Dual-Circularly Polarized Parabolic Reflector Antenna with Microstrip Antenna Array for 12-GHz Band Satellite Broadcasting Reception

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***Abstract* - NHK will start test satellite broadcasting of UHDTV in 2016 and practical broadcasting in 2018. The test broadcasting will be provided in the 12-GHz (11.7 to 12.75 GHz) band by using right-hand circular polarization. We are planning to provide multiple UHDTV programs for the practical broadcasting by using left-hand circular polarization in the same frequency band. For the UHDTV satellite broadcasting reception, we manufactured and tested a dual-circularly polarized reflector antenna that has a feed antenna composed of a 2 × 2 microstrip antenna array. Measured results showed that the fabricated antenna complied with our requirements, with voltage standing wave ratio of less than 1.4, antenna gain of 34.5 dBi (i.e., the aperture efficiency was 69 %) and cross polarization discrimination of 28.7 dB. In the future, we will improve the sidelobe characteristics.**

***Index Terms* — Reflector antenna, microstrip antenna, circular polarization, dual polarized antenna.**

1. Introduction

NHK will start test satellite broadcasting of UHDTV [1] in 2016 and practical broadcasting in 2018. The test broadcasting will be provided in the 12-GHz (11.7 to 12.75 GHz) band by using right-hand circular polarization (RHCP) transmitted by a satellite whose orbital position is 110 degrees east. We are planning to provide multiple UHDTV programs for the practical broadcasting by using left-hand circular polarization (LHCP) from a satellite at the same orbital position and in the same frequency band.

For the UHDTV satellite broadcasting reception, a right- and left-hand circularly polarized parabolic reflector antenna will make it possible to receive the services provided over the dual-circular polarization with a single reflector antenna. However, it is important to mitigate cross polarization interference because 16APSK [2], which is the modulation scheme for transmitting UHDTV programs, requires a higher CN ratio than that currently used in Japan.

To achieve sufficient cross polarization discrimination (XPD) throughout the 12-GHz band, we previously evaluated a dual-polarized reflector antenna with a 2 × 2 microstrip antenna (MSA) array [3]. Measured results showed that the antenna gain (33.7 dBi) and the XPD (25 dB) were complied with our requirements; however, these values were lower than that of the calculated results. Therefore, in this study we newly manufactured a 2 × 2 MSA array and evaluated the antenna performances of a dual-circularly polarized reflector antenna with the array.

2. Dual-Polarization Receiving Antenna

(1) Requirements for Receiving Antenna

Table 1 shows the requirements for a dual-polarization receiving antenna. The antenna gain is more than 33.7 dBi, which was determined from the peak gain of the 45-cm offset reflector antennas generally used in Japan (aperture efficiency: 70 %). The requirement of the XPD was derived from the reference pattern in Recommendation ITU-R BO.1213 [4]. To enable small signals to be received from the satellite, the upper limit of the voltage standing wave ratio (VSWR) is 1.5 throughout the 12-GHz band.

TABLE I
Requirements for Receiving Antenna

Receiving frequencies	11.70 to 12.75 GHz
Polarizations	RHCP and LHCP
Antenna gain	≥ 33.7 dBi (for both polarizations)
XPD	≥ 25 dB (at 0 deg.)
VSWR	≤ 1.5

(2) Design of Feed Antenna with MSA Array

To achieve the XPD of 25 dB throughout the 12-GHz band, we designed a dual-polarization 2 × 2 MSA array for the feed antenna of an offset reflector antenna. Fig. 1 shows the designed MSA element of the array, which has a multilayer structure with PTFE (ε_r is 2.59, $tan\delta$ is 0.0018) substrates to obtain a wide frequency bandwidth. A circular polarization can be obtained by feeding 90 degree shifted signals to the two feed lines. We confirmed that the element's calculated VSWR was less than 1.25 throughout the 12-GHz band.

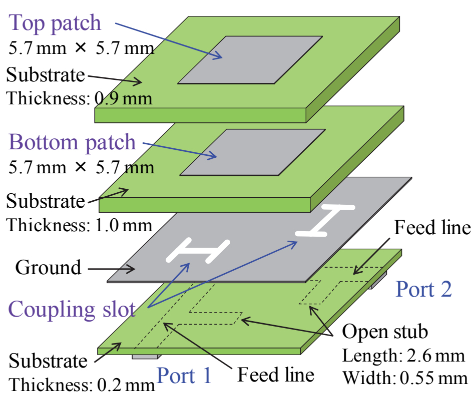
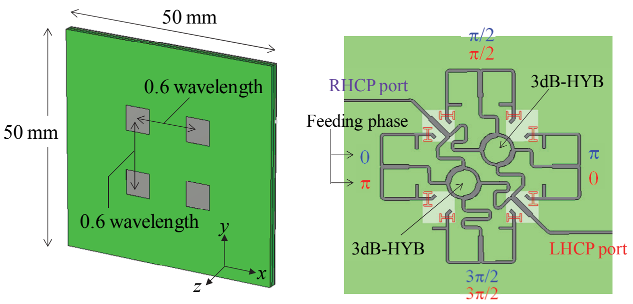


Fig. 1. Layer configuration of MSA.

