SATELLITE EXPERIMENT (ISPER) FOR SOLAR POWER SATELLITE OF A SANDWICH STRUCTURE

N. Kaya

Department of Computer and Systems Engineering, Kobe University
Rokkodai, Nada, Kobe 657, Japan

Abstract

We proposed a new SPS concept, which consists of a generator/transmitter of a sandwich structure and a large solar collector. The solar cells are directly connected to the high power amplifiers. A very light inflatable collector reflects and concentrates the solar power on the solar paddles. A new space experiment ISPER proposed here aims to verify the new SPS concept. The generator/ transmitter of the sandwich structure and the collector are installed on the satellite. The frequency of the microwave is 5.8 GHz in order to make the transmitter small. Half frequency of the microwave is used as a pilot signal of a retrodirective antenna to make RF circuit very simple. Propagation characteristics of the microwave and the pilot signal in the ionosphere and the atmosphere are examined by receiving the transmitted microwave.

1. Introduction

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. Many issues need further investigations to establish the SPS. The microwave power transmission is especially an important technology for the SPS. Since a step-by-step experiment is very effective and essential for the development of technology, we tried the fundamental demonstrations (MILAX, ISY-METS and Kansai-demo) of the microwave power transmission on the ground and in space. The successful results of the demonstrations brought us new and valuable information not only on the nonlinear plasma physics but also on the technologies for the future SPS. After the demonstrations, we have already started the new space experiment (ISPER: International Space Power ExpeRiment) using a satellite with international collaborations.

The ground test provides a good opportunity of demonstrating a feasibility of the wireless power transmission to the general public in addition of obatining critical data for the technical design of the system. We performed the ground-based power transmission test MILAX (MIcrowave Lifted Airplane eXperiment) on Aug. 29, 1992 by using a small airplane just like SHARP in Canada. The microwave power could drive the small model airplane to fly for a period of 40 sec at a height of about 10 m.

The ISY-METS (International Space Year - Microwave Energy Transmission in Space) rocket was launched on February 18, 1993. All the instruments aboard the rocket worked perfectly. A high power microwave of about 800 W was transmitted accurately by a newly developed active phased array antenna installed on a mother section of the rocket toward a separated daughter one. The wave observation in the HF range indicated that natural plasma waves are enhanced by the microwave energy through nonlinear interactions.

Our next project is the space experiment (ISPER). In this paper, we described the concept design of ISPER.

2. Concept of the ISPER

We are developing the new concept of the SPS as shown in Fig. 1 other than the Reference System, which consists of the generator/transmitter of the sandwich structure and the large collector. The concept has many merits. Heavy long transmission lines on the solar paddles and a rotary joint for the connection between the solar paddles and the microwave transmitter are unnecessary because the solar cells are directly connected to the high power amplifiers. The size of the solar paddles decreases to that of the transmitter. A very light inflatable collector can concentrate the solar power on the solar paddles to increase the efficiency of the solar cells. Thus, the SPS of the new concept can be very light enough to realize it. The new space experiment ISPER proposed here aims at verification of the new SPS concept.

The ISPER project is being designed using a Japanese satellite. The primary objective of the ISPER is to verify the total system from a power generator to a wireless power transmitter as a small SPS. Ionospheric effects on pilot signals for a retrodirective antenna and high power microwave are examined. Nonlinear interactions between the ionospheric plasma and microwave is also estimated to determine an allowable power density of the transmitting microwave.

The objectives of ISPER are as follows:

1. Development of power generator and transmitter module
(1)Antenna pattern of the transmitter
(2)Development of active cooling system of the module
(3)Mechanism of the deployment of the transmitter
(4)Attiitude control

2. Microwave beam control
(1) Development of retrodirective antenna
(2)Pilot signal in half frequency
(3)Effects of Ionosphere (Index of refraction)

3. Microwave frequency (5.8 GHz)
(1)Attenuation by the rain
(2)Effects in propagation (Refraction, Faraday rotation, Scintillation, Scattering and absorption of atmosphere)
(3)Nonlinear interaction between the ionospheric plasma and high power microwave

4. Collector of the solar power
(1)Collection efficiency
(2)Mechanism of the deployment
(3)Material for Collector (absorption of Infrared)

