New Research Facilities of Phased Array and Anechoic Chamber for SPS

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Abstract

A Space Solar Power Satellite/Station (SPS) requires high efficiency and low cost phased array for a microwave power transmission from the SPS to ground. For the phased array of the SPS, we have developed new phased array research facility, new rectenna (rectifying antenna) array research facility, and a special anechoic chamber for the SPS experiment in Kyoto University in FY2010. In this paper, I show the characteristics of the new phased array and rectenna array. I also introduce the new anechoic chamber for the SPS in Kyoto University.

1. Introduction

40 years passed from the first proposal of a Space Solar Power Satellite/Station (SPS) in 1968[1], which consists of a huge solar power satellite with a power transmission via microwave and a receiving site on ground. The SPS is considered as one of future hopeful power station whose electric power is stable without any CO_2 emission because the SPS is in geostationary orbit where there is no shadow of the Earth except a few days around the spring and autumn equinox and because the generated power is transmitted by microwaves which is not absorbed and scattered by rain and atmosphere. However, the SPS requires higher technologies, for example, a higher efficiency and lower cost phased array for a microwave power transmission, lower cost launch vehicles, and new building technologies and management technologies of the huge space segment[2][3]. After the proposal of the SPS, there are many research projects and field experiments for the SPS in the world[4][5]. However, we need new experiment to advance the SPS technologies especially for next satellite experiment toward the SPS. In Kyoto University in Japan, we have developed new phased array research facility, new rectenna (rectifying antenna) array research facility, and a special anechoic chamber for the SPS experiment in FY2010.

2. New Phased Array Research Facility and New Rectenna Array Research Facility

Fig. 1 New Phased Array Research Facility in Kyoto University

In Kyoto University, we have some kinds of the phased array with magnetrons called SPORTS-2.45 (Space POwer Radio Transmission System for 2.45 GHz) and SPORTS-5.8 (Space POwer Radio Transmission System for 5.8 GHz)[6]. We developed a phase controlled magnetron (PCM) for a phased array[7]. The PCM is higher efficient and lower cost device than conventional semi-conductor amplifiers. These are research facilities to carry out microwave power transmission experiments. However, in recent day, the efficiency of the semi-conductor amplifiers increases with new GaN device and F-class amplifier circuit technology. Therefore, we adopt the semi-conductor amplifiers with new GaN device and F-class amplifier circuit technology for a new phased array research facility in Kyoto University in order to advance the phased array technology for the SPS.

Fig.1 shows the picture of the new phased array research facility with GaN device and F-class amplifier circuit technology. Frequency is 5.8GHzCW. It consists of 256 F-class amplifiers with GaN FETs, whose power added efficiency in HPAs is over 70% in 7W output (Fig.2)[8], and 256 5-bit MMIC phase shifters. Total microwave power is over 1.5kW average. It is easy to separate the antennas and circuits to carry out various microwave experiments. In the phased array, there are software phase adjustments with REV (Rotating Electromagnetic Vector) method and software

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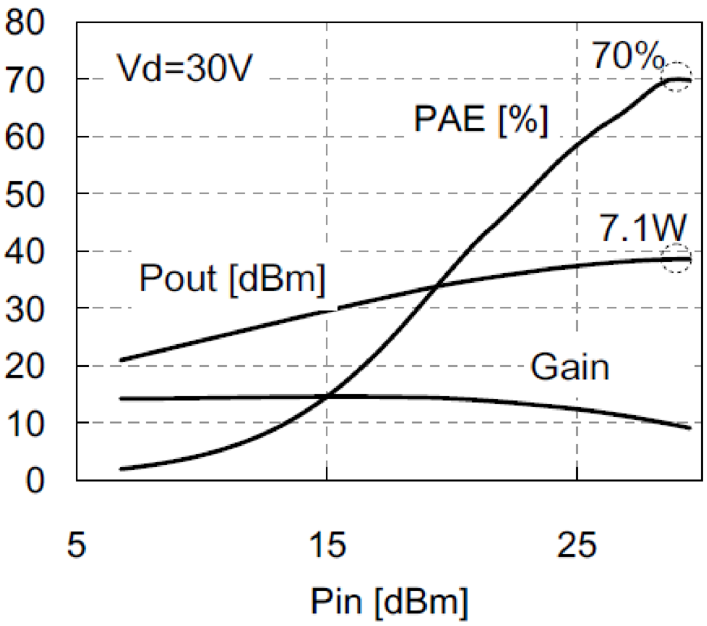

Fig.2 Measured Output Characteristics of the amplifier[8]

retrodirective target detecting with mono pulse pilot signal for beam controlling. The phased array is developed with Mitsubishi Electric Corporation.

