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Serial Rectifier Antenna (Rectenna) Microstrip Patch Circular 2.4 Ghz For RF Energy Harvester

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***Abstract*— The source of Radio Frequency (RF) electromagnetic wave energy in the atmosphere is currently abundant and wasted due to the rapid development of today's RF technology. Utilizing a rectenna system to harvest energy, this RF energy source can be used as an environmentally friendly distribution method. To improve the rectenna's ability to convert electromagnetic waves into a direct voltage (DC) source, a recttenna system is designed using a serial rectenna system. using 3 antennas and 3 rectifier circuits, to design a serial rectenna system. A circular patch microstrip antenna with a frequency of 2.4 GHz is used in a serial receiver system to receive WiFi signals. Schottky diode 2860 and 1nF smd price are used in voltage doubling 6 stage rectifier circuit, which is used in rectifiers. The microstrip patch antenna found is capable of capturing and directing voltage to DC through testing and measuring the serial rectenna system. The system antenna has a return loss value of -26.29 dB, - 21.75 dB, and -28.57 dB, VSWR 1.11, 1.16, and 1.07, impedance of 51.1, 55.56, and 50.22, and bandwidth of 60 MHz. The resonant frequencies for 60 MHz and 50 MHz are 2.42 GHz, 2.36 GHz and 2.48 GHz. so that at a distance of 25 cm a single rectenna system produces a voltage of 51 points 3 mV. During this time, the serial receiver system can convert a direct voltage of 151.08.**

***Keywords*— Rectenna; Serial Rectenna; Antenna; Rectifier; Voltage Doubler; Energy Harvesting;**

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I. INTRODUCTION

At the present time Almost all electronic devices today use direct current as a source of supply. Batteries are the most commonly used source of DC voltage. However, due to its chemical makeup and short life, Ananda battery (2018) becomes a product that contributes to environmental pollution. However, as cellular technology advances, radio frequency signals are becoming more widely used. As a result, radio transmitters such as base stations and access points have released excess RF energy into the atmosphere.

By energy harvesting, this abundant RF energy can be used as an energy source instead of distribution of low-power devices. (2015) (Ruhyat). Energy Harvesting according to Al-absi et al. and (2020) is a method to obtain electrical energy from environmental sources, such as RF signals, and convert it into a direct voltage (DC) source. Rectennas are very important for RF energy harvesting, according to (2013). Rectenna, according to Yuwono et al, (2016) combines a rectifier and antenna, with the role of an antenna to collect electromagnetic waves in the environment. Direct voltage (DC) will be generated by the rectifier by changing the connection and electrical signal sent by the antenna, Rectenna produces DC voltage, can be used as a wireless calculation for low-power devices without using batteries (Ruhyat, 2015).

A rectenna can work on RF Waves at a frequency of 2 GHz (access point frequency) can be operated by the rectenna. The RF waves of the access point are captured using a specific type of microstrip antenna, but to convert the RF waves into twice the DC output voltage, a rectifier circuit is needed that can correct and double the input voltage, Toudeshki et al recognized that, Crockroft-Walton voltage multiplier step-up transformers, charge pump circuits, capacitor-switch circuits, and boost or step-up converters are some examples of rectifier circuit techniques that can change voltage dc output becomes greater than the voltage received by the antenna, Rectenna has been implemented in previous studies using a single receiving antenna and rectifier voltage multiplier circuit with a number of stages of 5, and succeeded in producing a direct voltage of 5 mv at a distance of 25 cm from the transmitter (Dzakiyyah, 2016). In addition, a 3-stage rectifier circuit is used to implement the rectenna, and at a distance of 20 cm from the transmitter source produces an output voltage of 0 points092 mV (Hijriani et al., 2018). In addition, a direct voltage of 4.306 mV can be generated using a single rectifier system, consisting of a 2x2 microstrip patch array antenna and a dual diode rectifier circuit (Rifkiano et al., 2016). A weakness of previous studies was the generation of low output dc, which prevented it from serving as a replacement supply. And this is aimed at :

1) Creating a circular patch microstrip antenna with an operating frequency of 24 GHz.
2) Create a rectifier that can correct radio frequency waves. (RF) becomes direct current (DC).
3) Testing the working parameters of the serial receiver.
4) Use parameters to analyze the output of serial rectenna.

