12/21GHz Dual-band Feed Antenna for Satellite Broadcasting Receiving Reflector Antenna

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1. Introduction

The International Telecommunication Union (ITU) has allocated 21.4 to 22.0GHz (21-GHz band) to the broadcasting satellite service (BSS) for Regions 1 and 3. Because of its wide bandwidth, satellite broadcasting in this band is expected to transmit large-capacity signals such as those for ultra high definition TV [1, 2]. We assume a 21-GHz-band broadcasting satellite whose orbital position is 110 degrees east, which is the same position as that of the satellite for the 12-GHz-band BSS currently used in Japan. We have been developing the 12/21-GHz dual-band parabolic reflector antenna that enables reception of broadcast services provided over these two different frequency bands with a single reflector antenna.

This paper describes the configuration and the characteristics of the designed 12/21-GHz dual-band feed antenna. To achieve high gain in both bands, the edge illumination level (EIL) of the feed antenna in the 21-GHz band must be the same power level to that in the 12-GHz band. We evaluated the designed feed antenna with a particular focus on the voltage standing wave ratio (VSWR) and the EIL. The VSWR was less than or equal to 1.5 throughout the target range in both bands, and the EIL of the 21-GHz band was almost the same power level to that in the 12-GHz band. As a result of computing the radiation pattern for the parabolic reflector antenna fed by the designed feed antenna, the aperture efficiencies were 68 % and 70 % for the 12- and 21-GHz band, respectively.

2. Design of Dual-band Feed Antenna

2.1 Requirements for Dual-band Feed Antenna

Table 1 shows the requirements for the 12/21-GHz dual-band feed antenna. The receiving frequency is 11.7-12.75 GHz (currently used in Japan for the 12-GHz-band BSS) and 21.4-22.0 GHz (for the 21-GHz-band BSS). The dual-band feed antenna should have the separated output port for each band. We assumed the polarization of the 21-GHz-band BSS was right-hand circular polarization (RHCP), which is the same as that of the 12-GHz-band BSS in Japan. To receive small signals from the satellite, the upper limit of VSWR is 1.5 throughout the target range in both the 12- and 21-GHz bands.

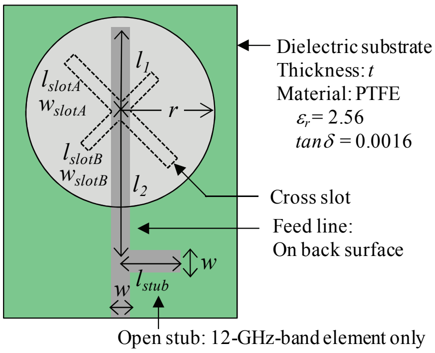
A horn antenna is generally used for satellite broadcasting receiving reflector antenna. Usually, the EIL of the reflector antenna is optimized with the aperture of the feed horn antenna. However, the suitable aperture of the 21-GHz-band horn antenna is narrower than that of the 12-GHz-band one. It is difficult to achieve a suitable beamwidth with a common feed horn for both the 12- and 21-GHz bands. Therefore, we chose the layered structure of the 2 x 2 microstrip array antenna to control the beamwidth for each band individually. The aperture angle of the typical receiving reflector antenna is 46 degrees. The upper limit of the mutual coupling level between elements is -20 dB as the standard value to decide the spacing of the microstrip elements.

Table 1: Requirements for dual-band feed antenna

Receiving frequencies	11.70-12.75 GHz, 21.40-22.00 GHz
Polarization of the feed	Left-hand circular
VSWR	≤ 1.5
EIL	-10 dB for 12/21 GHz (at 46 deg.)
Mutual coupling level between elements	$\leq$ -20 dB
Impedance	50 Ω

2.2 Structure of Designed Dual-band Feed Antenna

Figure 1 shows the geometry of the microstrip elements. The elements, which have circular disks loaded with a cross-slot of unequal slot length, are operated as circular polarized antennas. The substrate thickness was maximized to $\lambda_\varepsilon/16$ to increase the impedance bandwidth, where λ_ε is the wavelength in the dielectric [3]. The upper limit of the substrate thickness is decided by the 21-GHz-band element when the elements of both bands are configured on the same substrate plane. Therefore, the thickness of the 12-GHz-band element was maximized by using a stacked substrate (see Figure 2). The 12-GHz-band element has an open stub for impedance matching.



