Radiation Pattern Affected by Thermal Distortion and BFN Error of the Reconfigurable Antenna for the 21-GHz Band Broadcasting Satellite

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***Abstract* - The satellite broadcasting in the 21-GHz band is expected to transmit large capacity programs. We have proposed an array-fed imaging reflector antenna which is effective to exploit the limited resources because of its ability to control radiation pattern. An antenna configuration for engineering test is introduced. We evaluated radiation patterns affected by thermal distortion on the reflector and control error in the beam forming network.**

***Index Terms* — 21-GHz band, broadcasting satellite, surface distortion, BFN error.**

I. Introduction

The satellite broadcasting in the 21-GHz band is expected to transmit multi-program services of Super Hi-Vison (SHV) and other advanced services [1]. For the implementation of SHV, we assume to allocate two 300-MHz class wideband channels in the band 21.4 - 22.0 GHz, as shown in figure 1.

To supply enough power for such a wide band transponder, we proposed array-fed Imaging Reflector Antenna (array-fed IRA) [2]. It enables to combine enough power for large capacity signal transmission while the power from each feed horn is keeping small to avoid electrical discharges.

In addition, the array-fed IRA is effective to exploit the limited resources because of its ability to control radiation pattern in order to increase locally in the area of severe fading while keeping the flat pattern, as shown in Fig. 1.

We are on a process to fabricate an antenna for engineering test [3]. Assuming the fabricating antenna, we evaluate the radiation pattern affected by the thermal distortion on the reflector antenna and by the control error in the beam forming network (BFN) for the 21-GHz band broadcasting satellite.

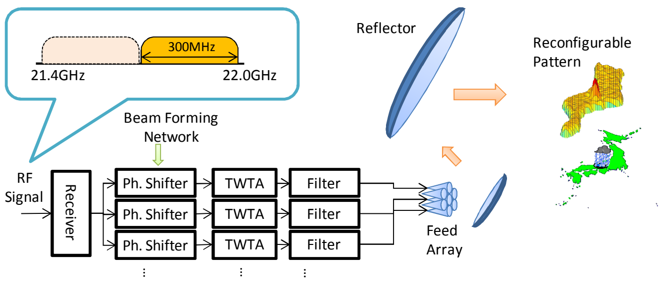


Fig. 1. Concept of the 21-GHz band broadcasting satellite

II. Radiation Pattern Reconfigurable Antenna

The radiation pattern reconfigurable antenna consists of a BFN, 32 feed horns and two parabolic reflectors.

In the BFN, the input RF-signal divided equally into 32 lines. A divided line is connected to an attenuator and a phase shifter which are controlled by a BFN controller. The minimum quantization unit is 11.25 degrees (i.e. 5-bits) for phase shifters and that the minimum amplitude step and approximate dynamic range for the attenuators are 0.5 dB and 7.5 dB, respectively (i.e. 4-bits).

The antenna configuration is depicted in Fig.2. The feed array consists of 32 horn antennas arranged in 1.8 wave length spacing. The output power of each horn antenna is fixed and has a tapered distribution from center (0 dB) to outside (-6 dB). The radiation pattern can be altered by controlling only the phase of each element.

The array-fed IRA has two parabolic reflectors to magnify the electromagnetic field radiated by feed horns.

Frequency Band	21.4 – 22.0 GHz
Orbital Location	110 deg.East
Polarization	RHC
Number of array elements	32
Spacing of array elements	24.9 mm (1.8 w.l.)
Magnification factor	10
Offset Angle	10 deg.

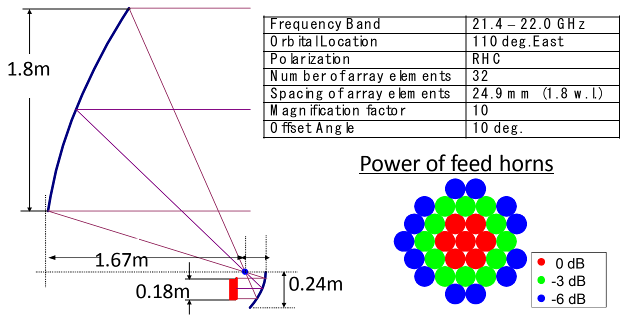


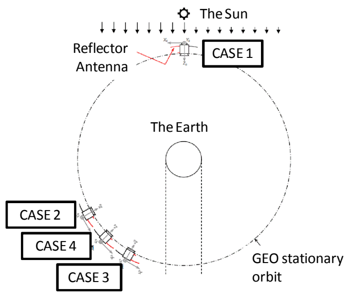
Fig. 2. Antenna configuration

III. Radiation Pattern Affected by Thermal Distortion and BFN Error

A. Thermal Distortion Analysis

Thermal analysis on the reflector antenna was performed in 4 cases on the GEO stationary orbit depicted in Fig.3. The main- and sub-reflector antennas were estimated to be exposed to the temperature from -176 to +74 degrees Celsius.

Then, we analyzed distortion on the reflector antenna. Estimated thermal distortion in the case 3 is depicted in Fig.4.



State	Temperature on Reflector
Case1: Hot	Main ref: +43〜+74 deg.C Sub ref: -24〜-15 deg.C
Case2: Cold	Main ref: -176〜-162 deg.C Sub ref: -174〜-171 deg.C
Case3: Half1	Main ref: -175〜+67 deg.C Sub ref: -162〜-149 deg.C
Case4: Half2	Main ref: -176〜+64 deg.C Sub ref: -169〜-157 deg.C

Fig. 3. State of Thermal Analysis on-board Reflector Antenna.