Fig. 2 shows the configuration of the feed antenna, which comprises a 2 × 2 MSA array that is sequentially rotated to enhance the polarization purity. The feeding phase of the m-th patch is shifted to $\pi(m-1)/2$ by using 3 dB, 90 degree hybrid couplers (3dB-HYBs) and differences in the line length. An element spacing of 0.6 wavelengths (14.7 mm) was determined to obtain the edge illumination level of –11 dB at ±38.6 degrees.

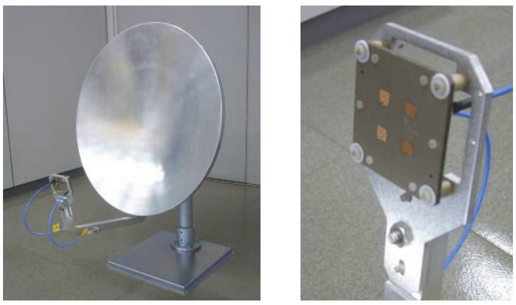


(a) Top view (b) Feed circuit (back view)

Fig. 2. Feed antenna with 2 × 2 MSA array.

(3) Fabricated Receiving Antenna

Fig. 3 shows the receiving antenna we fabricated and its antenna parameters. For a dual-circularly polarized antenna, the asymmetric geometry of an offset reflector creates deviations of the circularly polarized pattern peaks [5]. Therefore, we studied the relationship between antenna characteristics and F/D [3]. To obtain enough gain for both polarizations, we decided the diameter and F/D were 50 cm and 0.6, respectively. As shown in Fig. 2(a) and 3(b), the fabricated feed antenna has a 50 mm × 50 mm ground plane, which is smaller than that of the previous feed antenna [3] (70 mm × 70 mm).



(a) Offset reflector antenna (b) Feed antenna

(c) Antenna parameters

Diameter (D)	50 cm
Focal length (F)	30 cm (F/D = 0.6)
Aperture angle	38.6 deg.

Fig. 3. Fabricated dual-polarization receiving antenna.

3. Measured Results

Fig. 4 shows the measured results of the VSWR. The red box indicates the 12-GHz band. The VSWR was less than 1.4 in the target range of the frequency band. Fig. 5 shows the measured radiation patterns of the fabricated antenna. The calculated patterns and the reference patterns in Rec. ITU-R BO.1213 (BO.1213) [4] are also shown in these figures. The antenna gain and the XPD were 34.5 dBi (i.e., the aperture efficiency was 69 %) and 28.7 dB (at 0 deg.), respectively. Measured results showed that the fabricated antenna complied with our requirements. The measured co-polarization radiation patterns slightly exceeded BO.1213; therefore, we will improve the sidelobe characteristics by changing the element spacing of the array.

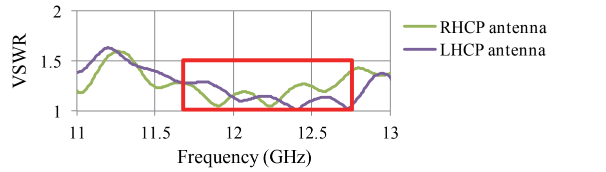


Fig. 4. Measured VSWR of fabricated antenna.

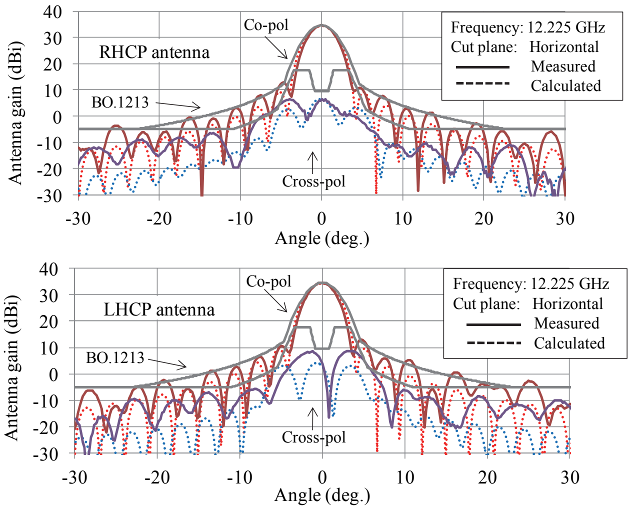


Fig. 5. Measured radiation patterns of fabricated antenna.

4. Conclusion

We manufactured and tested a dual-circularly polarized parabolic reflector antenna for the 12-GHz (11.7 to 12.75 GHz) band satellite broadcasting reception. The antenna has a feed antenna composed of a 2 × 2 microstrip antenna array. Measured results confirmed that the fabricated antenna complied with our requirements, with voltage standing wave ratio of less than 1.4, antenna gain of 34.5 dBi (i.e., the aperture efficiency was 69 %) and cross polarization discrimination of 28.7 dB. In the future, we will improve the sidelobe characteristics.

References

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