Unit (mm)	12-GHz-band element	21-GHz-band element
t	0.9	0.5
r	3.55	1.86
w	0.5	0.5
l_{slotA}	5.8	3.0
w_{slotA}	0.3	0.3
l_{slotB}	$l_{slotA}/\sqrt{2}$	$l_{slotA}/\sqrt{2}$
w_{slotB}	w_{slotA}	w_{slotA}
l_1	2.0	1.5
l_2	5.3	
l_{stub}	1.7	

Figure 1: Geometry of microstrip elements

Figure 2 shows the layer configuration of the designed feed antenna. The 2 x 2 microstrip array was composed on the stacked substrate for each band and was sequentially rotated in order to enhance the polarization purity [4]. The feeding phase of the mth patch was shifted to $\pi(m-1)/2$. When both the beamwidth and the mutual coupling were considered, the spacing of elements was 0.55 wavelengths (the spacing was 13.5 mm for 12-GHz-band elements and 7.6 mm for 21-GHz-band elements). The mutual coupling level is described in the following section.

3. Simulation Results of the Designed Antenna

3.1 VSWR

Figure 3 shows the VSWR of the designed dual-band feed antenna, which was less than 1.5 throughout the target range in both the 12- and 21-GHz bands. The fractional bandwidth was 8.8 % and 7.6 % for the 12- and 21-GHz band, respectively.

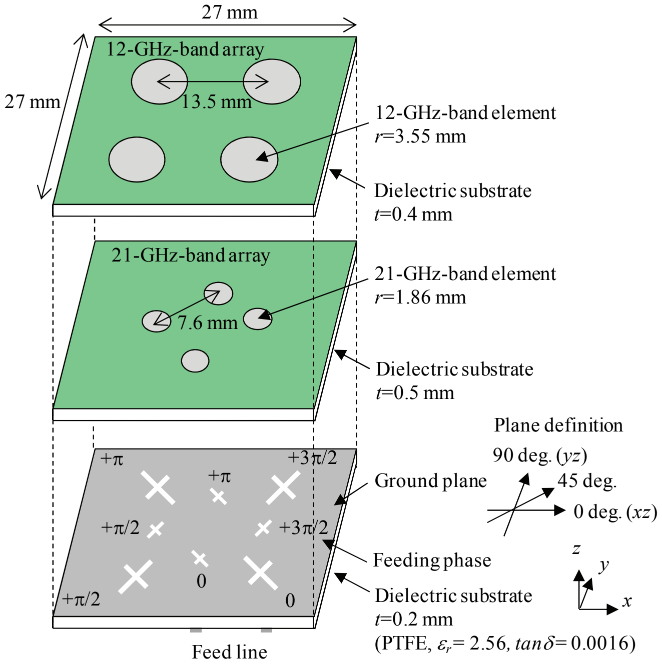
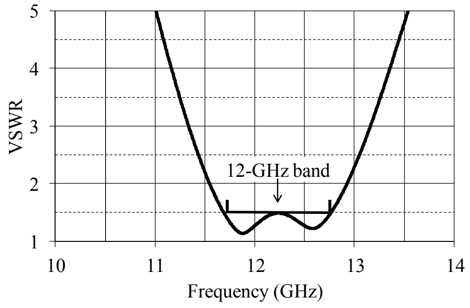
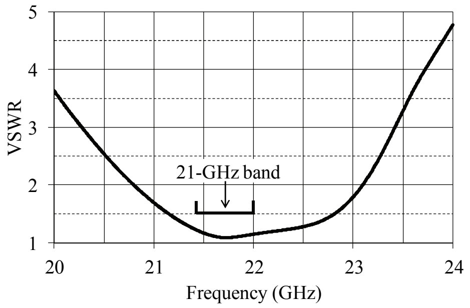


