The Effect of The Number of Array Elements from Printed Yagi Antenna Against Power Acquisition Efficiency for Implementation RF Harvesting Energy on Frequency 2.4 GHz

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***Abstract*— This paper introduces the design 3 printed yagi antennas which have different number of arrays for the study of energy harvesting systems using Radio Frequency. RF Energy Harvesting can be used to provide an alternative energy source for these types of embedded devices. This study is to analyze the effect of the number of elements of the yagi print antenna array on the efficiency of receiving power at a frequency of 2.4 GHz. The making of this harvesting energy system is aimed at making the energy around us maximally utilized and used as alternative energy by the community. The highest output voltage of the rectifier antenna at a distance of 10 cm from the access point is 219 mV for a single element yagi print antenna, 96 mV for a 2 element yagi print antenna, and 168 mV for a 4 element yagi print antenna. with no load, the number of array elements affects the output voltage of the rectifier in addition to the number of stage voltage multipliers. Based on Comparison 3 printed yagi antenna, the result of single element yagi print antenna is better than other.**

Keywords*—*Energy Harvesting, rectifier, printed yagi antenna

I. INTRODUCTION

Most low-power electronics, such as remote sensors and embedded devices, are powered by batteries. Replacement becomes expensive when there are hundreds of sensors in remote locations. Alternative energy sources are needed that are easily obtained, one of which is RF energy where its availability is quite abundant. One technology that can be used for this concept is RF Energy Harvesting.

Rectenna is a combination of rectifier and antenna where in this system the antenna is used to harvest RF energy emitted by the source. The rectifier will convert the power received in the form of AC voltage into DC voltage. It can also amplify the voltage to support the realization of a power supply device.

Some of the rectennas in the previous reference have been designed to harvest the available RF energy. A new rectenna coplanar waveguide-fed [1] for local Bluetooth / wireless 2.45 GHz network applications. Another rectenna with working frequency GSM-1800 and UMTS-2100 [2] to harvest RF energy. The next rectenna [3][4] omnidirectional antenna is a broad curved triangular antenna operating in the 850 MHz – 1.94 GHz frequency.

In this paper research, author will propose 3 printed yagi Antenna using frequency 2,45 Ghz with different number of array and analyze the effect of printed Yagi antenna array on the efficiency of power reception at the Wifi frequency of 2.45 GHz. The frequency of 2.45 GHz was chosen because the test process directly with the transmitter device can be carried out on a mobile basis because the distance between the transmitting and receiving antennas can be varied and without taking into account the height of the two antennas.

II. METHOD

A. Research Design

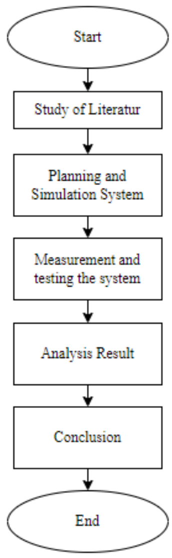


Figure 1. Flowchart Research Design.

B. System Design

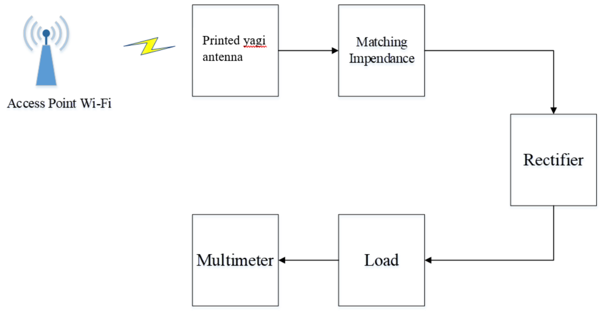
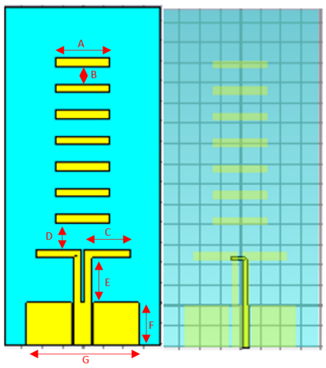


Figure 2. Block Diagram System.

Fig. 2 describes the system block of RF Energy Harvesting. Wifi access point act as a transmitter will send power to printed yagi antenna and then forward it to the transmission line [5][6]. Transmission line function is to reduce channel loss [7][8]. Rectifier is used to convert RF or AC voltage signals into DC voltages using Schottky diodes. Load act a resistance to suppress the ripple voltage so that the voltage displayed on the multimeter block can be maximized [9][10][11]. The multimeter is used to measure the output voltage from antenna reception.

