INTERNATIONAL CONFERENCE ON CLIMATE CHANGE AND SUSTAINABILITY ENGINEERING IN ASEAN

International Conference on Climate Change and Sustainability Engineering in ASEAN (CCSE-ASEAN)2019

University of Jember, Indonesia, 13-14 November 2019

Jalan Kalimantan 37, Jember, Jawa Timur, Indonesia 68121
Website: https://ccse-asean.org email: info@ccse-asean.org

27 September 2019

Dodi Setiabudi
University Of Jember

Subject: **Letter of Acceptance and Invitation to CCSE-ASEAN 2019**

Dear Dodi Setiabudi

We are pleased to inform you that your paper entitled *Design And Analysis Of Rectenna Using The Cockroft-Walton Method With L-Matching Impedance* has been accepted for oral presentation by the International Conference on Climate Change and Sustainable Engineering in ASEAN (CCSE ASEAN) 2019.

We hereby cordially invite you to participate as a presenter at CCSE-ASEAN 2019, which will be held at the Auditorium of University of Jember, Jember City, Indonesia on 13-14 November 2019. Details on the registration are herewith attached.

We would be thrilled to have you present your research at this conference. We would also love to hear your thoughts and opinions about how to enhance the role of engineering in dealing with concerns about climate change and sustainability in Southeast Asia.

We are looking forward to welcoming you at CCSE-ASEAN 2019.

Yours faithfully,

INTERNATIONAL CONFERENCE ON CLIMATE CHANGE AND SUSTAINABILITY ENGINEERING IN ASEAN

Dr. Eng. Triwahju Hardianto
General Chair of CCSE-ASEAN 2019
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Design and Analysis of Rectenna Using the Cockroft-Walton Method with L Matching Impedance

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Abstract. Electronic devices use a small DC (Direct Current) sources such as batteries with a limited lifetime. It is encouraging to produce new ideas and technologies that can be used from external sources which we commonly refer to as energy harvesters. Rectenna is a device that can be used to harvest electromagnetic waves, an antenna as a wave catcher and integrated with a rectifier or rectifier in the form of media to convert AC (alternating current) to DC voltage. Rectifiers consist of parallel series arrays between capacitors and diodes. High frequency and low level according to the special type of schotkky diode. Receiver antennas require large gain, one of which is a directional type antenna, which is a helical antenna spiral axial mode with a ground plane. To get a voltage greater than the input voltage, it is necessary to use Cockroft-Walton voltage multiplier rectifier which can create high voltage at low currents at a low cost. The proposed design and fabricated axial helix mode antennas have parameter values that have met the standard of working an antenna in general. The results of fabrication have GSM working frequency at 1900 MHz with return loss parameters of -20.3 dB and VSWR of 1.22. In designing the rectenna an antenna is needed that can work on GSM frequencies so that the frequency of 1900 MHz can be used on this device. While the analysis of the results of testing the DC voltage output of the two circuits shows different results, in general, the rectifier with matching impedance circuit produces a higher voltage than the rectifier without matching impedance. The output voltage is 85.3 mV with a distance of 100 m, 79.1 mV with a distance of 200 m, and 22.7 mV at a distance of 300 m, the rest of the rectenna cannot receive enough power level to be converted into DC voltage. The rectenna developing is very dependent on the effectiveness of power transfer from the antenna to the rectifier so that it also needs a topology matching type L matching impedance. The L matching impedance circuit produces a better DC voltage than without using a matching circuit. The results test prove that electromagnetic waves can be converted to DC with a value reaching +85.3 mV.
Keywords: Energy Harvesting, Rectenna, Voltage Multiplier, Cockroft-Walton, L Matching Impedance

1. INTRODUCTION

Today technology is advancing rapidly, especially in the telecommunications sector which shows significant changes. Both the hardware produced and the software contained in the electronic device. At present almost all electronic devices use a small DC (Direct Current) voltage [1]. The DC voltage source that we see and use most often is a battery, but in this case the battery has limited life time. On the other hand, the number of batteries that have reached life time causes pollution of the environment. This limited battery life has encouraged research to generate new ideas and technologies to drive wireless-based devices for an unlimited period of time or increase the time period [1]. Antennas are needed to convert electrical energy into electromagnetic energy in the receiver and transmitter parts also apply to the opposite of electromagentic energy converted to return to electrical energy [2,13].