II. MATERIALS AND METHOD

A. Equation

Determine the radius of the irradiating element of the antennamicrostrip by using the following equation.

$$\alpha = \frac{F}{\left\{1 + \frac{2h}{\pi \varepsilon_r F}\left[ln\frac{\pi F}{2h} + 1,7726\right]\right\}^{1/2}} \qquad (1)$$

First the calculation of the logarithmic function F is carried out. With fr = 2400 MHz; (εr) = 4.7, then the value of the logarithmic function F can be calculated by the equation

$$F = \frac{8,791 \times 10^9}{fr\sqrt{\epsilon r}} \qquad (2)$$

Determine the size of the antenna transmission line, that is, by *the feed inset* model, which has a channel impedance of 50 Ω. The design of *the inset feed* slot length can be determined by equation.

$$yo = 0,3d$$

$$yo = 0,3 \times 16,42 \qquad (3)$$

$$yo = 0,9852 \text{ cm} = 9,852 \text{ mm}$$

Specifies the width of *the feed inset* slot, using the equation

$$W_o = \frac{7,48 \times h}{e^{\left(Zo\frac{\sqrt{\varepsilon r+1,41}}{87}\right)}} - 1,25 \times t$$

$$W_o = \frac{7,48 \times 1,6}{e^{\left(50\frac{\sqrt{4,7+1,41}}{87}\right)}} - 1,25 \times 0.035 \qquad (4)$$

$$W_o = \frac{12,544}{4,1395} - 0,0437$$

$$W_o = 2,9865 \text{ mm} \approx 2,99\ mm$$

Determining the length of the transmission line, it can be calculated using the equation.

$$L_0 = 0{,}25\lambda_d \text{ (m)} \quad (5)$$

Antenna

The most important part of wireless communication, which serves as a means of sending and receiving information, is the antenna. An antenna is a device that can send and receive radio waves, according to "The IEEE Standard Definitions of Terms for Antennas." There are many types of antennas, such as wired antennas, aperture antennas, microstrip antennas, array antennas, reflector antennas, and lens antennas. In accordance with the standards it adheres to, each antenna serves a unique purpose.

Antena Mikrostrip

Microstrip antenna is an antenna consisting of very thin radiation elements (conductors) placed in the ground plane, where between the plane and the radiation elements (conductors) are separated by a dielectric substrate with a certain dielectric constant value (εr). This antenna is lightweight and easy to fabricate because it has a small size so that it can be easily placed on all types of surfaces [5].

Microstrip antennas have three main elements: patch as a radiation element, dielectric substrate, and groundplane element. Each of these parts has a different function [6].

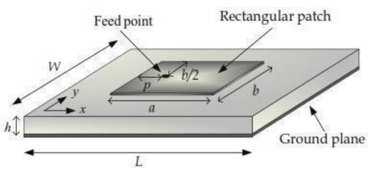

Figure 1. Microstrip Antennas [5]

Microstrip Patch Circular Antenna

A circular microstrip antenna is an antenna in the form of a circular patch. This shape antenna has the same performance as a rectangular patch microstrip antenna. In certain applications, such as arrays, circular patches have an advantage over other patches. The advantage of circular microstrip is the small substrate height h << λ [6].

Enumeration Insert Feed Technique

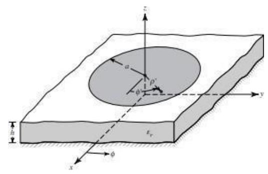

Figure 2. Antena Mikrostrip Patch Circular [6].

The patch antenna is connected to the transmission line using a technique called feeding.

The ability to apply this feeding method on the same substrate E and produce a planar structure is an advantage. To match the channel impedance with the patch without using additional adjustment elements, inserts are provided into the patch.

Figure 3. *Insert Feed* Antena Mikrostrip [10]

Rectifer

A rectifier (wave rectifier) is a part of the power supply that converts an AC voltage signal into DC voltage. The diode performs the function of a rectifier element using forward bias. Important parts of the voltage rectifier circuit are voltage reducers (transformers), wave rectifiers (diodes), and filters (capacitors). The two basic types of wave rectifiers are half-wave rectifiers and full-wave rectifiers [9]. Schotky HSMS 286 diode.

One type of diode that can function at low voltages is the Schottky diode. Schottky diodes, in contrast to ordinary diodes, can operate at an input voltage of 0.15-0.45 volts, in contrast to 0.7-1.7 volts for ordinary diodes. Schottky diodes can also operate between 0 and 5 GHz. To say that Schottky diodes are diodes that operate at high frequencies.

