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## Patch microwave absorber for RF energy harvesting as renewable energy

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## Patch microwave absorber for RF energy harvesting as renewable energy

Z Muslimin<sup>1</sup>, N Anugraha<sup>2</sup>, A Suyuti<sup>3</sup>, E Palantei<sup>4</sup>, and Indrabayu<sup>5</sup>

<sup>1</sup>Doctoral Student of Electrical Engineering Department Faculty of Engineering, Universitas Hasanudin. Jl. Poros Malino km.6, Kampus Teknik Gowa. Makassar, South Sulawesi, Indonesia.

<sup>2</sup>Postgraduate Student of Electrical Engineering Department Faculty of Engineering, Universitas Hasanudin. Jl. Poros Malino km.6, Kampus Teknik Gowa. Makassar, South Sulawesi, Indonesia.

<sup>3,4</sup>Electrical Engineering Department Faculty of Engineering, Universitas Hasanudin. Jl. Poros Malino km.6, Kampus Teknik Gowa. Makassar, South Sulawesi, Indonesia.

<sup>5</sup>Informatic Engineering Department Faculty of Engineering, Universitas Hasanudin. Jl. Poros Malino km.6, Kampus Teknik Gowa. Makassar, South Sulawesi, Indonesia.

E-mail: [zaenab\\_muslimin@yahoo.com](mailto:zaenab_muslimin@yahoo.com)

**Abstract.** Renewable energy is a form of energy produced from natural resources. Besides from nature, renewable energy can also be obtained from electronic devices that emit electromagnetic waves. Electromagnetic waves can develop and be used as a source of power, especially low power consumption equipment such as sensors. One method that can be used to harvest the electromagnetic waves is of Energy Harvesting method using microstrip antenna. Energy Harvesting is one of the green technologies that are rapidly evolving nowadays. This study aims to design a microstrip antenna to harvest energy with 1x2 parallel array configuration and ISM (International Standard for Mobile communication) frequency operation of 2.4 GHz. The antenna's performance is based on the value of Voltage Standing Wave Ratio (VSWR), Return Loss (S11), gain and radiation pattern. Ansoft HFSS v.13 simulates the antenna's design. The simulation results are compared with the measurement results to analyze the antenna performance. The results showed that VSWR and Return Loss parameters in simulation and measurement have different performances, but still intolerance performing range. The simulation antenna gain obtained 2.52 dB.

### 1. Introduction

Energy has an important role in modern life. Whereas the current energy source is still very limited and mostly depends on fossil fuel, such as petroleum. It is known that petroleum resources cannot be renewed. Therefore, the use of renewable energy began to bloom in use. Renewable energy is a form of energy generated from natural resources includes solar, water, electric, nuclear, petroleum and gas energy.

Indonesia is one of the most abundant renewable energy potentials. However, the potential of renewable energy resources is still not utilized optimally. This is because now Indonesia is still dependent on fossil energy sources that presents a big problem. Therefore, the use of environmentally friendly renewable energy is needed to reduce the impact of environmental damage resulting from the use of fossil energy.

Beside from the earth, energy can also be generated from electronic equipment that emits electromagnetic waves. The free energy of the electromagnetic equipment can be reconstituted by



harvesting energy method using rectifier antenna (Rectenna) to be reused as an energy source for small power equipment, e.g., sensors.

Rectenna is a tool that can be used for harvesting energy consisted of rectifier and antenna. This paper focuses on the antenna design for harvesting energy as initial research. The microstrip antenna is one of the most common types of antennas used. However, it has a disadvantage of low gain value [1]. There are several ways to increase the gain, i.e., replacing the substrate dielectric constant, changing the design of the field (patch), using parasitic radiators, and arranging the patch with array configuration [2].

The performs design and analysis of microstrip antenna at a frequency of 850 MHz for practical antenna application with three types of the patch, i.e., quadrilateral, circle, an equilateral triangle. As a result, the gain value is still low, that is -0.205 dB, -0.673 dB and -2.322 dB, respectively [3]. Meanwhile, the study designed a single elementary microstrip antenna for a wireless power transmission system that works at 2.5 GHz frequency for wireless power transmission by changing and optimizing the size of the patch design and obtaining a gain value of 1.86 dB [4]. Since the gain is still low, in this study the design a microstrip array antenna to increase the gain value. The model and dimensions of the patch antenna based on the design [4].

**2. Literature Review**

There are two methods for designing microstrip antennas with array configurations, that is by the serial array and parallel array [5]. One of the advantages of array configuration in parallel is if one patch on the antenna is interrupted, the other patch will not be affected [6]. Simulation of the antenna system is using Ansoft HFSS v.13 software. After the simulation is complete, the antenna design will be fabricated, then the measurement of the antenna performance is done based on the generated VSWR parameter value, Return Loss and gain.