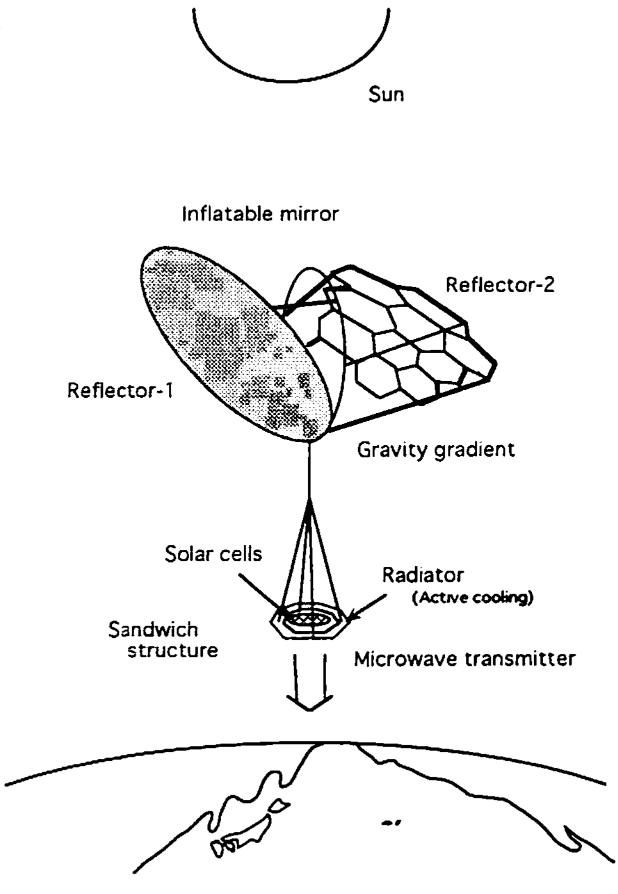

Fig.1 A schematic illustration of the SPS with collectors

A schematic illustration of the ISPER is given in Fig. 2. The microwave generator/transmitter is deployed from the satellite. Because the solar-cell side cannot be controlled to direct to the sun, we try a large reflector/concentrator of solar enegry. The reflector is made of inflatable structure to reduce its weight. The ISPER transmits power via a 5.8 GHz microwave in contrast to 2.45GHz for the SPS. Because the microwave of the higher frequency reduces the size of the transmitting antenna and hence the volume and weight of the SPS.

One of the new technological aspects of the ISPER is the development of an unified module of solar cells and microwave transmitter. The module consists of three layers; high efficiency solar cells on one side; transmitting antenna arrays on the other side; and F-class FET power amplifiers between the solar cell and the antenna plane as shown in Fig. 3. The direct connection of the DC output of the solar cells to the FET amplifier of each active antenna element makes it possible to design much simpler structure not only of the ISPER but also of the future SPS. In the SPS Reference System studied by NASA/DOE, DC electric power generated by the solar cells must be collected by a DC power collecting network in the huge SPS solar paddle. A critical technology of using super-conductor network for the current collection is being considered for the SPS. This DC power collection network is not necessary for the ISPER. If this technology is once established, the design of the future SPS would become much simpler and less expensive. Another critical technological problem raised in the SPS Reference System is a mechanical rotary joint which electrically connects the differentially rotating solar paddle and the microwave transmitting antenna in vacuum.