The discussion included the design of axial mode helix antenna and 8x Cockcroft-Walton voltage multiplier system as wave surrender. The use of this method was chosen because of its ability to create high voltages at low currents and to double these voltages significantly at low cost [11]. The biggest advantage of this circuit is the voltage at each stage is equal to twice the peak input voltage in the rectifier half wave, while in the full wave rectifier is three times the input voltage [5].

The above axial helix mode antenna uses a copper wire wrapped around a PVC pipe (Polyvinyl Chloride) in a ground plane using aluminum plate material connected with a pigtail using a SMA connector [11,13]. Axial helix mode antenna in 3 dimensional geometry is presented with D, S, C, L as in Figure 1.

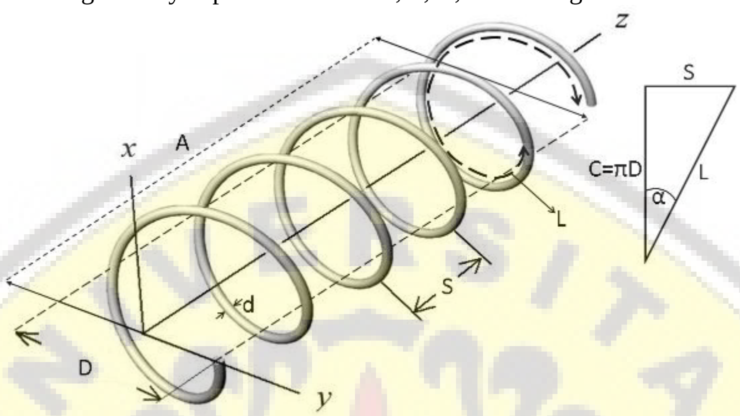


Figure 1. Axial Helix Mode Antenna

D as the circle diameter, S is the spacing between circles, A axial overall length, C around the circle, L length of wire in a circle, and α is pitch angle [10].

This Cockroft-Walton Rectifier series is a simple multiplier series popular with Cockroft and Walton. The disadvantage of this circuit is that the regulation of voltage is very bad, as the voltage drops very quickly as a function of the output current. [6,11]

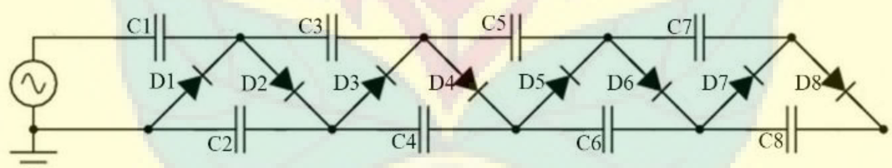


Figure 2. Cockroft-Walton Rectifier 8x

Voltage multiplier is the same as the double voltage of the two in maximizing power transfer can be implemented with passive components such as capacitors and inductors. [8]

Matching impedance is needed in RF circuit design to provide the possibility of maximum power transfer between source and load. In the impedance transmission line the load has a SWR (Standing Wave Ratio) equal to one, in order to transmit a certain amount of power without reflection. The L type matching circuit is a circuit that uses a capacitor and one inductor. Capacitors and inductors connected to form L are often used as circuit impedance matching components. As shown in figure 3 which is one of the various kinds of topology matching impedance circuits. [7]

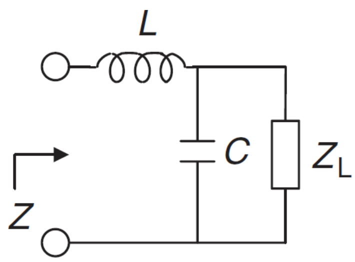


Figure 3. L Matching Impedance Circuit

2. RESEARCH METHOD

Figure 4 block diagram describes the flow of the design of the rectenna circuit obtained from the GSM signal. Rectifiers use the Cockroft-Walton method which is integrated with axial mode helix antennas, between rectifiers and antennas, there are L matching impedance circuits. After the core of the rectenna has been assembled with the appropriate specifications, the next experiment is to harvest the energy from the rectenna. Figures are presented center, as shown below and cited in the manuscript.

