Development of 24 GHz Rectennas for Fixed Wireless Access

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Abstract

We need electricity to use wireless information. If we reduce amount of batteries or electrical wires with a wireless power transmission technology via microwave (MPT), it is a green communication system. We Kyoto University propose a Fixed Wireless Access (FWA) system with the MPT with NTT , Japan. In this paper, we show mainly development results of 24GHz rectennas, rectifying antenna, for FWA. We developed some types of the rectennas. Finally we achieve 65% of RF-DC conversion efficiency with output filter of harmonic balance.

1. Introduction

Nicola Tesla had a dream of wireless energy world in the first period of 20^{th} century[1]. We need electricity not only for wireless information but also for all our life. We also need extra wires or batteries to use the electricity. If we reduce amount of batteries or electrical wires, it is better for our life and we can call it a green communication system. A hundred years later of Tesla, we can transmit the electrical power without wires with a wireless technology. We use a radio waves to carry the electrical power. Microwave is suitable frequency for the wireless power transmission (WPT). It is called a microwave power transmission (MPT). With the MPT, mobile devices are connected to electrical sources without wires and we do not mind a rest of the batteries. We can reduce amount of batteries because mobile devices are always connected to electrical sources without wires.

We Kyoto University proposed some MPT applications and carried out experiments, for example, an Ubiquitous Power Source[2], a wireless building[3], a wireless charging system of an electrical vehicle[4]. The MPT can be applied for a Space Solar Power Satellite/Station (SPS)[5][6]. We apply the MPT technologies for the FWA system.

2. Fixed Wireless Access System with MPT

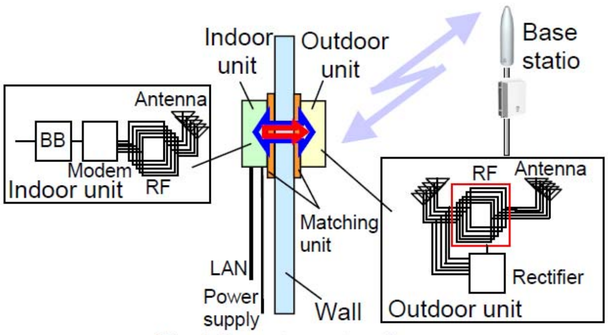

Fig. 1 Repeater system image

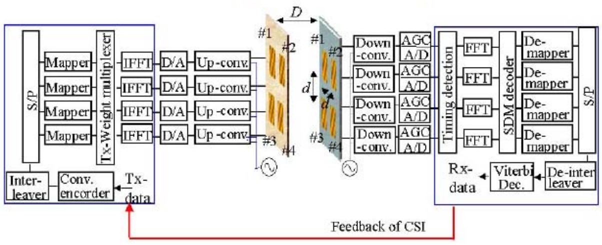

Fig.1 MIMO testbed and measurement scenario for FWA by NTT [7]

We Kyoto University has a collaborative research with NTT, Japan. We propose a Fixed Wireless Access (FWA) system with the WPT. System studies of the FWA are being conducted at millimeter-wave frequency for high-speed wireless communications such as several Gbit/s with short range MIMO transmission technology by NTT (Fig.1)[7]. Between the indoor unit and outdoor unit, the high-speed wireless communications are established. In the present system, they need extra power line or batteries to drive an outdoor unit. It is easy to supply a power to an indoor unit. Therefore, we propose the WPT from the indoor unit to the outdoor unit.

We choose 24GHz for the WPT. They would like to use millimeter-wave frequency for high-speed wireless communications in near future, for example, 60GHz. Their requirement of the power is 10W. So we would like to choose the millimeter-wave frequency for the WPT. Among the millimeter-wave frequency, we choose 24GHz for the WPT because the 24GHz band is on ISM

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(Industrial, Scientific, Medical) band. When frequency increases, DC-RF or RF-DC conversion efficiency and the power decrease. Fig.2 indicates frequency dependence of RF-DC conversion efficiency of previous developed rectennas. The rectenna is one of key technologies for the WPT and the MPT. The rectenna can receive the microwave power and can rectify the microwave to DC with high efficiency. In previous work, the RF-DC conversion efficiency of 35GHz rectenna was below 39% at 60 mW,400Ω, 35GHz[8] and 60% at 25 mW, 213Ω, 35GHz[9]. Based on the trend, we aim to develop 24GHz rectenna with over 50% RF-DC conversion efficiency at 1W microwave input.

