STUDY OF RECTANNA USING DIRECTIVE ANTENNA AT FREQUENCY OF 2.45 GHZ

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ABSTRACT The popularly renewable energy is the wireless power transmission which the electromagnetic wave is transformed to electric energy at 2.45 GHz. This research studies the directive antennas which are rectangular waveguide antenna, cylindrical waveguide antenna, yagi-uda antenna and microstrip antenna, what the best of four antennas type can be transformed electromagnetic wave to electric power. The designed antennas are simulated by using computer simulation technology (CST) to analyze the characteristic, and then, the antenna prototype is fabricated. Secondary, we design the rectification prototype, it performed alternative-current (AC) Circuits to direct-current (DC) Circuits as shown the transformed energy system. The experimental results shows that a rectangular waveguide antenna can transform the most electric energy as voltage and current of 642 mV and 4.71 µA, respectively with distance between transmitted antenna and rectanna around 2 – 3 m.

1. INTRODUCTION

In Thailand and other countries, renewable energy is extensively used such as solar cell, wind turbine, water-power, and so on. One of popularly renewable energy is the electromagnetic wave which is transformed to electric energy because of the wireless power is used in many public places (Takhedmit H., et al., 2009), (Young-Ho Suh, et al., 2002) and (Ramesh G.P. and Rajan A., 2014). Basically rectanna element consists of an antenna, impedance matching and filtering, rectification and load (Shuai Ji, et al., 2014). An antenna as it is popularly known component in the function blocks of the rectanna circuit (Jouko Heikkinen, et al., 2000). Various kinds of rectannas have been demonstrated since Jouko and et al. presented the three planar rectannas on different PCB materials with 70 conversion efficiency at 2.45 GHz (Moorth M.R., el al., 2013). In wireless power transmission, the propagation wave is mostly propagated with omnidirectional radiation pattern and an antenna in the rectanna circuit should be directional antenna to direct the receiving pattern to wireless transmission.

This paper studies the directive antennas which are rectangular waveguide antenna, cylindrical waveguide antenna, yagi-uda antenna and patch microstrip antenna and we focuses on what the best of four antennas type can be transformed electromagnetic wave to electric power at 2.45 GHz as illustrated in Figure 1.

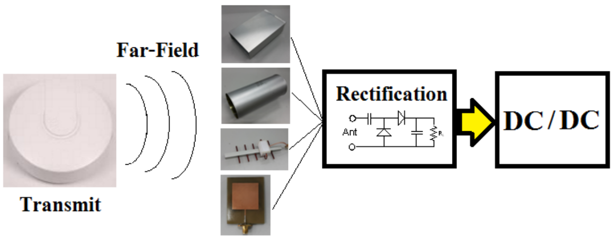
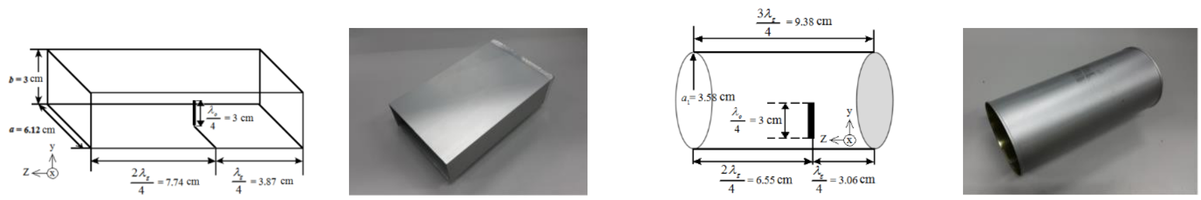


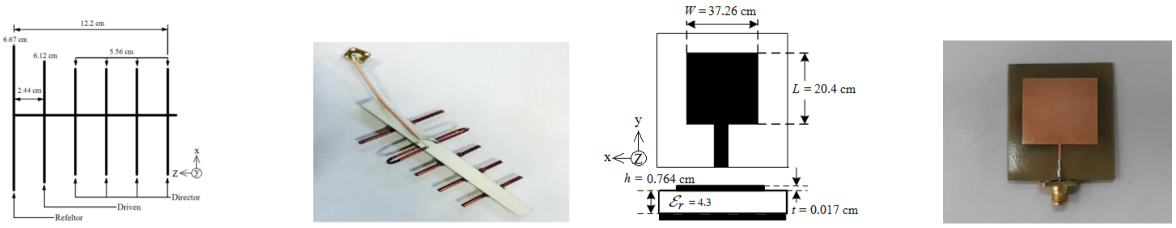
Fig. 1 Geometry for the rectanna system consisting of wireless transmission, directive antennas, and rectification circuit.

2. RECTANNA DESIGN

Let us consider geometry for the rectenna system that consists of transmitting power and rectenna. In this design, the directive antennas and rectifier circuits were all first designed, fabricated, and characterized separately.