C. Antenna Design

In this section, the design of the Print yagi antenna will be described. There are some structural adjustments from the calculation results with simulations to get the required resonant frequency.



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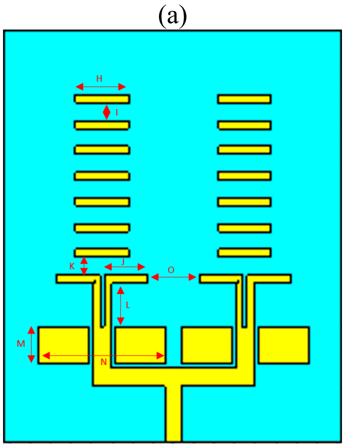

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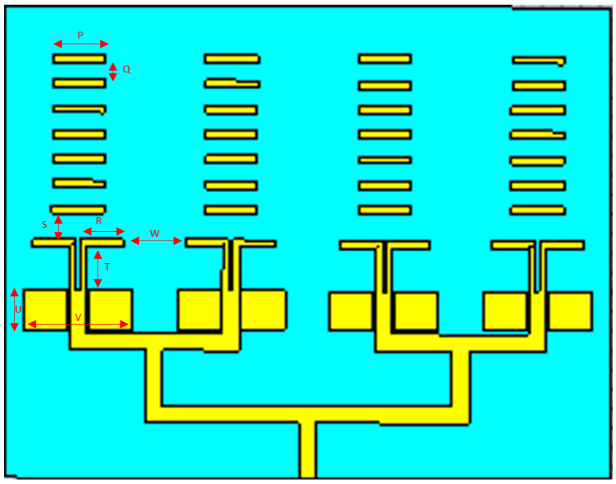


(c)

Figure 3. proposed antenna model (a). Front and back view of single element yagi print antenna (b). Front view of 2- element yagi print antenna (c). Front view of 4-element yagi print antenna.

TABLE I
PROPOSED ANTENNA GEOMETRY

Geometry	Name	Value (mm)
A	Length of Director	26.76
B	Distance between director	13.38
C	Driven	44.6
D	Distance driven to director	17.84
E	Distance driven to reflector	22.3
F	Width of reflector	20
G	Length of reflector	51.29
H	Length of Director	25.8
I	Distance between director	8.6
J	Driven	43
K	Distance driven to director	8.6
L	Distance driven to reflector	21.5
M	Width of reflector	20
N	Length of reflector	58.05
O	Distance between driven	25
P	Length of Director	25.2
Q	Distance between director	8.4
R	Driven	42
S	Distance driven to director	8.4
T	Distance driven to reflector	21
U	Width of reflector	20
V	Length of reflector	56.7
W	Distance between driven	26

Fig. 3 shows the proposed antenna model of Printed yagi ntenna in front and bottom views. Table I presents the detail geometry of the proposed after optimation results with simulations using software CST to get the required resonant frequency.

D. Rectifier Design

In this final project chose to use a Schottky Type HSMS 282x diode because this diode has a threshold voltage starting from 0.34 V [12].

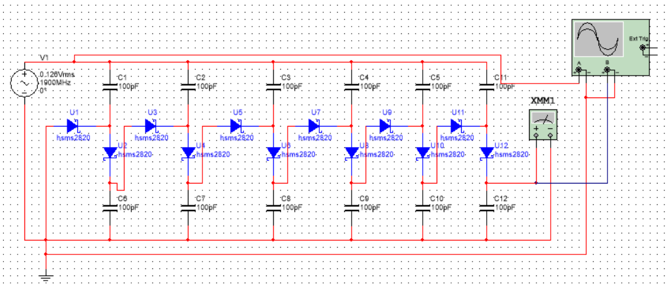


Figure 4. Voltage Multiplier Circuit Simulation Using Software Multisim

Fig. 4 shows a rectifier being designed using a voltage multiplier circuit. A voltage multiplier circuit acts as a rectifier and a large multiplier of its output voltage [13]. In this study, we used a voltage doubler circuit with the Dickson.

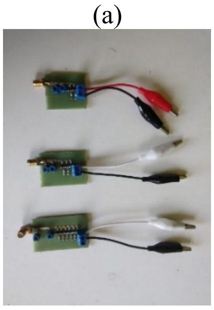
III. RESULTS AND DISCUSSION

The results of the study were to analyze the parameters of each simulation, test, and implementation of the fabricated yagi printed antenna.

