DEVELOPMENT AND DEMONSTRATION OF NEW RETRODIRECTIVE ANTENNA SYSTEM FOR SOLAR POWER SATELLITE OF SANDWICH STRUCTURE

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Abstract

The Solar Power Satellite (SPS) is one of the unique and hopeful electric power stations to satisfy ever-increasing energy demand on the ground without destroying the environment of our mother planet Earth. However, we must investigate new breakthroughs on the SPS, because the reference system designed by DOE/NASA is too huge and too expensive for the realization. We have proposed a new concept of the SPS, which consists of a generator / transmitter of a sandwich structure and large collectors. We are developing the new high power microwave transmitter with a beam control of a retrodirective antenna in the sandwich structure in order to realize our new concept of the SPS. The new microwave transmitter has successfully been improved as follows:

1) Higher frequency can make the transmitter smaller. The frequency of the microwave is 4.8 GHz to make the diameter of the transmitter half.
2) Half frequency (2.4 GHz) of the microwave is used as a pilot signal of the retrodirective antenna to make RF circuit very simple and accurate.
3) The control system of the power beam is very accurate and flexible using the retrodirective antenna system and/or computer control.
4) The transmitting antenna is directly connected to the amplifiers to reduce the loss of cables and the weight of the antenna.
5) A honeycomb antenna is used as the receiving antenna for the pilot signal considering its light weight and heat reduction.

1. Concept of the light SPS with the sandwich structure and inflatable mirrors

The Solar Power Satellite (SPS) proposed by Dr. P. Glaser generates an electric power of the order of several hundreds to thousands of mega-watts by solar cells and transmits the generated power via microwave power beam to the ground. DOE and NASA investigated its concept in detail to design the SPS of 5 GW as a Reference system in 1978. In the Reference system, the generated electric power is transformed to high voltage with very heavy DC-DC converters and supplied through very heavy power transmission lines and a rotary joint to the transmitting antenna. The power lines must be so thick enough to reduce an energy loss by resistance of the power lines that they are very heavy. The rotary joint rotates one turn every day. Because the solar paddle always faces to the sun, while the transmitting antenna faces to the earth. The SPS can be much lighter and simpler if the DC-DC converters, the power lines and the rotary joint are removed from the SPS.

Figure 1 shows a schematic illustration of the new SPS concept proposed here. It consists of the generator/transmitter of the sandwich structure and a pair of the large reflectors. The sun light reflected by a reflector (shown by Reflector-1 in the figure) is again reflected by another reflector (Reflector-2). The second reflector concentrates the solar energy ten times into the solar paddle on the sandwich module in the figure. The inflatable mirror used as the reflector is very light due to a structure of a balloon. The surface of the reflectors should be coated to reflect only solar ray convertible to electric power by the solar cells and to absorb the unnecessary infrared ray only heating the solar cells.

The reflectors are connected to the sandwich module with a long tether. The SPS can stably stay in space by force of gravity gradient between the reflectors and the sandwich module. Thus, the sandwich module always faces to the ground, while the reflectors are pulled at the opposite direction from the Earth. A drive mechanism to rotate the Reflector-1 is necessary to concentrate the solar ray on the solar paddle all day long.