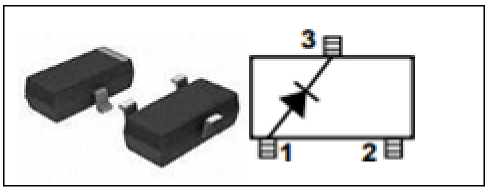

Figure 4. *Diode Schottky* [10]

Antenna Dimension Calculation Results

Tabel 2.1 Antenna Dimensions of the Calculation Results

No.	Dimension	Value (mm)	Information
1.	α	16,42	Radius antenna
2.	Yo	9,852	length slot inset feed
3.	Wo	2.99	Transmission Line Wide
4.	Lo	14,41	Transmission line length
5.	L	42,44	Ground plane length
6	W	42,44	Groundplane Wide

Research Flowchart

Flow of Design and Serial Creation of Rectenna In this final Project, Figure 5 illustrates the process of designing and manufacturing rectenna. Next, select antenna specifications, such as operating frequency, substrate type, and patch and groundplane size. Ansoft HFSS 13.0 software was then used to simulate the antenna. Next, create a rectifier using the n-stage voltage multiplier method, which requires a number of electronic components, including active components (diodes) and passive components (capacitors) The working frequency of the rectenna is used to determine which electronic components to use. A rectifier that converts the dc output of the antenna into a shape that can be measured by the AVO meter, serialized with the antenna to increase the output.

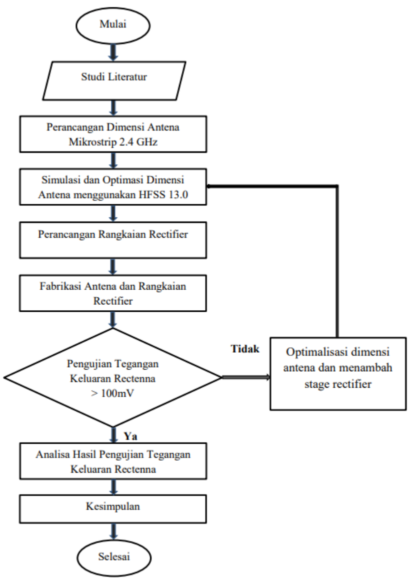

Figure 5. Flowchart Proposed schematic

Prepare the equipment needed in making this research such as Collecting all data from various reference sources such as books, journals, articles and other sources related to the design of this circular patch microstrip antenna . Before designing using software, it begins with doing antenna calculations to determine antenna dimensions.

The design of a circular patch microstrip antenna with HFSS software is carried out through several stages, starting with patch design by creating substrates and groundplanes, designing supply channels by combining patches with insert feed channels, designing ports by entering coordinate values and designing boundaries with the material becoming water (air) by entering its coordinate value.

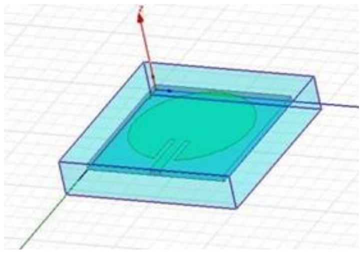

Figure 6. Antenna Design on HFSS Software Simulation

Antenna simulation

Simulates an antenna design with a frequency of 2.4 GHz, the highest number of phases needed, and the highest possible delta S value. Set the sweep type to fast and the frequency of the adjustment type to a linear step after that to edit the sweep window. In addition, its size is 0.01 GHz and its frequency is set between 2 and 3 GHz. If the design you want, select analyze all from the HFSS menu bar. It is necessary to do a lot of optimization if the simulation design is not as desired.

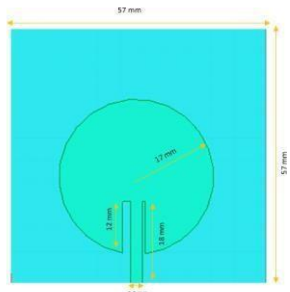

Figure 7. Optimized Antenna Design

Antenna Fabrication

Fabricate the results of antenna optimization that has been done by preparing tools and materials, cutting double layer PCB according to antenna size, attaching sticker paper that has been printed using corel draw, dissolving double layer PCB with solution (H3, HCL, H2O2), cleaning the solution with water and applying the sticker paper, connect the female SMA connector to the port Antennae by soldering on the *patch*. After that, take antenna measurements to get parameter values with measuring instruments that suit your needs.