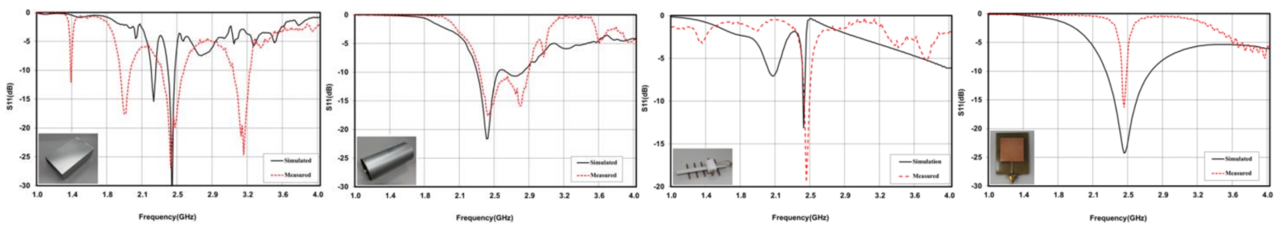


(a) (b)



(c) (d

Fig. 2 Directive antennas (a) rectangular waveguide (b) cylindrical waveguide (c) Yagi-Uda and (d) patch microstrip antenna



(a) (b) (c) (d)

Fig. 3 S_{11} (a) Rectangular waveguide (b) Cylindrical waveguide (c) Yagi-Uda and (d) Patch microstrip antenna.

Then they were combined to realize a complete rectennas. In this research each of directive antennas is used to test the conversion efficiency form wireless transmission at frequency of 2.45 GHz.

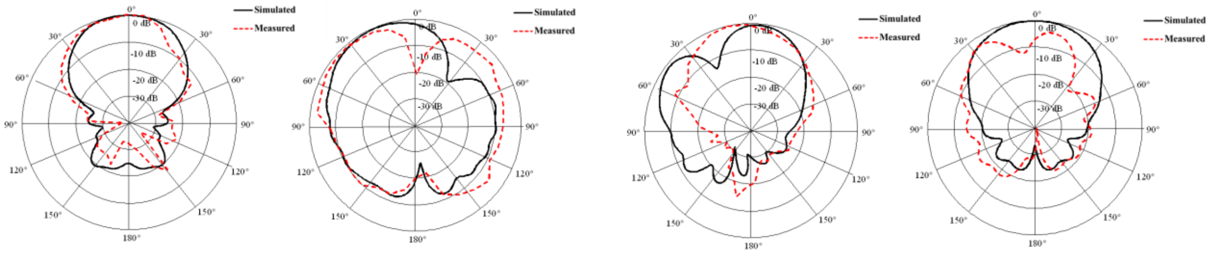
2.1 Directive Antenna Design

Figure 2 shows the antenna designs that are rectangular waveguide antenna, cylindrical waveguide antenna, Yagi-Uda antenna and patch microstrip antenna (Balanis, 1982) together with the dimensions of the 50-Ω matching antennas are illustrated.

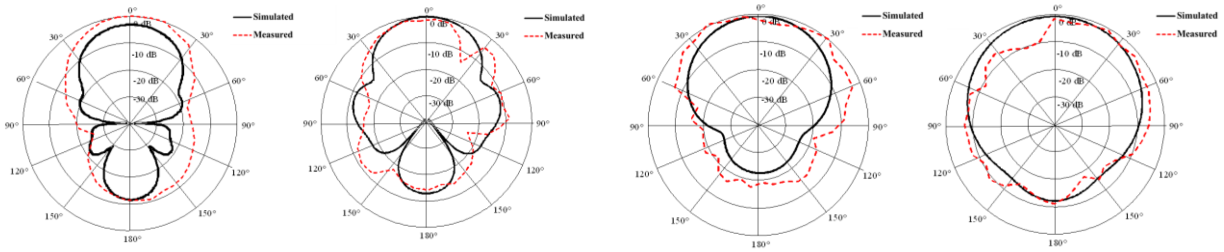
From the design, the prototype antennas is fabricated and measured as shown along with Figure 2. Rectangular and cylindrical waveguide antennas are fabricated on aluminium and feeding system by using a $\lambda/4$ wire probe connected with SMA connector. In addition, Yagi-Uda is constructed on cooper wire, consisting of driven, director and reflector. Moreover, patch microstrip antenna is fabricated on 1.6-mm-thick FR-4 substrate with a relative dielectric constant of 4.4 in the z-direction of the material. This measurement in S_{11} corresponds to improved power transmitting efficiency at 2.45 GHz. Let us consider in Table 1, there are measurement results of antenna prototypes. The rectangular waveguide antenna has the most directive gain of 8.92 dBi, so it is probable the best converter to convert the electromagnetic wave. In Fig. 5 the radiation patterns of antennas are illustrated, it is directional radiation pattern.