Figure 2: Layer configuration of designed antenna



(a) 12-GHz band



(b) 21-GHz band

Figure 3: VSWR of designed antenna

3.2 Mutual Coupling Level between Elements

Figure 4 shows the worst mutual coupling level between the elements. To simplify the study, we supposed that the spacing of the 12-GHz-band elements was equal to that of the 21-GHz-band elements in the wavelength-ratio. The mutual coupling level (in dB) was in inverse proportion to the spacing of the elements. The spacing, where the mutual coupling value was under -20 dB, was 0.55 wavelengths. Therefore, we chose 0.55 wavelengths for the spacing of the elements.

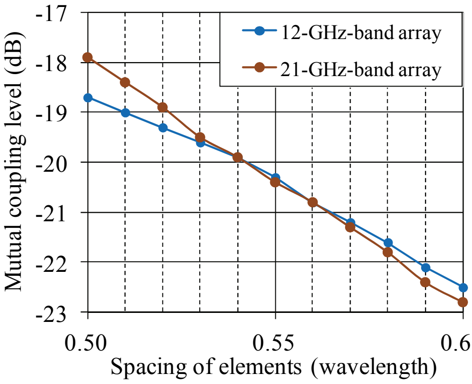
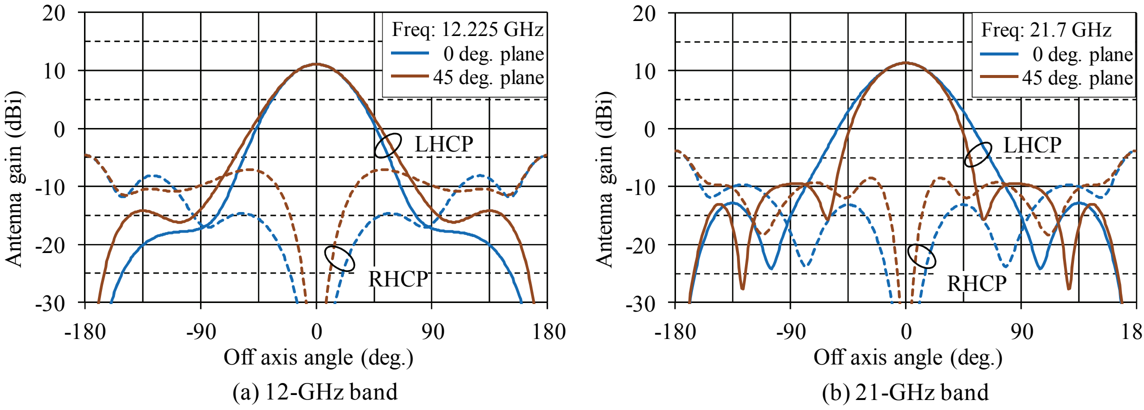


Figure 4: The worst mutual coupling level

3.3 Radiation Pattern of Dual-band Feed Antenna

Figure 5 shows the radiation patterns of the designed feed antenna. The plane definition is indicated in Figure 2. The radiation pattern was calculated at the center frequency of each band. The peak gain was 11.1 dBi and 11.3 dBi for the 12- and 21-GHz band, respectively. For the 12-GHz band, the EIL was -10.8 dB and -9.5 dB for the 0-degree plane and 45-degree plane, respectively. For the 21-GHz band, the EIL was -8.7 dB and -12.9 dB for the 0-degree plane and 45-degree plane, respectively. The 45-degree-plane beamwidth of the 12-GHz band was almost the same value to the 0-degree-plane beamwidth of the 21-GHz band since the 12-GHz-band array and the 21-GHz-band array corresponded to 45-degree rotation. The cross polarization (RHCP) was suppressed by using the sequentially rotated array technique.