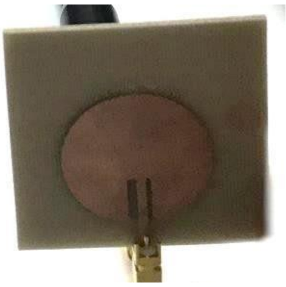

Figure 8. Antenna Fabrication Results that have been assigned port connectors

RF Harvester Design and Fabrication

After troubleshooting *the* design of the rectitifier circuit, the next step is to fabricate the RF Harvester by making an RF Harvester circuit using eagle software so that the layout can be arranged. After that, printing the layout onto the PCB is then dissolved and paired with components and soldering is done so that the RF Harvester circuit can be tested.

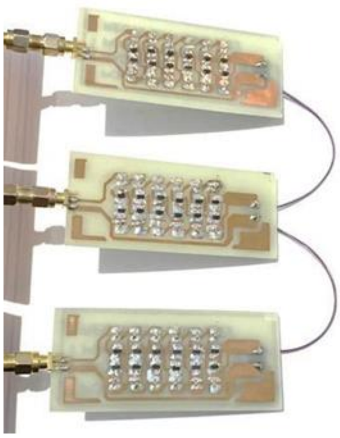

Figure 9. RF Harvester Seial Series

III. RESULT AND DISCUSSION

A. *Antenna Measurement Results*

To compare the antenna parameters obtained from the Ansoft HFSS 13.0 simulation with the actual measurements, antenna measurements were carried out. The desired antenna parameters, namely return loss, VSWR, and radiation patterns, are obtained through direct antenna measurements.

Return Loss Measurement

From Figure 10, it can be seen that the antenna return loss measurement uses Network Analyzer on antenna 1 with a blue line of -26.29 dB at a frequency of 2.425 GHz, antenna 2 with a red line of -21.75 dB at a frequency of 2.365 GHz, and antenna 3 with a green line of -28.57 dB at 2.485 GHz.

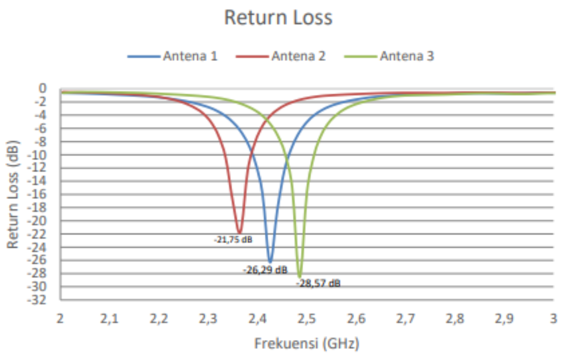

Figure 10. Antenna return loss measurement

VSWR Measurement

VSWR measurements are related to the reflection coefficient of an antenna. In general, the parameter values in a good VSWR are $1 \leq VSWR \leq 2$. The results of antenna VSWR measurements can be seen in figure 11.

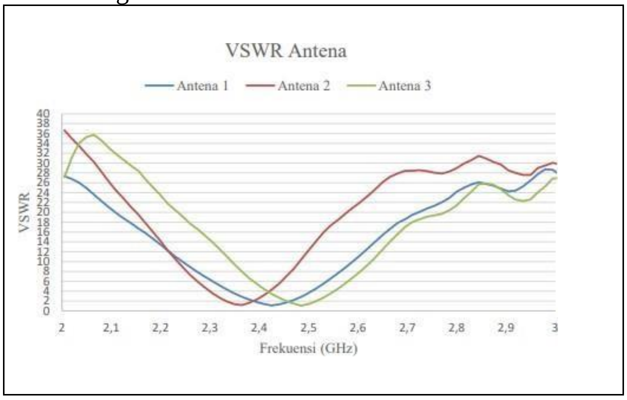

Figure 11. Antenna VSWR Measurement Results

Radiation Pattern Measurement

When the antenna is designed, measurements are taken to determine the direction of the wave beam. The antenna signal beam pattern is focused in only one direction according to the findings of polarization measurements made during antenna fabrication, namely unidirectional and bidirectional.