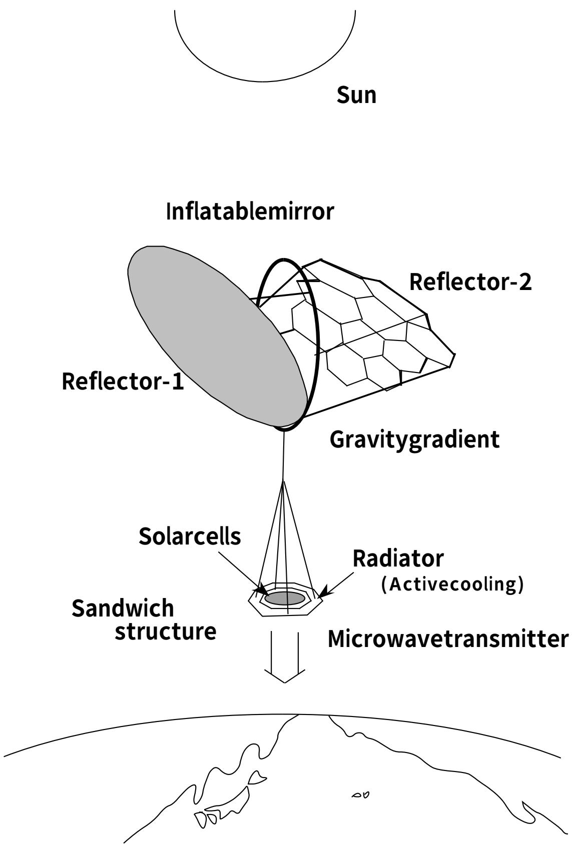

Fig. 1 Artistic drawing of the Solar Power Satellite of the sandwich structure

2. New transmitter with retrodirective antenna system

The structure of the generator/transmitter is shown in Fig. 2. Each block of the solar cells is directly connected to high efficient amplifiers of high power microwave with no voltage converters and no heavy power transmission lines. The microwave is radiated from printed slot antenna, which is directly connected to the amplifier. The printed slot antenna has a very simple and light structure, which is composed only of a stripline as a radiator and a very small slot. The board which the amplifiers are attached to, works as a heat radiator, though there are many small halls as the slots for the transmitting antenna. The printed slot antenna is suitable for the transmitting antenna of the sandwich type, because the grand plan can be used as the heat radiator.

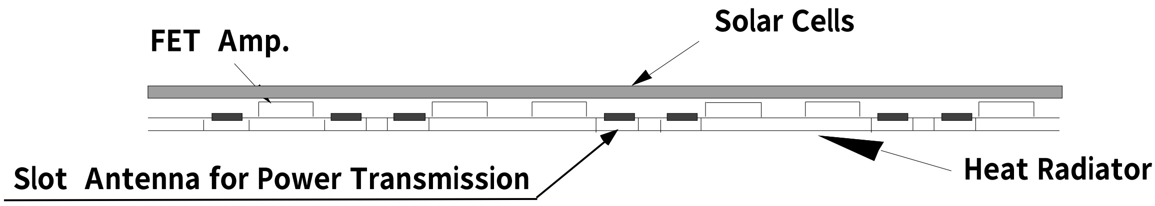

Fig. 2 Configuration of the sandwich structure

There is another critical issue on the control of the microwave beam. The microwave transmitted from the SPS must be exactly concentrated on the rectenna. The retrodirective antenna is expected as the most practical system for the control of the microwave beam. In the retrodirective antenna system, transmitting phases of the microwave are determined by the pilot signal transmitted from the rectenna. However, the frequency of the pilot signal can never be the same as that of the microwave for the power transmission, because the pilot signal cannot be distinguished from the high power microwave. We are developing a new retrodirective antenna using a pilot signal at the half frequency of the transmitting microwave. It has no phase ambiguity and needs only a very simple circuit. A phase detector for the pilot signal, which is separated from the power transmitter, can output received phases of the pilot signal as digital data, which can easily be doubled and conjugated with digital circuits. The transmitting phase of the high power microwave can be controlled by digital phase shifter with the above data. The control system of the power beam is very accurate and flexible with computer control.

We developed a demonstrator of the retrodirective antenna and rectenna to verify our beam control system. An active phase array antenna as a power transmitter is composed of four panels shown in Fig. 3, while each of the four rectenna panels has four LEDs to be illuminated by the transmitted microwave (Fig. 4). Each transmitter panel can radiate microwave of 8 W at a frequency of 4.8 GHz with the retrodirective antenna system. The pilot signal transmitter is radiated from a small antenna attached to the second rectenna from the left side in the picture, while the frequency is 2.4 GHz. The high power microwave can successfully turn on LED lamps of the rectenna, which is attached with the pilot signal antenna. That means the transmitted high power microwave can successfully be controlled with the pilot signal and concentrated on the rectenna with the pilot signal antenna to lighten the LED lamps. The demonstration can verify our microwave beam control system with the new retrodirective antenna.