Figure 4. Block Diagram of the Project

Table 1. Specification Antenna Parameters

No.	Parameters	Value
1	Terminal Impedance	50 ohm
2	VSWR	< 2
3	Return Loss	$\leq$ -10 dB
4	Gain	$\geq$ 2 dBm

Table 2. Dimension of Designing Axial Helix Mode Antenna

No	Parameters	Variable	Dimention
1	Wavelength	λ	324,324 mm
2	Diameter of the helix antenna	D	103,326 mm
3	Around the helix antenna	C	324,324 mm
4	Pitch Angle	α	12^o
5	Distance between turns	S	68,937 mm
6	Length	A	551,5 mm
7	Diameter ground plane	DGP	308,108 mm

Axial mode helix antenna is designed to work at the GSM frequency. In this study, it is expected to be able to give the desired results according to the specification and parameters table 1,2 and 3 dimension of designing axial helix mode antenna.

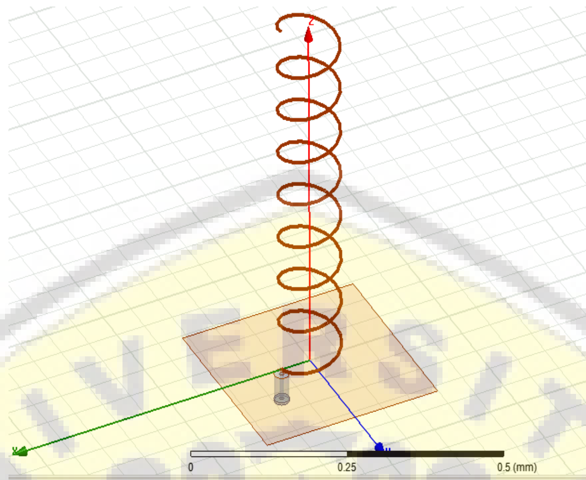


Figure 5. Axial Helix Mode Antenna Design

No.	Parameters	Variable	Value
1	Q factor	Q	12,2
2	Capacitor	C_S	43,1 pF
3	Inductor	L_S	0.72 nH

Table 3. Component Value Specifications Matching Series

Testing cockroft-walton rectifiers using 8 BAT 17-04 schottky type diodes with 330 nF capacitors compiled according to cockroft-walton rules using NI software Multisim v14.1 is shown in the following figure 6. In the picture marked yellow is a series of L matching impedance.

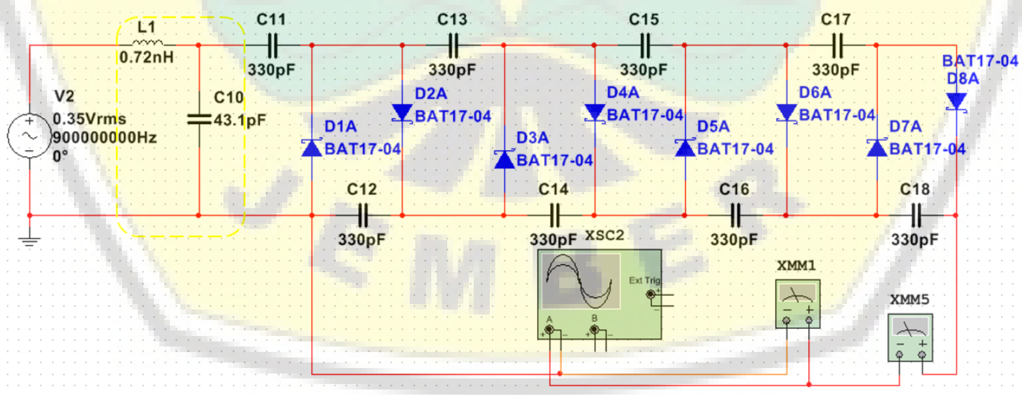


Figure 6. Rectifier Circuit with L Matching Impedance

3. RESULTS AND ANALYSIS

3.1. Hardware Fabrication

The fabrication process is carried out after the design process using HFSS v13 software with dimensions according to the design. The matching impedance of the antenna uses 81.08x4x0.2 mm copper plate, and the rectifier impedance uses 0.72 nH capacitors and 43.1 pF inductors. The axial mode helix antenna that has been fabricated can be seen in Figure 7 and rectifier in Figure 8.