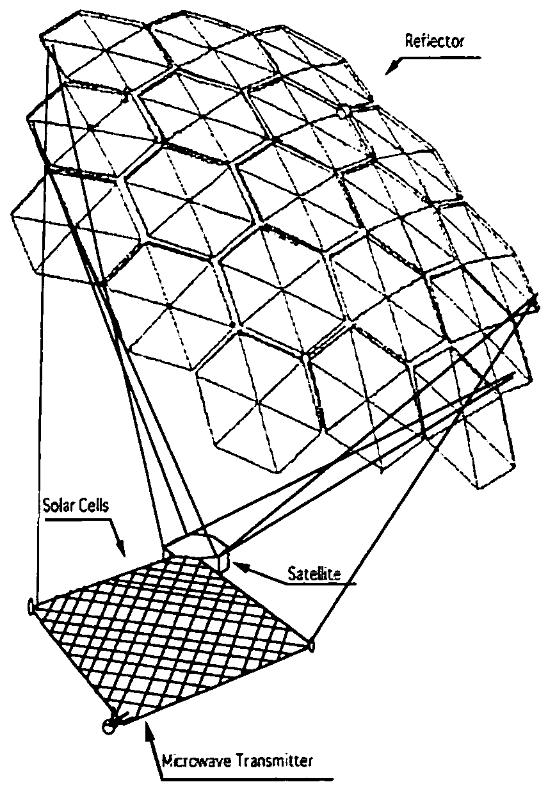

Fig. 2 A schematic illustration of the ISPER

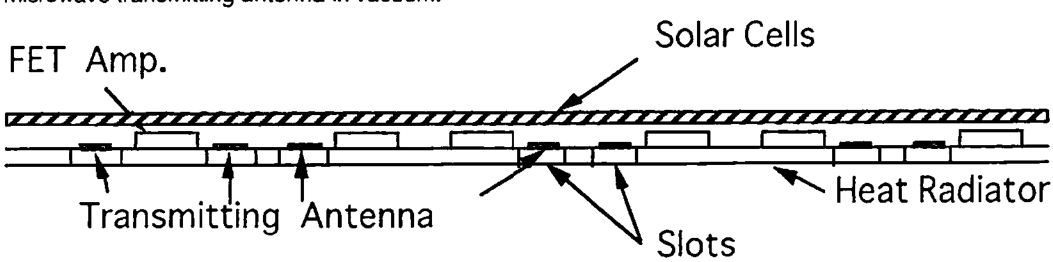

Fig. 3 A block diagram in the sandwich structure

This is one of the difficult technological points of the SPS. However, the present ISPER does not need such a rotary joint because the DC electric power is directly fed to the FET amplifier.

The specifications of the ISPER are as follows:

(1)Frequency	5.8 GHz
(2)Pilot signal	2.9 GHz
(3)Beam control	Retrodirective Antenna
(4)Antenna system	Active Phased Array Antenna
(5)Antenna element	Patch / Slot / Dipole
(6)Antenna gain	55 dB
(7)Size of solar cell	10 m x 10 m
(8)Collector	10 times (200 kW)
(9)Transmitting power	50 kW (25 %)
(10)Power density on the Ground	4.8 mW/m^2 (500 km)

Experimental Modes of ISPER are summarized in the following:

(1) Transmission test for checkout (Short transmission)

Purpose:verification of generator & transmitter module

Measure:radiation pattern, transmitting power, generating power, collection efficiency, attitude control

(2) Transmission test to the ground

Purpose:verfication of retrodirective antenna and observation of attenuation by rain

Measure:comparison between received power in or not in rain effects in propagation (refraction, Faraday rotation, scintillation, scattering and absorption of atmosphere)

(3) Physical experiment

Purpose:experiment on nonlinear Interactions between ionospheric plasma & high power microwave

4. Conclusions

We succeeded in newly developing the active phased array antenna for the MILAX demonstration and the METS rocket experiment. The transmission experiments showed that the transmission system developed for the MILAX and the ISY-METS could transmit enough power and accurately control the microwave beam for the flight of the model airplane and the daughter section, respectively. The ISPER is expected to be the first step toward the SPS.

References

(1) N. Kaya, H. Matsumoto, S. Miyatake, I. Kimura, M. Nagatomo and T. Obayashi, Nonlinear Interaction of Strong Microwave Beam with the Ionosphere, Space Power, 6, 181-186, 1986.

(2) I. Kimura, H. Matsumoto, N. Kaya and S. Miyatake, Plasma wave excitation by intense microwave transmission from Space Vehicle, Adv. Space Res., 8, 291-294, 1988.

(3) N. Kaya, H. Matsumoto and R. Akiba, Rocket experiment METS -Microwave Energy Transmission in Space-, Space Power, 11, 267-274, 1992.

(4) N. Kaya, H. Kojima, H. Matsumoto, M. Hinada and R. Akiba, ISY-METS Rocket experiment for microwave energy transmission, Acta Astronautica, Vol. 34, 43-46, 1994

(5) J. McSpadden, N.i Kaya, A. Brown and K. Chang, A recceiving rectifying antenna for the International Space Year-Microwave Energy Transmission in Space (ISY-METS) rocket experiment, IEEE Aerospace and Electronic Systems Magazine, Vol. 9, No. 11, 36-41, 1994