Radio Wave Anechoic Chamber for the Microwave Energy Transmission Experiments

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1. Introduction

Human beings are facing many problems about the Earth and themselves, such as explosion of population, energy crisis and environmental pollution. It is believed that the Solar Power Station(SPS) can solve the energy crisis and the environmental problem by introducing a clean and inexhaustible energy source. A fundamental concept of SPS was proposed by Peter E. Glaser in 1968[1]. Since then technological and environmental studies have been made under an initiative of NASA and DOE. As a result, a reference system was defined in 1978[2].

One of the key important technologies in the SPS is microwave energy transmission (MET). Key issues in the MET technology are not only the technological development of microwave power transmission with high efficiency and high safety, but also scientific analysis of microwave impact onto the space plasma environment. Toward the development of the MET technology, we carried out several MET experiments in Japan. We had two MET rocket experiments[3][4] in 1983 and in 1993. We also carried out two MET experiments on the ground. One is an MET experiment from the ground to a fuel-free airplane in 1992. The other is a ground-to-ground MET experiment which was carried out in 1994 and in 1995. We focused on a rectenna array and analyzed data concerning the rectenna array in the MET experiment.

Since then we have developed several new rectennas for 2.45 GHz microwave. The rectenna means 'rectifying antenna' and is an element which receives and rectifys the incoming microwave. With a newly built radio wave anechoic chamber, we carried out some experiments concerning the developed rectennas.

2. Radio Wave Anechoic Chamber for the MET Experiments

A radio wave anechoic chamber (RWAC) has been newly built at Radio Atomospheric Science Center (RASC) of Kyoto University. The RWAC was designed for MET experiments and is placed in a faculty called "METLAB" (Microwave Energy Transmission LABolatory).

The size of the RWAC is 7 (m) × 7 (m) × 16 (m). The RWAC is a shielded chamber with attenuation capability of -100 dB for electromagnetic waves of 14 kHz to 40 GHz.

Inside the shield walls two different types of electromagnetic absorbers are installed. One is a commonly used absorber for low power EM waves. This has a maximum absorbable power level of 0.2 W/cm^2 for 8 hour exposure and -35 dB attenuation at 2.45 GHz. The other is a spatial absorber designed for large power microwaves. The maximum power level for the absorption is 1 W/cm^2 for 8 hour exposure and the attenuation level is -20 dB at 2.45 GHz. A quiet zone of 2 mϕ is -30 dB at 2.45 GHz with condition that the path length is equal to 12 m.

In addition to the RWAC, we have a MET system which is composed of a microwave power transmitter and a microwave receiver (rectenna array) in the METLAB. The microwave power transmitter consists of a 2.4 mϕ offset parabolic antenna and a 5kW magnetron. The microwave frequency is 2.45 GHz and its polarization is linear. The magnetron is set at the outside of the RWAC. We lead the microwave into the RWAC with an ellipse waveguide. We can remotely control the magnetron in a measurement room. A rectenna array with diameter of 1mϕ is placed in the RWAC. We can use the rectenna array as a standard receiver for development of a microwave transmitter. The microwave power transmitter is used for development of a rectenna.

We also have a measurement system for the MET experiments. In the RWAC we have a 2mϕ turntable and a 6×6 m X-Y positioner. In the measurement room we have a spectrum analyzer, signal generator, power meter, multi-meter and digital oscilloscope. These measurement facilities with a GP-IB controller are effective for systematically development the MET system.

3. Developed Rectennas

We experimentally investigated characteristics of a large system of rectenna array by a ground-to-ground MET experiment which was conducted in 1994 and 1995 in Japan. The experimental group was formed by those from RASC of Kyoto University, Kobe University, and Kansai Electric Power Company. For the field experiment, we developed new rectennas, each element of which can effectively rectify microwave of 2.5 W at 2.45 GHz (Fig.3.1). During the field experiment, we obtained a data set of the DC output of the rectenna array consisting of newly developed 2,304 rectennas which covers an area of 3.2 m × 3.6 m. We adopted a sub-array in the rectenna array system. The sub-array consists of nine rectennas connected electrically in parallel. Spacing between rectennas was 0.5 λ. The whole rectenna array system is composed of $16 \times 16 = 256$ sub-arrays. As a rectifying circuit of the rectenna, we adopted a bridge rectifier with 16 diodes. The maximum RF-DC conversion efficiency of a rectifying circuit with an input filter is 64 %. The rectenna is designed to be matched with the input microwave of 2~4 W. The diode used in the circuit is 1SS281 made in NEC. An effective aperture of the electromagnetically coupled circular microstrip antenna is approximately 20 cm^2. An advantage of the antenna is that we can construct the rectenna array system on a plane. As a result, the efficiency of the rectenna array (0.5 λ space) was not good. Therefore we improved our rectenna for the METLAB.