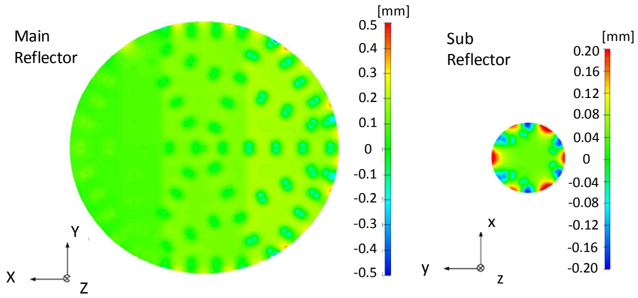


Fig. 4. Estimated Thermal Distortion on-board Reflector (Case 3).

B. *Radiation Pattern Affected by Thermal Distortion*

We evaluated radiation patterns considering thermal distortions on the reflector antenna in 4 cases. The reflector antenna was assumed to be a membrane structure made of triaxial woven carbon fiber material, which was applied well in space because of its low rate of thermal expansion [4]. Radiation pattern of the uniform gain distribution in the coverage area was calculated. The radiation pattern with and without thermal distortion (flat beam) of the case 3 were depicted in Fig.5. Contour lines with and without distortion were in good agreement as well as the other 3 cases.

The gain changes in 8 cities were depicted in Fig.6. The gains of cities in fringe area (Wakkanai, Tsushima and Naha) degraded due to a large thermal difference on the reflector.

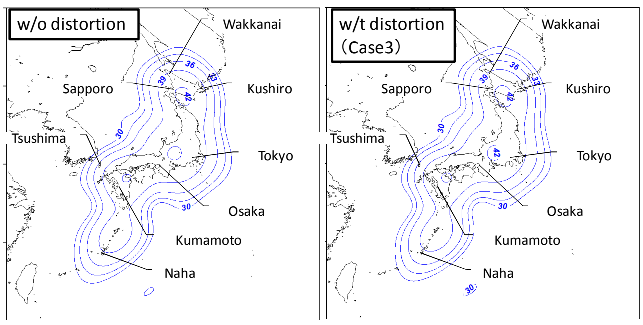


Fig. 5. Radiation Pattern with and without Distortion on the Reflector.

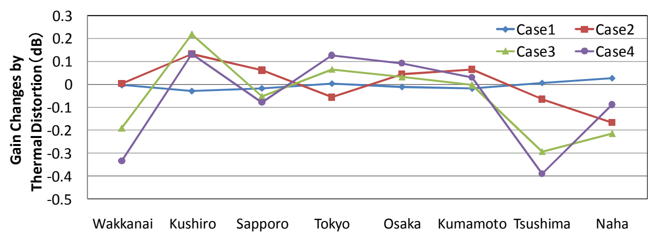


Fig. 6. Gain Changes by Distortion on the Reflector.

C. *Radiation Pattern Affected by BFN Error*

We fabricated a prototype BFN and measured transmission characteristics (S21) of every states controlled by phase shifter and attenuator. Then, we calculated radiation patterns with measured S21 value by the prototype BFN, which can control its phase and amplitude with r.m.s. error of 5.34 deg. and 0.73 dB, respectively [3]. The flat beam patterns were calculated with 32 different data sets.

The gain changes due to BFN error was depicted in Fig.7. The standard deviation (i.e. the error bar) in Osaka was about 1 dB that was relatively large comparing with other cities. Then the gain affected by thermal distortion and BFN error was depicted in Fig. 8. The gains considering the deviation in 5 cities apart from fringe area were more than 40 dBi.

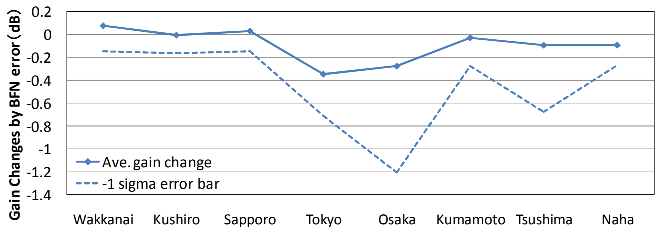


Fig. 7. Gain Changes by BFN error.

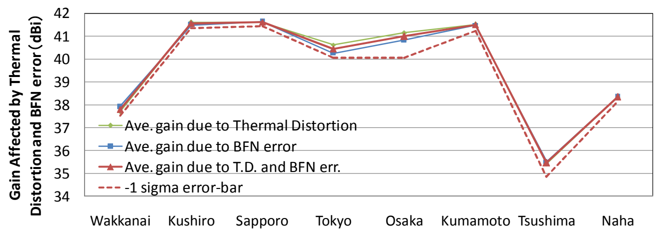


Fig. 8. Antenna Gain Affected by Thermal Distortion and BFN error.

IV. CONCLUSION

We introduced an array-fed imaging reflector antenna for 21 GHz-band broadcasting satellite. We evaluated radiation patterns affected by thermal distortion on the reflector and control error in the BFN. The antenna gains considering the deviation due to thermal distortion and BFN error in 5 cities apart from fringe area were high enough to receive signals.

ACKNOWLEDGMENT

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