Additionally we develop some experimental equipment for the phased array. ‘PAC (Position and Angle Correction) method’, ‘Closed loop method’, and ‘Parallel method’ are installed as DOA algorisms of the phased array. The ‘PAC method’ detects the position error of each antenna panel by using the pilot beam from the rectenna, and corrects this error for the high efficient beam forming. The ‘Parallel method’ uses phase modulation signals to achieve same purpose as ‘PAC method’. The ‘Closed loop method’ monitors the beam direction error at rectenna and corrects this error for the high accuracy beam direction controlling. These algorisms are proposed by Mitsubishi Heavy Industry ltd. (MHI). We can carry out the DOA and beam forming experiments with these three algorisms in the phased array equipment. Fig.3 indicates theoretical beam patterns of the phased array.

We need a rectenna array for the experiment of the microwave power transmission. Therefore, we also have developed a new rectenna array research facility (Fig.4) in Kyoto University. The rectenna array consists of 256 rectenna elements with over 50% of a RF-DC conversion efficiency at 1mW microwave input without LPF. The rectenna is based on the previous work by Mitsubishi Electric Corporation and Kyoto University[9]. We adopt a Frequency Selective Surface (FSS)[10] for suppression of re-radiation. We have other research facility of suppression of the re-ration from the rectenna array and have that of an optimum load control system for the rectenna array.

(a) (b) (c)

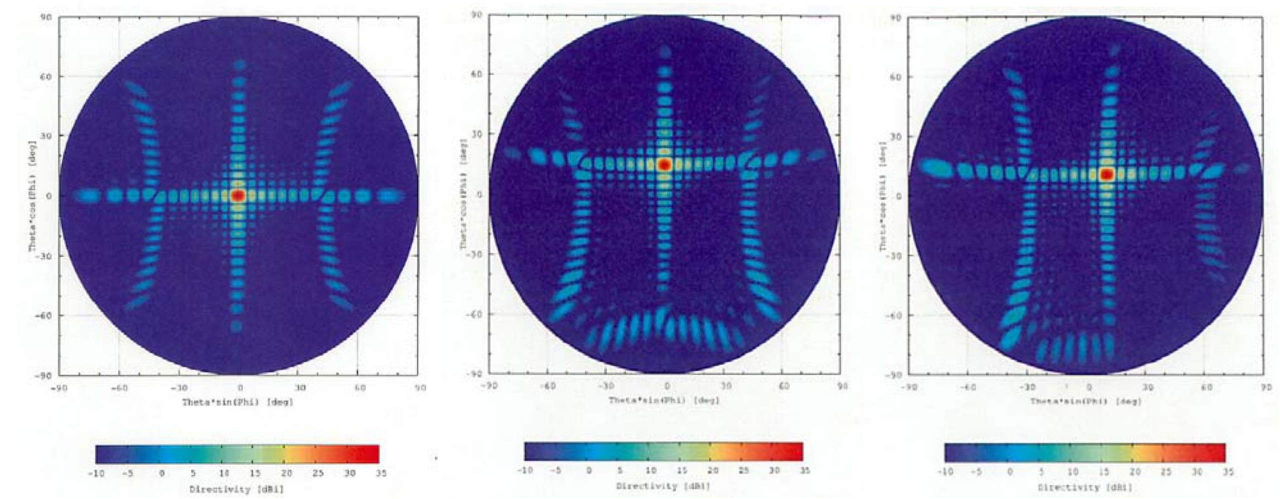

Fig.3 Theoretical beam pattern of new phased array
(a) Focus Point [θ, ϕ]=[0deg,0deg], (b) [θ, ϕ]=[15deg,0deg], (c) [θ, ϕ]=[15deg,45deg]