We then adopted a 3-element Yagi-Uda antenna printed on a di-electric base (Fig.3.2). There are two reasons why we adopt this type of antenna. One is that the bandwidth of the dipole utilized in the Yagi-Uda antenna is wider than that of the microstrip antenna. The other is that the antenna gain of the printed 3-element Yagi-Uda antenna is as large

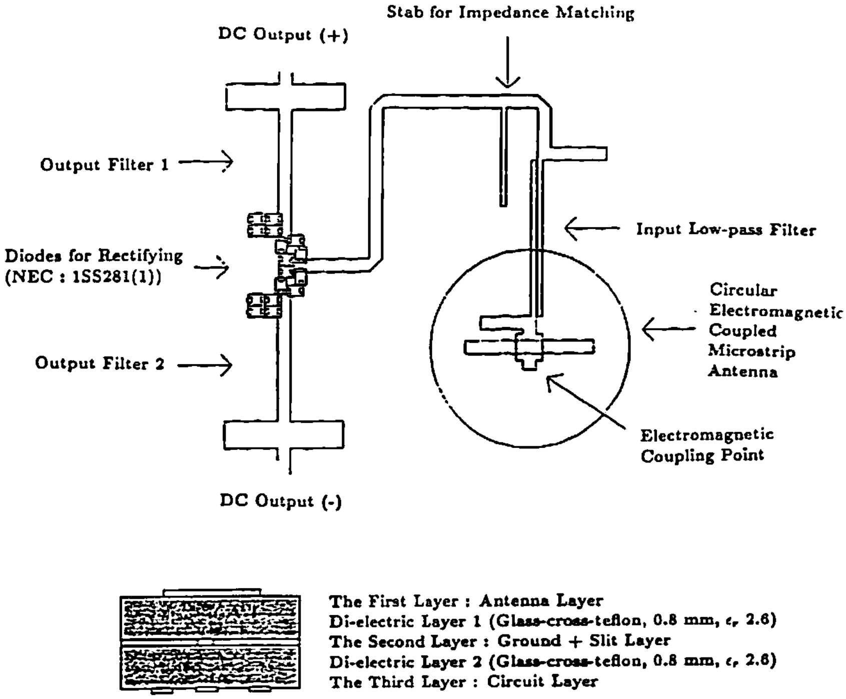

図 3.1: Rectenna used in the field MET experiment in Japan

as that of the microstrip antenna. Measured value of the gain of the printed 3-element Yagi-Uda antenna is 8.73 dB. The effective aperture of the printed 3-element Yagi-Uda antenna is approximately 89 cm^2 which is four times larger than our previous rectenna. We also improved the input filter and the rectifying circuit. As a result, the maximum RF-DC conversion efficiency of the improved rectifying circuit section increased up to 74 %.

4. Conclusion

Microwave energy transmission (MET) is a key technology for Solar Power Station (SPS). To the end, we need to develop and study rectennas, "rectifying antennas", for receiving the microwave power.

We have built a radio wave anechoic chamber (RWAC) which is designed for the MET experiments at the RASC. We call the RWAC and measurement system for the MET experiments "METLAB".

We have developed two type of the rectennas. Both type of the rectennas adopted a bridge rectifier. One is composed of an an electromagnetically coupled circular microstrip antenna. The other is composed of a printed 3-elements Yagi-Uda antenna. The RF-DC conversion efficiency is approximately 74 %.

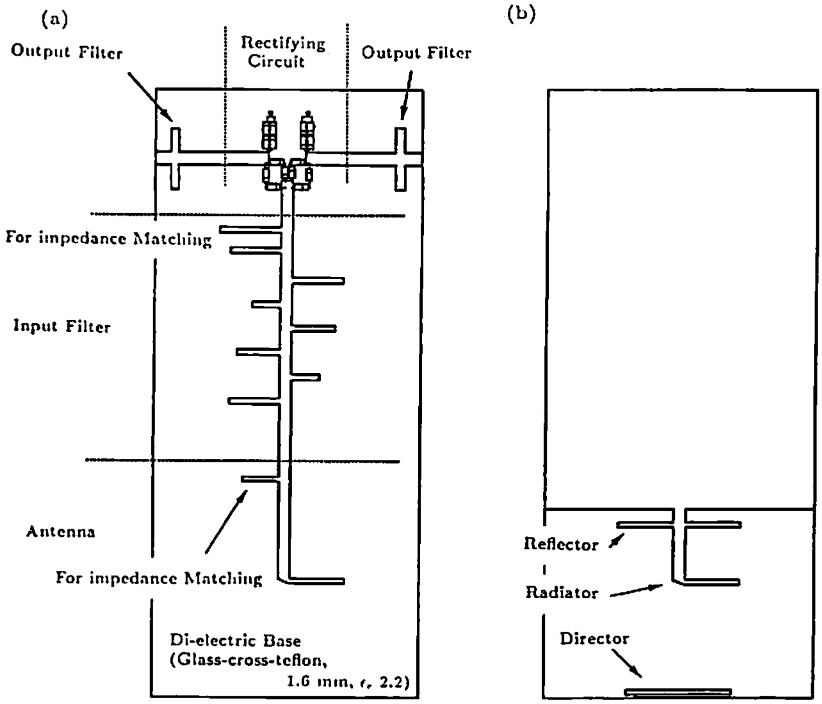

図 3.2: Improved Rectenna (a) Up Side (b) Reverse Side

Reference

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