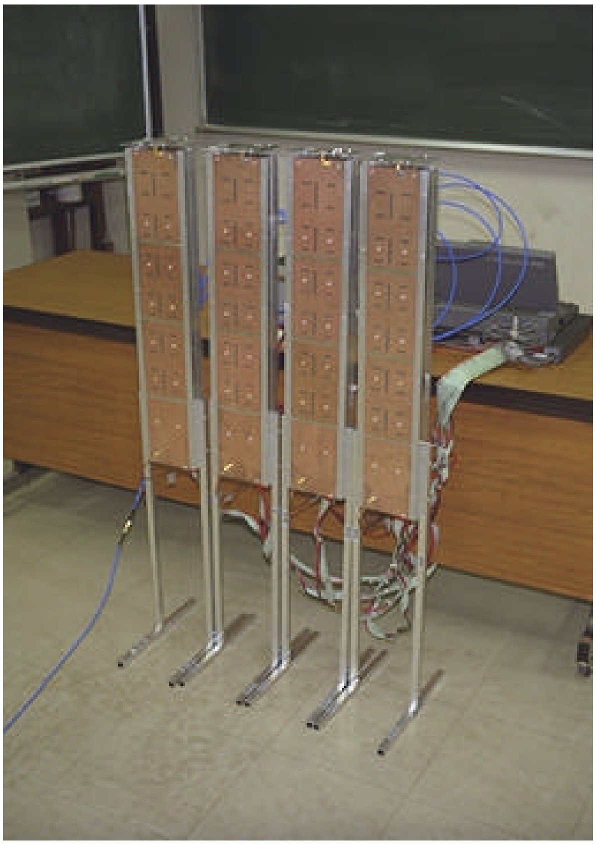

Fig. 3 Picture of the active phased array antenna with the retrodirective antenna system

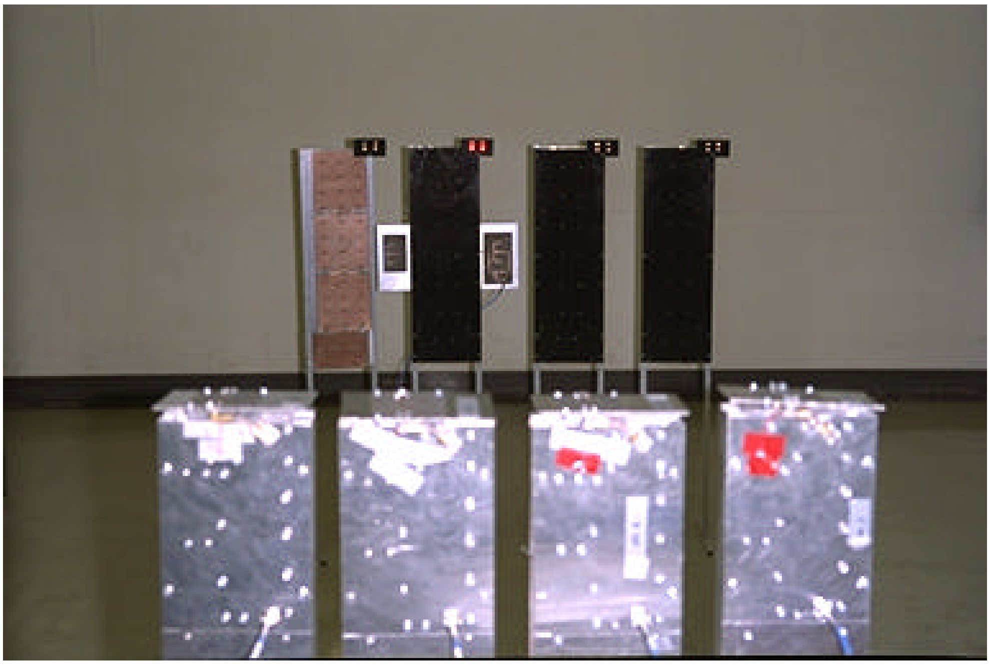

Fig. 4 Picture of the rectenna with LEDs and pilot signal antenna over the phased array antenna