A. Fabricated Antenna and Rectifier

The results of the simulation of the antenna that is by the working frequency of 2.45GHz and meet the minimum requirements for the value of VSWR < 2 and return loss < -10 dB [14] as well as simulation of voltage multiplier will be fabricated.

(a)



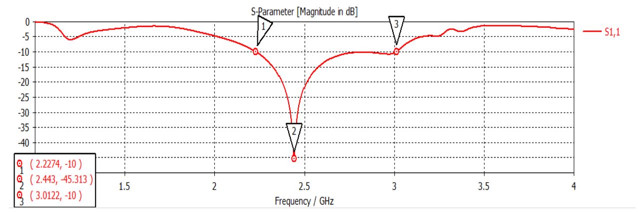
(b)

Figure 5. Fabricated result (a). Printed yagi Antenna (b). Voltage multiplier 2-stage, 3-stage and 6-stage

Fig. 5 shows the result of fabricated antenna and rectifier that will be tested and implementation in system.

B. Return Loss

The simulated return loss result of the proposed 3 Yagi print antenna is shown in the Fig. 6. After many iterations conducted on the CST Microwave Studio 2019, the antenna achieved the targeted parameter less than -10dB. A single element yagi print antenna resonating at a frequency of 2.443 GHz has a return loss value of -45.313 dB with a bandwidth of 784.8 MHz from a lower frequency of 2.2274 GHz and an upper frequency of 3.0122 GHz [15]. A 2-element yagi print antenna resonating at a frequency of 2.455 GHz has a return loss -38.085 dB with a bandwidth of 189.1 MHz from a lower frequency of 2.379 GHz and an upper frequency of 2.5681 GHz [16]. A 4-element yagi print antenna resonating at a frequency of 2.4495 GHz has a return loss value of -43.661 dB with a bandwidth of 481.1 MHz from the lower frequency is 2.3899 GHz and the upper frequency is 2.7871 GHz.



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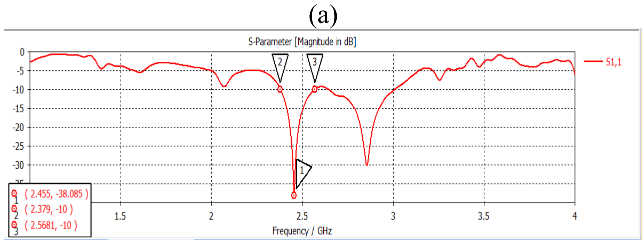

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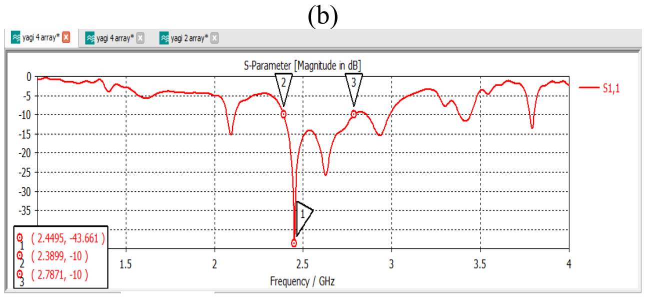
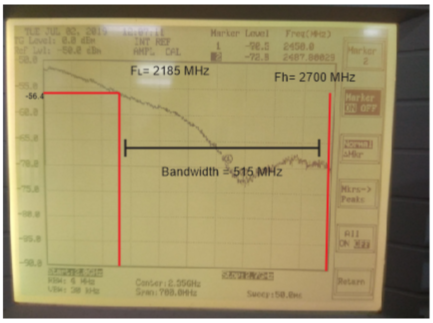


(c)

Figure 6. Return loss simulated result (a). single element yagi print antenna (b). 2-element yagi print antenna (c). 4-element yagi print antenna

The Measurement return loss result of the proposed 3 Yagi print antenna using spectrum analyzer is shown in the Fig. 7. A single element yagi print antenna resonating at a frequency of 2.487 GHz has a return loss -26.4 dB from the test frequency range of 2 GHz – 2.7 GHz, the bandwidth is 515 MHz with a lower frequency of 2.185 GHz and an upper frequency of 2.7 GHz. A 2-element yagi print antenna resonating at a frequency of 2.545 GHz has a return loss -27 dB from the test frequency range of 2 GHz – 2.7 GHz, the bandwidth is 700 MHz. A 4-

element yagi print antenna resonating at a frequency of 2.575 GHz has a return loss -30 dB from the test frequency range of 2 GHz – 2.7 GHz, the bandwidth is 615 MHz with a lower frequency of 2.085 GHz and an upper frequency of 2.7 GHz.



