ABSTRACTS (PH D THESIS)

Study on Beam Forming for Phased Array Antenna of Panel-structured Solar Power Satellite

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A solar power satellite (SPS) is a huge satellite designed as an electric power plant in a geostationary Earth orbit. The SPS generates electricity using solar cells in outer space and transmits the generated electricity to a receiving site on the Earth through microwave power transmission. A panel-structured SPS corresponds to the main structure of a tethered SPS. The transmission antenna of the panel-structured SPS is a phased array antenna, consisting of many antenna elements. The radiation pattern of the phased array antenna can be manipulated by controlling the output phases and the power of microwaves radiated from each antenna element. The panel modules are connected exibly, and the shape of the panel-structured SPS is easily deformed (Fig.1). When the shape of the panel-structured SPS is deformed, the beam shape of the power transmission microwave is deformed due to errors caused by the change in the positions of the antenna elements. Hence, this deformation must be corrected for electricity to be transmitted with high efficiency.

First, in this study, we perform experiments using an actual phased array antenna consisting of 256 antenna elements and we simulate the beam forming using the experimental phased array antenna. The results of these experiments incdicate that we can control the radiation patterns and the beam direction with exceedingly high accuracy using current technology. Moreover, by comparing the experimental with the simulation results, we confirm that we can simulate the radiation patterns with high accuracy. We then simulate the radiation pattern of the phased array antenna on the panel module of the panel-structured SPS. The results indicate that the peak directivity is decreased to 90% when the size of the beam direction is 30◦ and is decreased to 50 % when the size of the beam direction is 40^o.

Second, we evaluate the position and angle correction (PAC) method, which was proposed for the phased array antenna of the panel-structured SPS. The PAC method estimates the positions of the antenna elements and calculates the correction values of the output phases from the pilot signal that is radiated from the receiving site on the Earth in order to detect the receiving site. A simplified simulation model, which corresponds to a panel structured SPS consisting of panel modules with a linear phased array antenna, is constructed to simulate the PAC method. The simulation results confirm that the PAC method can be applied to correct the beam shape, even if the pilot signal phase measurement contains errors. Moreover, when the distance between the pilot signal receiving points widens, the size of the phase correction errors decreases. In fact, when the standard deviation of the phase measurement errors is defined as 10^o and the pilot signal receiving points are placed at the ends of each panel module, the standard deviation of the output phase correction errors is approximately 16^o.

Third, we propose and evaluate ambiguity elimination methods for the angle estimations of the panel modules in the simplified simulation model. From the previous evaluations, the distance between the pilot signal receiving points must be widened to improve the phase correction accuracy of the PAC method. However, when the distance between the pilot signal receiving points is longer than half the wavelength of the pilot signal, the angle estimation of the panel module may fail due to ambiguities in the phase measurement of the pilot signal. Hence, we increase the number of pilot signal receiving points, and the ambiguities are eliminated by an unequal interval array of pilot signal receiving points. Evaluating the ambiguity elimination methods with three and four pilot signal receiving points, we confirm that the ambiguities can be perfectly eliminated using four pilot signal receiving points (Fig.2). We then propose an ambiguity elimination method with a flatness maintaining system. Evaluating the ambiguity elimination method with the atness maintaining system, we confirm that the ambiguities can be perfectly eliminated using the flatness maintaining system and three pilot signal receiving points.

Finally, we consider the pilot signal receiving antennas. A patch antenna is used as a power transmission antenna in the panel-structured SPS. Here, we propose using a patch antenna as a pilot signal receiving antenna. We design antennas to equalize the size of pilot signal receiving antennas and power transmission antennas. Thus, the power transmission antenna is replaced with the pilot signal receiving antenna, and the output phases are corrected by the PAC antenna in the panel-structured SPS. We simulate the mutual coupling effect in the pilot signal phase measurement. From the simulation, the mutual coupling is found to have little effect on the pilot signal phase measurement when the pilot signal phase receiving antenna is not adjacent to other pilot signal receiving antennas.

Furthermore, the ambiguity elimination methods can be used when we use the pilot signal receiving antennas in the PAC method, and we confirm that the patch antenna can be used as the pilot signal receiving antenna in the panel-structured SPS.

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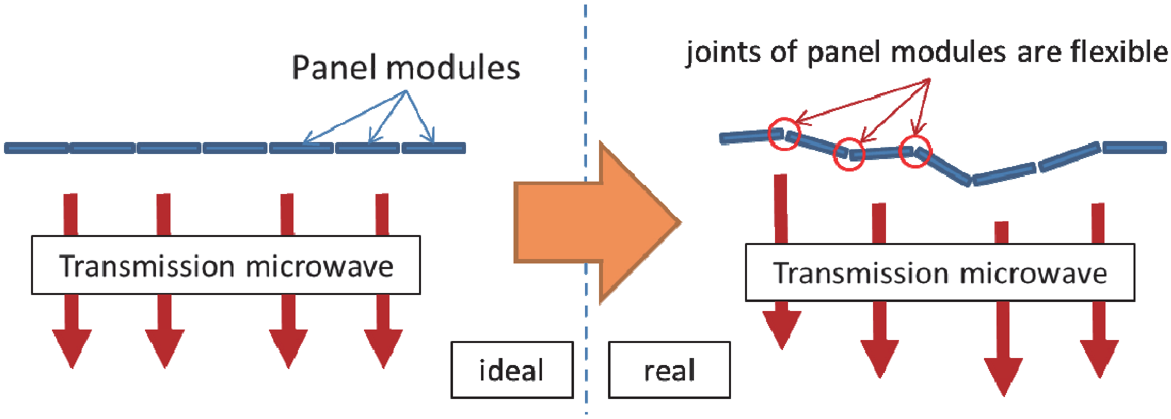

Fig.1. Concept of Panel Structure Antenna for SPS

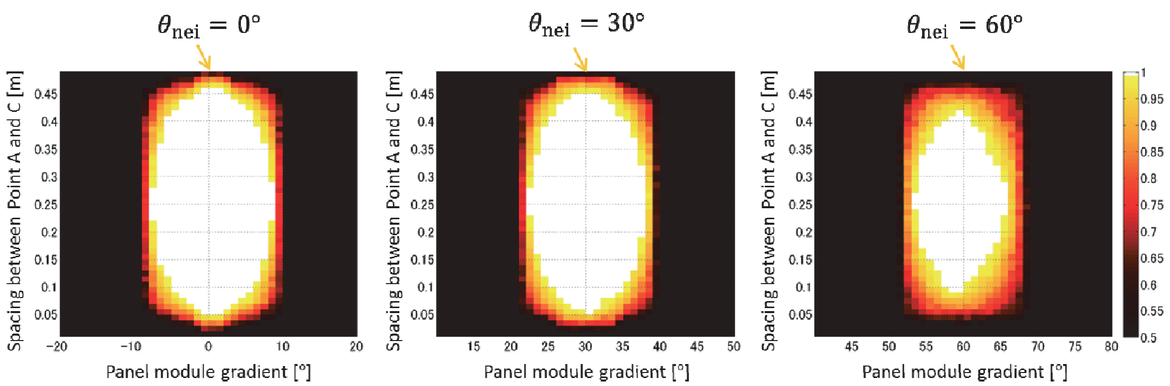

Fig.2. Result of ambiguity elimination method