Table 1 Directive antenna characteristics.

Antenna	Characteristics	Measurement Results
Rectangular waveguide antenna	S_{11} (dB)	-26.92
	VSWR	1.09:1
	Z_{in} (Ω)	48.22+j4.17
	Gain (dBi)	8.92
Cylindrical Waveguide antenna	S_{11} (dB)	-33.66
	VSWR	1.04:1
	Z_{in} (Ω)	50.58+j1.99
	Gain (dBi)	7.42
Yagi-Uda antenna	S_{11} (dB)	-22.82
	VSWR	1.2:1
	Z_{in} (Ω)	52.44+j11.48
	Gain (dBi)	3.24
Patch Microstrip antenna	S_{11} (dB)	-18.20
	VSWR	1.28:1
	Z_{in} (Ω)	42.30+j7.20
	Gain (dBi)	3



(a) (b)



(c) (d)

Fig. 4 Radiation pattern (a) Rectangular waveguide (b) Cylindrical waveguide (c) Yagi-Uda and (d) Patch microstrip antenna.

2.2 Rectification Circuit

Voltage multiplier circuit is used to supply a DC voltage with higher voltage and the load current is low, regardless of the output voltage to the load too much. The principle of this circuit is to use a capacitor, which is charged and discharged receiver in each half cycle of AC voltage. The output voltage is the summation of the voltage that across the capacitor to the input voltage. The initial circuit of increasing the voltage is included diode and capacitor in series with the AC input voltage. Hence, the voltage multiplier circuit is the better choice to design the rectifier as shown in Fig. 5 (Bin Alam, S., et al., 2013).

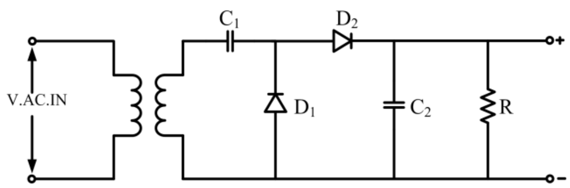
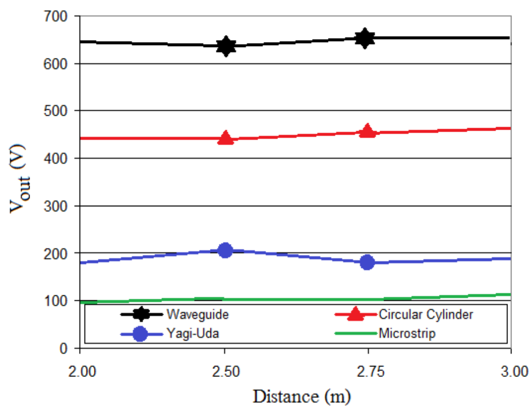


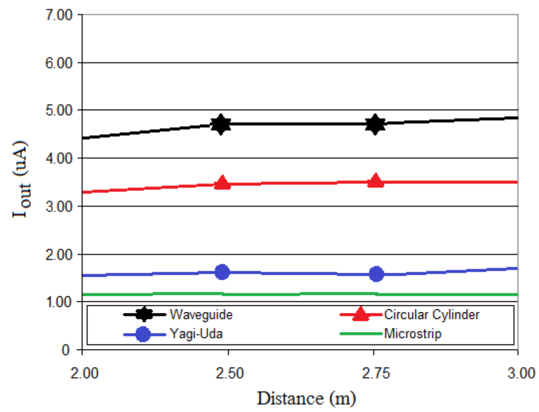
Fig. 5 Voltage multiplier circuit.

3. EXPERIMENTAL RESULTS

Since this work is measured the receiving power is plotted in Fig. 6 when the transmitting power is propagated from access point at frequency of 2.45 GHz. The distance between access point and rectenna is around 2-3 m as shown the system in Fig. 1. The experimental research confirmed that the rectenna by using a rectangular waveguide connecting with the voltage multiplier circuit can be transformed the electromagnetic wave to electric power of 642 mV, 4.71 μA, and 3.02 mW.



(a)



(b)

Fig. 6 Measurement results of electric power.

CONCLUSION

In this paper, RF to DC voltage and power conversion by using directive rectennas receiving has been discussed. When the high gain rectenna is used, the output electric power is high. In wireless transmission at 2.45 GHz case, a rectangular waveguide rectenna can be conversed the electromagnetic power to voltage of 642 mV and current of 4.71 µA. Second, a cylindrical waveguide rectenna can be conversed the electromagnetic power to 451 mV and 3.37 µA. Third, a Yagi-Uda rectenna can be conversed the electromagnetic power to 198 mV and 1.59µA. Finally, a patch microstrip rectenna is the wost, it can be conversed the electromagnetic power to 124 mV and 1.22 µA.

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