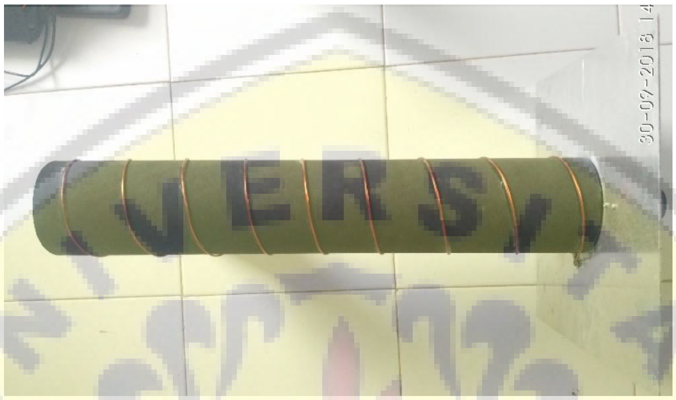
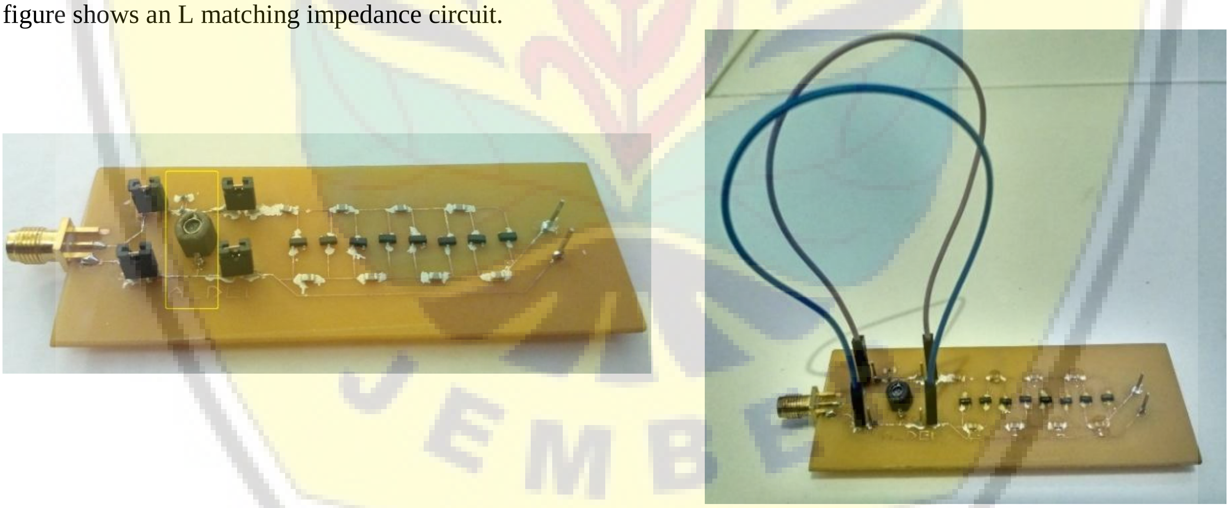


Figure 7. Axial Helix Mode Antenna

Cockroft-Walton Rectifier uses dual mode jumpers so that in one series can be changed using matching circuits or not using matching circuits. In figure 8 is a rectifier connected to the L matching impedance circuit using 4 mini jumper series 2.54. Figure 9 uses 2 jumpers that directly pass through the matching circuit. The yellow box in the figure shows an L matching impedance circuit.