Some calculations that are required before designing the feeder supply Patch. The width of the microstrip channel (W) depends on impedance characteristic (Z0) that used. The formula to calculate the width of the microstrip channel [7] is:

$$W = \frac{2h}{\epsilon_r} \left\{ -1 - \ln(2 - \epsilon_r) + \frac{\epsilon_r - 1}{\epsilon_r} [\ln \epsilon_r - 1] + 0,39 - \frac{0,61}{\epsilon_r} \right\} \tag{1}$$

With  $\epsilon_r$  is the relative dielectric constant, and

$$W = \frac{60^2}{Z_0 \sqrt{\epsilon_r}} \tag{2}$$

The used parameters of the microstrip antenna are shown in table 1:

**Table 1.** Antenna's Parameter.

Frequency	Substrate	Relative Constant Dielectric	Dielectric Loss Tangent	Impedance	Thickness The substrate (h)
2.4 GHz	FR4-Epoxy	0.02	0.02	50 Ω	1.6 mm

Based on the formula (1) and (2) we obtain the calculated channel feed width for 50 Ω of 2.91 mm and the feeder channel width for 70.7 Ω of 1.57 mm with the length of 26.58 mm.

Some antenna parameters that commonly used as the performance of the antenna are:

- i. Voltage Standing Wave Ratio (VSWR)

VSWR is the comparison between the amplitude of maximum ( $V_{max}$ ) and minimum ( $V_{min}$ ). In the transmission line, there are two components of the voltage wave, that is the transmitted voltage ( $V_{0+}$ ), and the standing wave reflected voltage ( $V_{0-}$ ). The comparison between the reflected voltage and the transmitted voltage is referred to as the reflection coefficient [7]. The best condition is when the VSWR value is equal to 1 or  $S = 1$ , which means there is no reflection when the channel is in the perfect matching state. [8].

ii. **Return loss**

Return loss is the ratio between the amplitude of the reflected wave to the amplitude of the transmitted wave [9].

iii. **Gain**

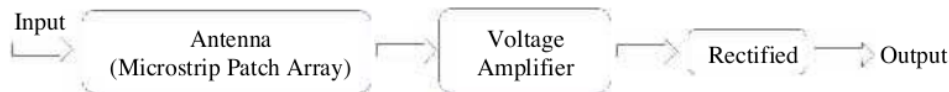
Gain is a value scale that indicates the addition of signal level from the input signal to the output signal. Gain depends on its severity and efficiency [2].

iv. **Radiation Pattern**

The radiation pattern is formed from the far field jet on the antenna. The radiation pattern is a depiction of radiant energy antenna that serves as the coordination of space. The emission of energy is the intensity of the electric field [10].

### 3. Proposed System

To absorb residual energy from electronic equipment, one of the tools that can be used is Rectenna (Rectifier and Antenna). This study focuses on designing a microstrip antenna for harvesting energy with 1x2 parallel array configuration. The block diagram of the energy harvesting system using antenna array as in figure 1 below:



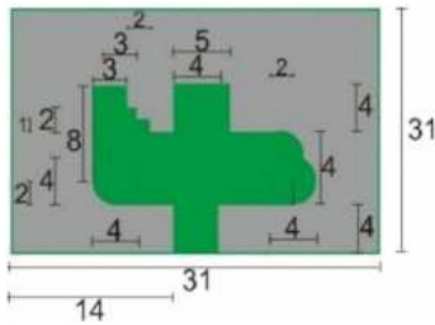
**Figure 1.** Block Diagram of Energy Harvesting System Using Rectenna.

Before the full fabrication and design of Ansoft HFSS simulator, the steps that must be done is to characterize the length and width of the channel that is going to be used. From several optimizations that have been done, we finally obtained the desired characteristics. These characteristics include substrate types and dimensions, patch size, feeder channel impedance and length and width of feeder channels used.

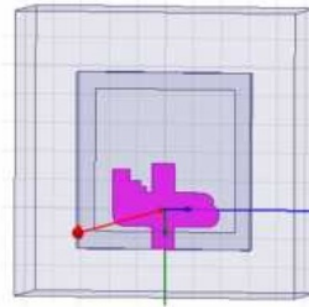
#### 3.1. The Result Single Element Microstrip Antenna Design.

The designed microstrip antenna is a model of a single plane-shaped element with patch size was obtained from several optimization processes. Figure 3 shows a single element microstrip antenna layout image. While 4 shows a design Ansoft HFSS v.13 simulator design result.

The comparison of the results obtained between the direct measurements and the results obtained through simulations designed in Ansoft HFSS v.13 simulator.



**Figure 2.** Microstrip antenna design with single element.



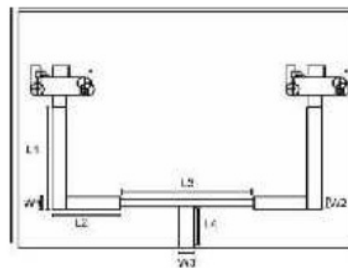
**Figure 3.** Microstrip antenna design with single element on HFSS.

3.2. Final Result of Microstrip Array Antenna Configuration Array.

The gain value obtained is 1.84 dB [4]. One of the used methods to obtain the larger gain is designing antennas with array configuration [2]. So, in this study, the antenna will be designed with 1x2 array configuration.