3. New anechoic chamber for the SPS

In Japan, ‘Basic plan for space policy’ was established by Strategic Headquarters for Space Policy in June 2009. This Basic Plan for Space Policy forged this time is based on the Basic Space Law established in May 2008 and is

Fig.4 New Rectenna Array Research Facility in Kyoto University

a Japan's first basic policy relating to space activities. In the plan, the SPS was selected on measure nine systems and programs for the use and R&D of space as follows;
"As a program that corresponds to the following major social needs and goals for the next 10 years, a Space Solar Power Program will be targeted for the promotion of the 5-year development and utilization plan." and "Government will conduct ample studies, then start technology demonstration project in orbit utilizing "Kibo" or small sized satellites within the next 3 years to confirm the influence in the atmosphere and system check."[11][12].

For the next hopeful satellite experiment for the SPS, we need a new anechoic chamber for the phased array experiment. In FY2010, we built a special anechoic chamber with high power microwave absorbers and large near field scanner (Fig.5). The size of the building is 34.0m(L) x 21.0m(W) x 9.97m(H) and that of the anechoic chamber is 18m(L) x 17m(W) x 7.3m(H) with high power absorber of 10kW/cm^2 which you see as a black wall in Fig.5(b). We call it a A-METLAB (Advanced Microwave Energy Transmission LABoratory). The near field scanner in the A-METLAB is plane-polar type and it can measure a phased array of 10ϕ, 10 tons and 10kW microwave. You can use the A-METLAB as a clean room of class 100,000 to carry out a satellite experiment. We Kyoto University has other anechoic chamber for the microwave power transmission[13]. You can use the both as an international and inter-university collaborative research for the radio wave technologies and the SPS.

(a) (b) (c)

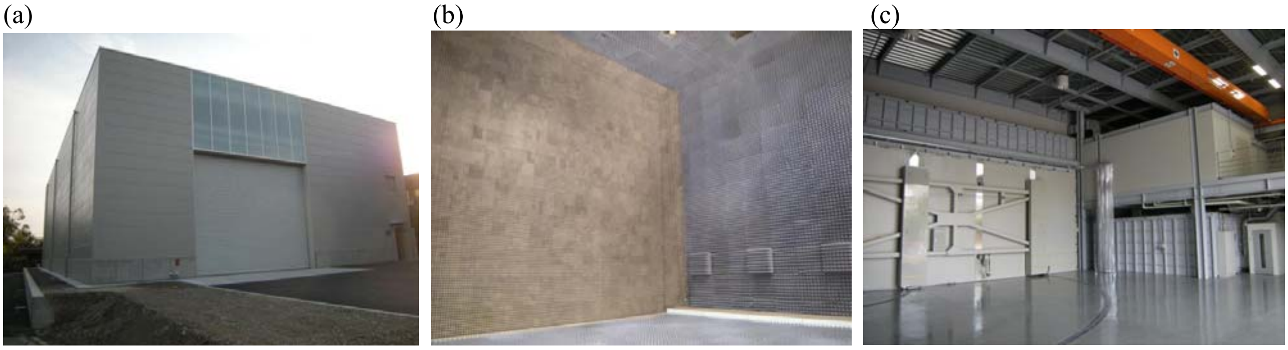

Fig.5 New Anechoic Chamber in Kyoto University (a) Building (b) Anechoic Chamber (c) Preparation Area

4. Conclusion

We consider that the SPS will help us in near future. However, the SPS requires much higher technologies including the microwave, solar cells, launch vehicles and space segments than the present technologies. We Kyoto University focus at the microwave power transmission technologies, especially the phase array technologies and have developed new research facilities of a phased array, a rectenna array, and an anechoic chamber in FY2010 in order to advance the microwave power transmission technologies toward a satellite experiment for the SPS. These facilities are open for an international and inter-university collaborative research. We would like to collaborate the SPS project with these research facilities.

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