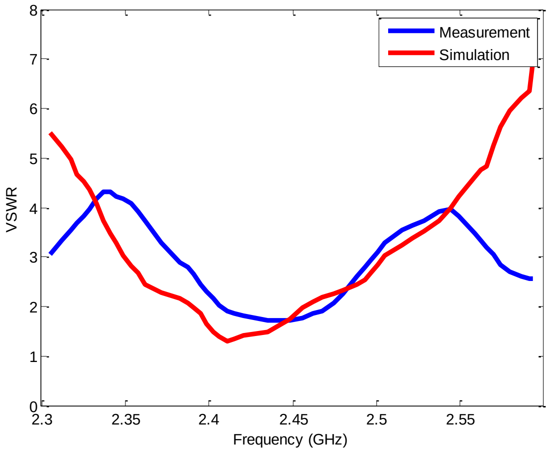

Fig. 7. VSWR value

C. Gain Test Results

Gain measurement determines how much power can be emitted by the antenna at a certain angle. This study obtains the gain value by analyzing the coefficient S_{21}. The value of S_{21} is obtained based on the value shown by the designed antenna to the reference antenna (antenna monopole). From the importance of S_{21}, a calculation result using to get the designed antenna's gain value.

Before testing the gain of the designed antenna, first, know the power of the reference antenna. This antenna serves as a comparison so that the measured gain is the same as the comparison gain or Gt = Gr. The following equation calculates the measured reference antenna where S_{21} is -37,358 dB.

D. Radiation Pattern

From the measurement results of the antenna in the horizontal and vertical planes, the radiation pattern is relatively the same as the radiation pattern of the simulation results. A comparison of the designed antenna radiation pattern results with the simulated radiation pattern is in Fig. 8 and Fig. 9.

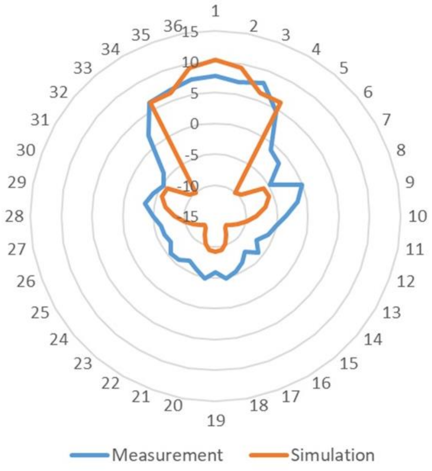

Fig. 8. Horizontal radiation pattern

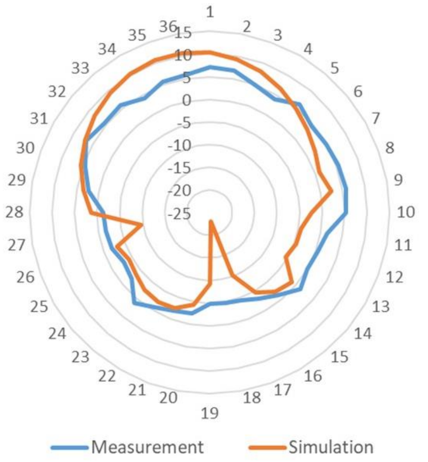

Fig. 9. Vertical Radiation pattern

The radiation pattern of the designed antenna tends to have a smaller radiation pattern than the simulated radiation pattern. Although there are still variances, the value may differ from the mark displayed by each primary lobe and side lobe at each corner. Several factors cause this difference in simulation and measurement. In the simulation, the parameters generated are in perfect form. In contrast, in the measurement process, the parameters can be affected by the environment, and materials used in the manufacturing and measurement processes.

The radiation pattern shown by this design antenna shows the shape of the radiation pattern with a directional direction, namely the direction of the antenna beam leading to a certain angle shown in the main lobe.

CONCLUSIONS

Based on the measurement results of the E-shape array microstrip patch antenna, there is a slight difference in center frequency, which in the simulation obtained a gain value of 10.83 dB, VSWR of 1.48, bandwidth of 40 MHz, and S_{11} of -40,569 dB with a center frequency of 2450 MHz. Meanwhile, the measurement results obtained a gain value of 7.139 dB, VSWR of 1.7, a bandwidth of 60 MHz, S_{11} of -30.117 dB at a center frequency of 2435 MHz, and It has linear polarization.

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