**Table 2.** Comparison between W and L measurement before and after optimization.

No	Parameter	Measurement before optimization	Measurement before optimization
1	L1	23.2 mm	34.8 mm
2	L2	11.6 mm	15.9 mm
3	L3	26.58 mm	39.87 mm
4	L4	11.6 mm	13.8 mm
5	W1	2.91 mm	4.365 mm
6	W2	1.57 mm	2.355 mm
7	W3	2.91 mm	4.365 mm



**Figure 4.** Array Parallel 1x2 Microstrip antenna design.

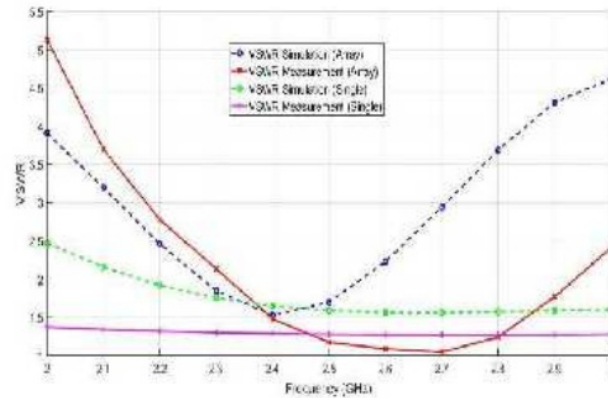
4. Discussions Analysis

The used parameters to determine the performance of an antenna is the value of Return Loss >-10 dB, and VSWR <2 working at a predetermined working frequency.

#### 4.1 VSWR Microstrip Antenna.

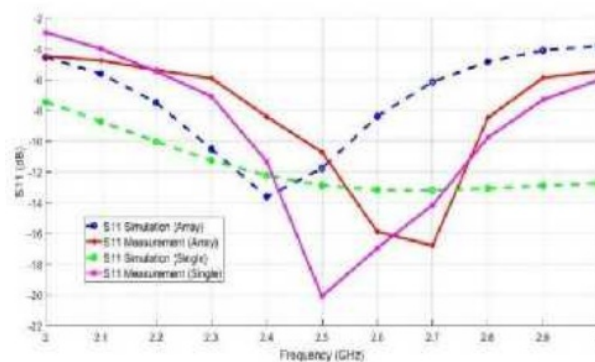
VSWR test and analysis is to find out VSWR value of single dimension microstrip antenna and with the array configuration either based on a value obtained in the simulator or based on the direct measurement on the antenna. Measurement of VSWR value is determined based on the smallest VSWR value of the antenna or VSWR value of the antenna working frequency.

Figure 5 shows a comparison of VSWR value of single and array dimension for simulation and measurement result.



**Figure 5.** Comparison of single and array VSWR antenna microstrip.

#### 4.2 Return Loss Microstrip Antenna.



**Figure 6.** Comparison of single and array Return Loss antenna microstrip.

Based on the optimization that has been done, the value of Return Loss for single dimension and with the configuration of the array can be seen in Figure 6, where obtained Return Loss results for single dimension on the simulator is -12.247 dB and on the direct measurement in the antenna is -11.342 dB, while the antenna with the array configuration, the value obtained in the HFSS simulator is -13.623 dB and on the direct measurement is of -8.415 dB, where each of them working on a frequency of 2.4 GHz.

#### 4.3 Gain.

In this study, the main objective is to increase the gain by design an antenna in the form of the parallel array configuration. Gain obtained on the antenna with a single dimension is 1.84 dB while the antenna with the array configuration has an increase of the gain value by 37% (2.52 dB).

#### 4.4 Radiation Pattern.

The radiation pattern from the simulation result of microstrip antenna array is shown in Figure 7.

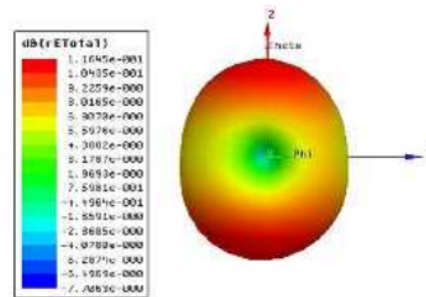


Figure 7. Radiation Pattern microstrip antenna array.

#### 5. Conclusion

One of the most environmentally and friendly renewable energy types comes from electronic equipment. Such free energy can be collected and reused using rectenna. One type of antenna that can be used is microstrip patch array. Microstrip array antenna design has been done in this research. Antenna performance based on VSWR, Return Loss and Gain values. From the results obtained, it can be viewed that there are differences in the results of measurement and simulation of VSWR and Return Loss. For example, VSWR measurement results for a single dimension obtained the value of 1.645 while the direct measurement obtained 1.288. For array dimension, the VSWR value in simulation and measurement obtained 1.256 and 1.467, respectively. The gain of array antenna increases 37% comparing to the single antenna design in simulation.

For the further research, the design of microstrip antenna that has been made will be integrated with a series of rectifiers and amplifier circuits to obtain for harvesting energy on satellite.

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