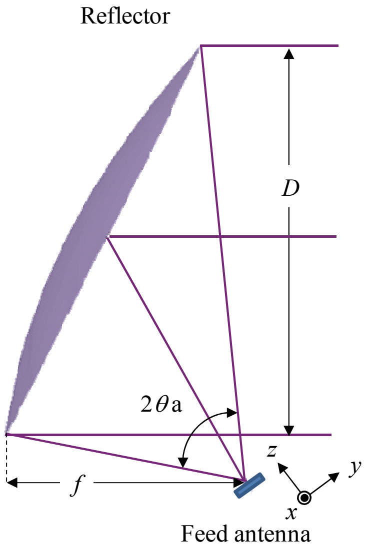
(a) 12-GHz band

(b) 21-GHz band

Figure 5: Radiation pattern of designed feed antenna

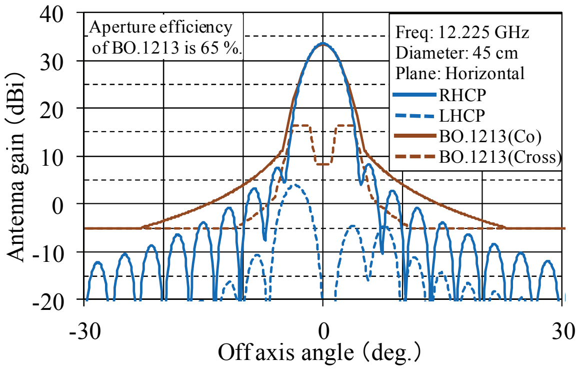
3.4 Radiation Pattern of Parabolic Reflector Antenna

We assumed an offset parabolic reflector antenna for the dual-band antenna. The reflector antenna is shown in Figure 6, and the dimensions are the measured data of a commercial parabolic antenna used for receiving the 12-GHz-band BSS in Japan. Figure 7 shows the results of the calculations for the radiation pattern of the reflector antenna fed by the designed dual-band feed antenna. The frequencies of 12.225- and 21.7-GHz were the center frequencies of each band. The gains of the reflector antenna were 33.6 dBi and 38.7 dBi for the 12- and 21-GHz band, respectively. Therefore, the aperture efficiencies were 68 % and 70 % for the 12- and 21-GHz band, respectively. The radiation patterns of the reflector antenna complied with the reference patterns recommended by ITU-R BO.1213 (for the 12-GHz band) and ITU-R BO.1900 (for the 21-GHz band) [5, 6].

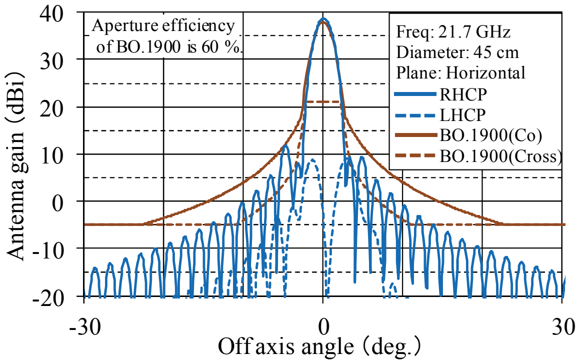


Diameter D	450 mm
Aperture angle θa	46 deg.
Focal length f	212 mm
f/D	0.47

Figure 6: Parabolic reflector antenna



(a) 12-GHz band



(b) 21-GHz band

Figure 7: Radiation pattern of offset parabolic reflector antenna fed by designed feed antenna

4. Conclusion

We designed a 12/21-GHz-band feed antenna applying a circularly polarized microstrip array antenna for satellite broadcasting receiving antenna. Simulation results show that the VSWR was less than 1.5 throughout the target range in both bands and the beamwidth of the 12-GHz band was almost the same value to that in the 21-GHz band. We computed the radiation pattern of the parabolic reflector antenna fed by the designed feed antenna; the aperture efficiencies were 68 % and 70 % for the 12- and 21-GHz band, respectively. The reflector antenna with the designed feed antenna was confirmed to have reception compatibility for both bands. In the future, we will manufacture a dual-band feed antenna and evaluate its performance in the 12/21-GHz-band.

References

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