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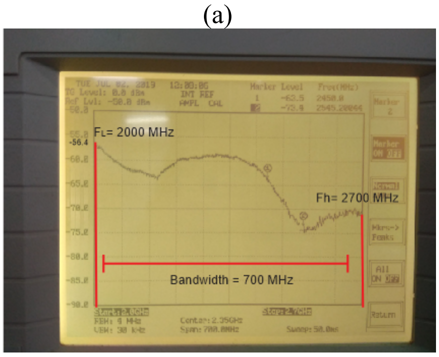

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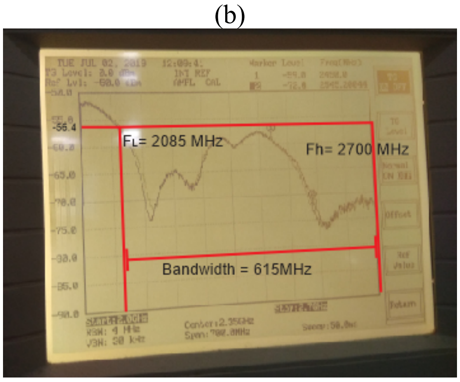

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Figure 7. Return loss measurement result using spectrum analyzer (a). single element yagi print antenna (b). 2-element yagi print antenna (c). 4-element yagi print antenna

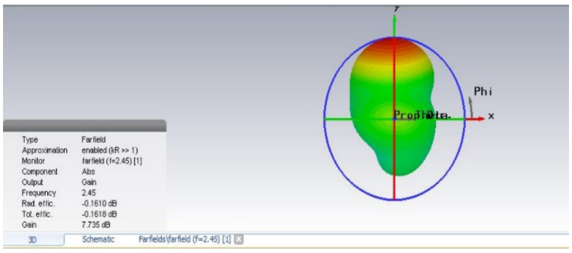
C. Voltage Standing Wave Ratio (VSWR)

Based on the simulation and return loss testing that was carried out previously, the comparison value of the VSWR values of the simulation results and measurements of the 3 Yagi print antennas is shown in Table II.

TABLE II
COMPARISON RESULT OF VSWR SIMULATION AND MEASUREMENT

Antenna	Simulation	Measurement
Single Element	1.01	1.10
2-Element	1.02	1.093
4-Element	1.0139	1.065

D. Gain



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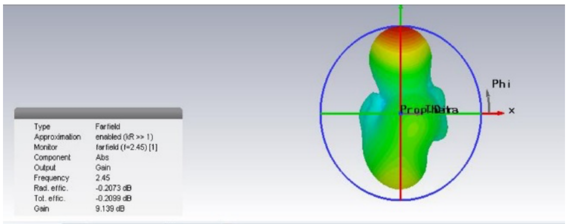

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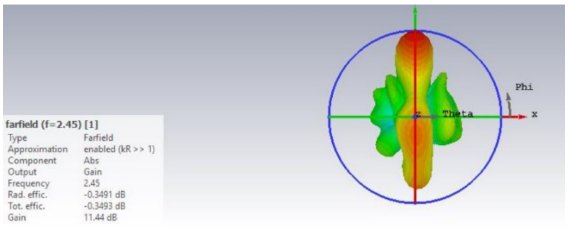

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Figure 8. Result of Gain simulation (a). single element yagi print antenna (b). 2-element yagi print antenna (c). 4-element yagi print antenna

The simulated result of Gain is presented on the Fig. 8 for The single-element, 2-element and 4-element yagi print antennas are 7,735 dBi, 9,129 dBi and 11.44 dBi, respectively.

Antenna gain measurement results can be determined by comparing the power reception level on the Antenna Under Test (Microstrip Antenna) with the power reception level on the reference antenna. Fig. 9 shows a comparison of the gain of 3 printed Yagi antennas with a test frequency of 2.4 GHz to 2.5 GHz