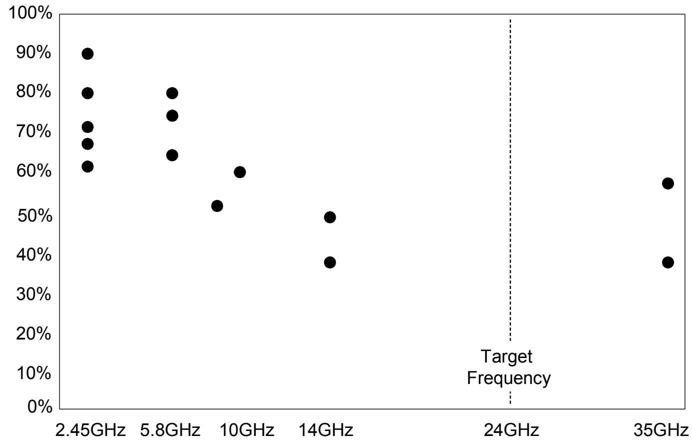

Fig.2 Frequency Dependence of RF-DC conversion efficiency of previous rectennas

3. Development of 24GHz Rectenna

As I showed, the system requires 10W. However, it is difficult to increase the power to rectify at 24GHz. Therefore, At first, we developed ordinary power rectenna at 24GHz (Fig.3). We use a microstrip antenna. Gain of the MSA is 6.8 dBi which is measured by span loss method. We use a conventional single shunt rectifier on microstrip lines shown in Fig.4. We adjust line length of L1 and L2 to increase the efficiency. The diode on the circuit is MADS-001317-1320AG (M/A-COM). We use a waveguide to measure the efficiency and the reflection rate (Fig.5). RF-DC conversion efficiency of the rectenna is 42.9% at 40mW, 140.7Ω (Fig.6). The connected load is optimum for highest RF-DC conversion efficiency. We put the rectenna at an exit of the waveguide.