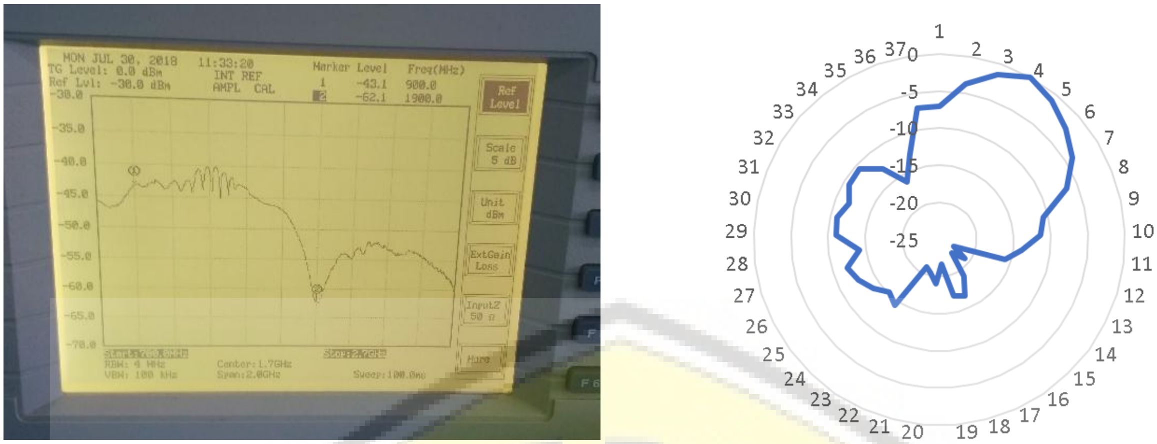


(a) (b)

Figure 8. (a) Rectifier Cockroft-Walton with L matching Impedance, (b) Rectifier Cockroft-Walton without L matching Impedance

3.2. Antenna Analysis and Measurement

The results of measuring the axial antenna helix return loss parameters using the Spectrum Analyzer get the return loss value at the frequency of 1.90 GHz, namely -20.1 dB, can be seen in Figure 10.



(a) (b)

Figure 10. (a) Result of Measurement of Return Loss Antenna, (b) Antenna Radiation Pattern.

Generally there are significant changes with the simulation results influenced by many factors in the presence of a factor of mean square error (MSE) that occurs due to external influences. In the theory of tolerance in general it is often used in many cases without the existence of clear ideas on achievement factors and of course it is often necessary for designers to establish tolerance without the existence of a complete theory [4]. In this case it is well recognized that the occurrence of differences in resonance frequency is influenced by substrate or wire material which has a different thickness with the simulation results. Changes in the maximum value in resonant frequency occur in thicker substrate [3].

3.3. Implementation of Rectenna energy harvesting

The experiment was carried out with several distances from BTS to different rectenna instead of the different power levels from the source of electromagnetic waves. The distance from the measurement location to the BTS is determined using the Cell Tower Locator v1.27 software. The basis is to distinguish from the input of electromagnetic waves from high to low, for the farthest distance means the power level received is getting lower while the closest distance is the received power level the greater in dBm units. Tests are carried out at distances ranging from 100 m, 200 m, 300 m, 400 m, and 500 m. The output voltage results can be seen as in Tables 4 and Table 5.

Figure 12. Testing of Energy Harvesting Rectenna

No	Distance Ranging (m)	V DC (mV)
1	100	85,3
2	200	79,1
3	300	22,7
4	400	1
5	>500	0

Table 4. Data Results Data DC Voltage Measurement Rectenna with L Matching Impedance

No	Distance Ranging (m)	V DC (mV)
1	100	62,3
2	200	50,0
3	300	2,0
4	>400	0

Table 5. Data Results Data DC Voltage Measurement Rectenna without L Matching Impedance

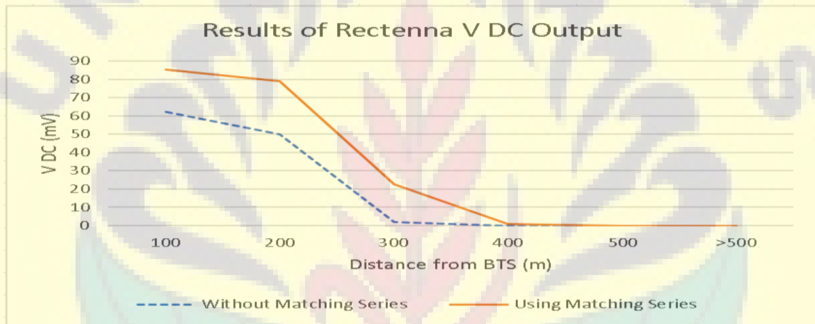


Figure 13. Graph of V DC Rectenna Results

4. CONCLUSION

In designing and fabricating axial helix mode antennas have parameter values that have met the standard of working an antenna in general. The results of fabrication have GSM working frequency at 1900 MHz with return loss parameters of -20.3 dB and VSWR of 1.22. In designing the rectenna an antenna is needed that can work on GSM frequencies so that the frequency of 1900 MHz can be used on this device.

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