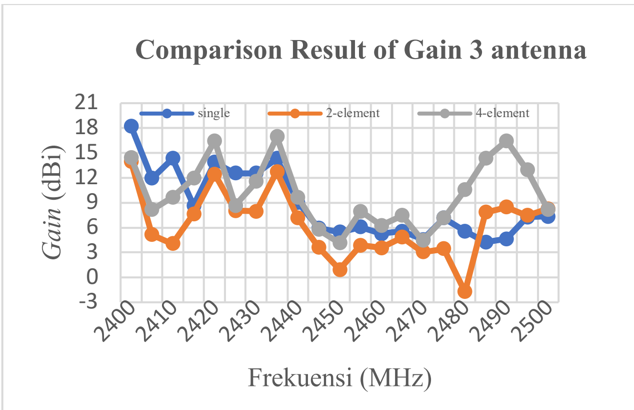
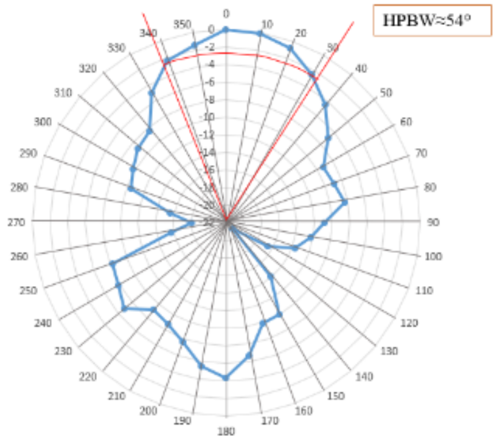


Figure 9. Comparison graph of the measurement results of 3 yagi print antennas

Fig. 9 shows that the highest gain value is obtained by a single element yagi printed antenna with a value above 18 dB at a frequency of 2.4 GHz.

E. Radiation Pattern



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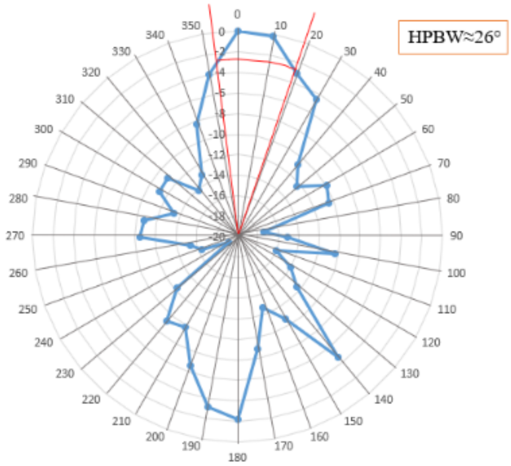

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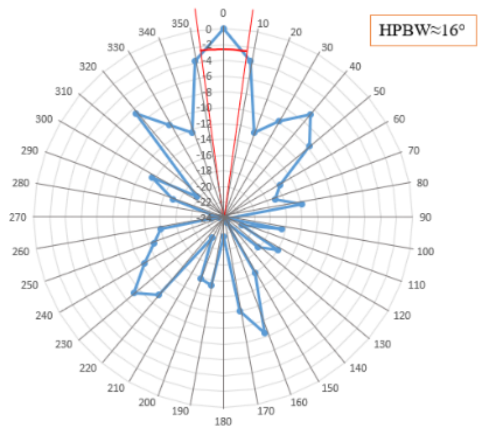

(c)

Figure 10. Polar Diagram from Measurement of Radiation Pattern (a). single element yagi print antenna (b). 2-element yagi print antenna (c). 4-element yagi print antenna

Fig. 10 shows that the three printed yagi antennas have a directional radiation pattern where the highest receiving power level of the antenna is at an angle of 0° and 360°. A single element yagi print antenna has a half maximum power is at an angle of approximately 32° and 338°. A 2-Element yagi print antenna has a half maximum power is at an angle of approximately 19° and 353°. A 4-Element yagi print antenna has a half maximum power is at an angle of approximately 8° and 352°.

F. Implementation Antenna

The implementation for RF energy harvesting according to the designed system is shown in Fig. 11.

Figure 11. Implementation of system energy harvesting

TABLE III
COMPARISON RESULT OF ANTENNA USING VOLTAGE MULTIPLER

Distance (cm)	Output (mV)		
	Single Element	2-Element	4-Element
10	219	96	168
20	148	56	91
30	115	67	90
40	45	45	66
50	64	13	25

Based on Table III, it can be seen that the distance and number of array elements can affect the output voltage of the RF energy harvesting system as evidenced by the highest value of the three antennas obtained at a distance of 10 cm with each value of 219 mV, 96 mV and 168 mV.

IV. CONCLUSION

The Three Yagi print antennas with a different number of array elements have been successfully designed, simulated and analyzed. The proposed antenna has met the targeted criteria parameter. The results of the power reception of each integrated antenna with the rectifier affect the number of array elements and the distance from the transmitter source is indicated by the highest value being at a distance of 10 cm between the receiving antenna and the transmitting source which has a value of 219 mV for a single element yagi print antenna.

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