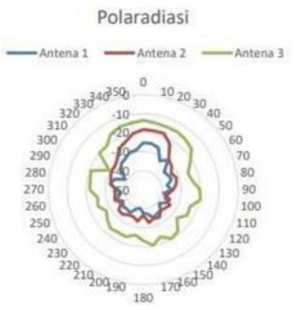

Figure 12. Fabricated Antenna Radiation Pattern

In measuring the radiation pattern for antenna 1, namely on the blue line, the radiation pattern is unidirectional, for antenna 2, which is on the red line, the antenna radiation pattern almost resembles the radiation pattern of antenna 1, which is *unidirectional*, while for antenna 3, which is on the green line, *the radiation pattern is* bidirectional .

B. Antenna Simulation Results Using HFSS 13.0 Software

This simulation is carried out to physically design an antenna with antenna parameters that match the desired specifications. The parameters seen during the simulation are *return loss*, VSWR, and radiation patterns.

Return Loss Simulation

To get the frequency that matches the patch, and the frequency that matches the specifications, several times optimization of the *patch* size is carried out by increasing its size. So that the *best return loss* during simulation is -24.66 dB at a frequency of 2.4 GHz as seen in figure 13.

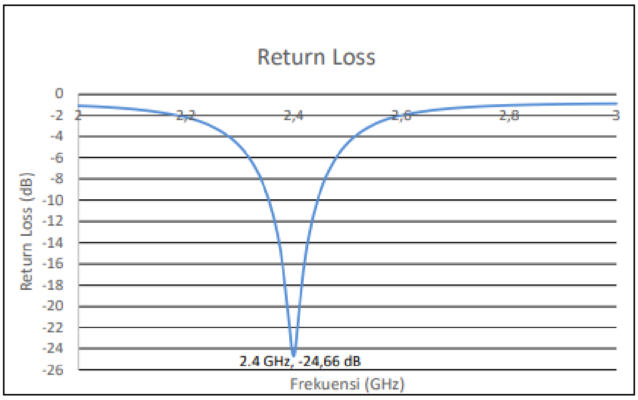

Figure 13. Antenna Return Loss Simulation Results

VSWR Simulation

In addition to affecting the return loss value, antenna dimension optimization also affects VSWR parameters. The VSWR value obtained during the simulation meets the criteria of a good antenna of 1.01 which works at a frequency of 2.4 GHz as shown in figure 14.

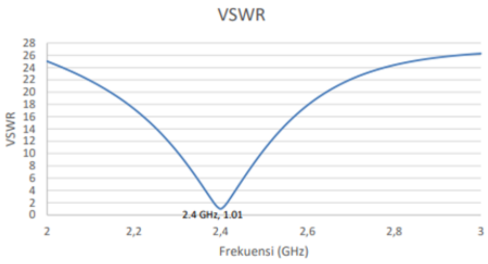

Figure 14. Antenna VSWR Simulation Results

Pattern Radiation Simulation

The antenna parameters determined during the next simulation are radiation patterns. The results of the simulation antenna radiation pattern that has been optimized form a *unidirectional radiation pattern* for a frequency of 2.4 GHz. This means that the simulated antenna has a transmit power that focuses in one direction can be seen in figure 15.

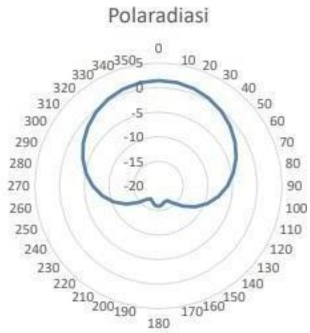

Figure 15. Simulated antenna radiation patterns

IV. CONCLUSION

From the design and testing of a circular antenna patch microstrip rectifier serial for RF energy harvesting in this final project it can be concluded that:

1. It has been designed circular microstrip patch antenna with a ground size of 57x57 mm and a frequency of 2.4 GHz.
2. To design the rectifier, a 6-stage voltage multiplier model was used. At a distance of 25 cm from the transmitter source, a single system produces a voltage of 50 points 1 mV, and a serial receiver produces a voltage of 151 points 8 mV.
3. Network analyzers, RF generators, and spectrum analyzers are used in the creation of the antenna measurement process, which produces results for circular patch antennas operating at a 2-point frequency of 42 GHz.
4. Bandwidth 60 MHz, 60 MHz, and 50 MHz, as well as directional polarization, are present at 2.36 GHz

and 2.48 GHz respectively. Return loss values are -26,29 dB, -21.75 dB, and -28.57 dB respectively..

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