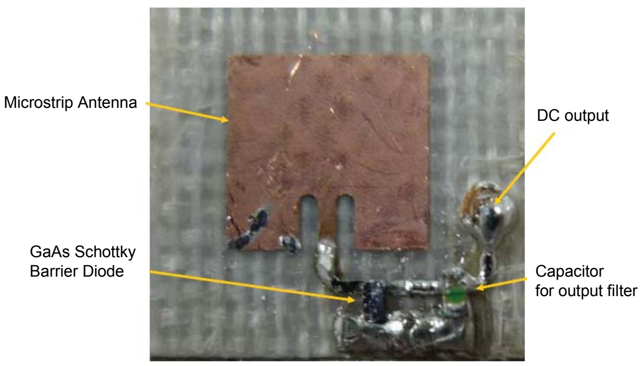

Fig.3: ordinary power rectenna at 24GHz

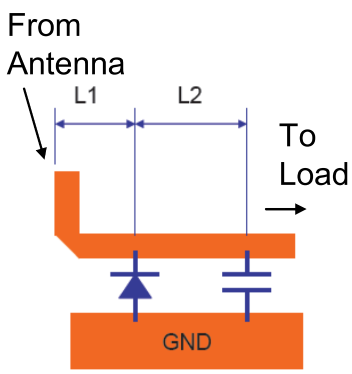

Fig.4 Rectifying Circuit

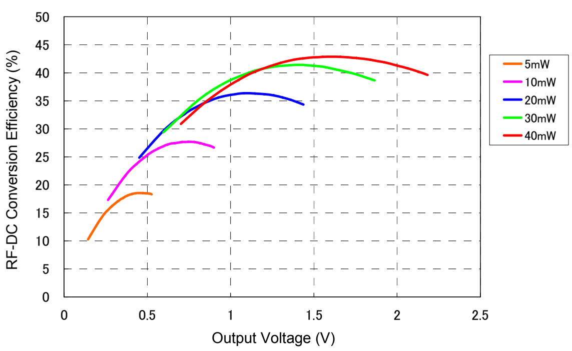

Fig.5: RF-DC conversion efficiency of ordinary power 24GHz rectenna

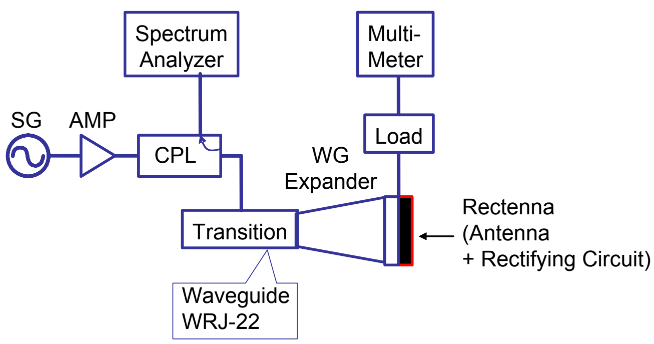

Fig.6 Measurement Setup

For the next step, we revised the rectenna to increase the RF-DC conversion efficiency. We use the same diode described in the ordinary power rectenna. We add the adjust stub and resonator after the diode to increase voltage on a diode in order to increase RF-Dc conversion efficiency. The resonator is put after the adjust stub and consists of high impedance line (120 Ω) and DC pad (Fig.7). As a result, the RF-DC conversion efficiency increases to 54.2% at 130mW, 400Ω, 5.6V (Fig.8). In next step, we use 12-way power divider between the antenna and the rectifying circuits to increase a received power. We can receive and rectify twelve times larger power in the new rectenna than in one rectenna element. The return loss of the developed 12-way power divider is -19.1 dB and the pass losses are -0.15 dB of the minimum and -0.46 dB of the maximum. We developed 500mW rectenna at 24GHz with the power divider (Fig.9). We use the same waveguide to measure the efficiency and the reflection rate. the RF-DC conversion efficiency increases to 43.6% at 500mW, 40.2Ω (Fig.10). In this case, VSWR of the waveguide is 2.25 and it is larger than in the previous experiments. We consider this is one of the reasons of low efficiency.

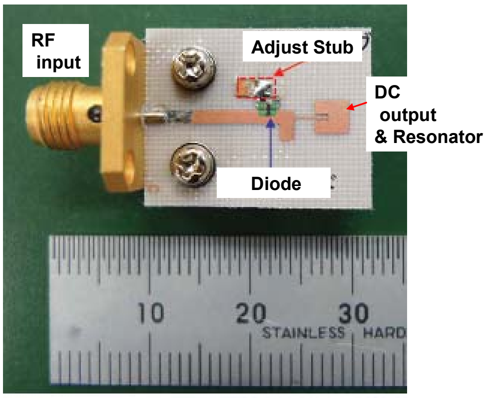

Fig.7: Revised low power 24GHz rectenna

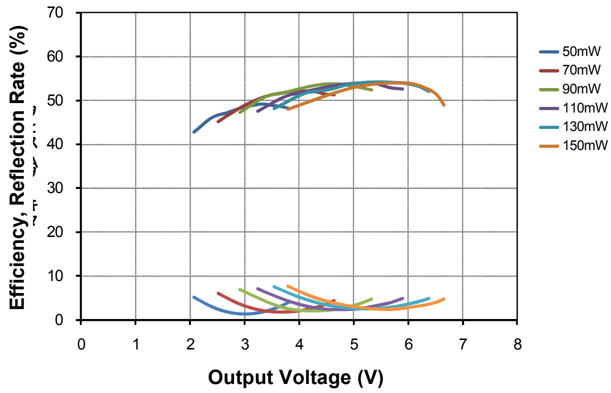

Fig.8: RF-DC conversion efficiency of revised rectenna

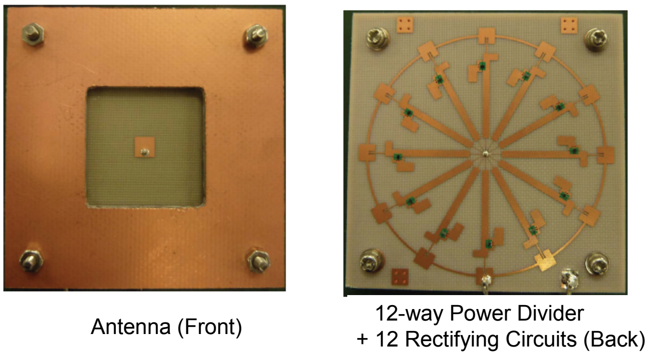

Fig.9: High power 24GHz rectenna

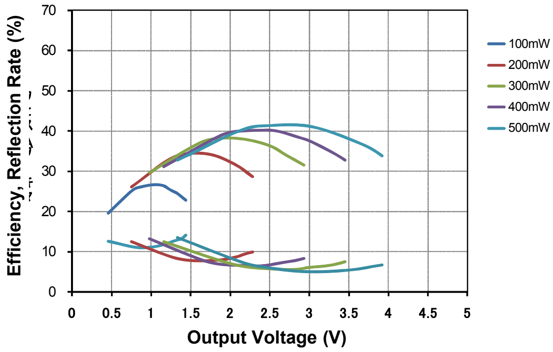

Fig.10: RF-DC conversion efficiency of high power rectenna

4. Conclusion

We have developed some types of the rectenna of 24GHz for the Fixed Wireless Access applications. We have achieved 54.2% as the RF-DC conversion efficiency of the rectenna at 130 mW input and have achieved 43.6% at 500mW. The system requirement is 10W power from the wireless power. So we need more efficient rectenna, however, the efficiency gets over an initial target of 50%. We think the wireless power transmission system can reduce amount of wires and batteries for the green communications. For the next step, we have to develop revised rectenna with over 60% efficiency.

5. Acknowledgments

Experiments of the rectennas are carried out with Sho Engineering Corp. and Nihon Dengyo Kosaku Co., Ltd.

6. References

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