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SIMPLE SATELLITE TRACKING PATCH ARRAY ANTENNA FOR ETS-VIII APPLICATIONS AND OUTDOOR EXPERIMENTS USING A PSEUDO SATELLITE

Toshimitsu TANAKA[1], Josaphat Tetuko S.S.[2], Koichi ITO[1], Hiroyuki YOSHIMURA[3]
David DELAUNE[1], Daisuke ISHIDE[3], Kenichi ISHIGE[3],
Amane MIURA[4], and Shin-ichi YAMAMOTO[4]

[1] Graduate School of Science and Technology, Chiba University
[2] Center for Frontier Electronics and Photonics, Chiba University
[3] Faculty of Engineering, Chiba University
1-33 Yayoi-cho, Inage-ku, Chiba, 263-8522 Japan

[4] Kashima Space Research Center, Communications Research Laboratory
Hirai 893-1, Kashima, Ibaraki, 314-8501 Japan
[1] toshi-tanaka@graduate.chiba-u.jp [4] amane@crl.go.jp

1. Introduction

The Japan Aerospace Exploration Agency (JAXA) plans to launch a geostationary satellite called Engineering Test Satellite-VIII (ETS-VIII). ETS-VIII will conduct orbital experiments on mobile satellite communications aiming at multimedia applications at the S-band frequency, especially to support the development of a technology for digital mobile communications, such as phones, broadcasting, faster disaster relief, etc [1]. One of the experimental purposes is the development of a technology enabling the transmission and reception of multimedia information such as voice and images by use of the geostationary satellite for land vehicle systems. A small and light antenna having a high gain value on a wide angular range is desired although the required specifications depend on the services and systems available. Up to now, several antennas able to meet these demands have been extensively investigated [2],[3], and are available in the literature. Among them, the tracking beam antennas can be found. The beam generated by satellite tracking systems is always directed towards the satellite direction even when the azimuth of the vehicle station changes. Therefore, such antennas have the possibility to reach a relatively high gain as compared to the omni-directional antennas such as conical beam antennas.

In this research, a simple satellite tracking 4-element patch array antenna with four electronically-steered beams has been developed. This antenna does not require a phase shifter and the beam is switched by use of a simple "ON" and "OFF" feeding control. Therefore the size and fabrication cost can be reduced. In addition, the outline and results of outdoor experiments using the 4-element patch array antenna mounted on a test vehicle, and a pseudo satellite are presented.

2. Specifications and targets

Table 1 shows the specifications and targets of the antenna for mobile satellite communications aiming at ETS-VIII applications. Here, a thin miniaturized antenna designed for a few hundred kbps data transfer (gain 6 dBic) is analyzed. In addition, the measurements are assumed to take place in the center of Tokyo. As a result, the targeted elevation angle El is set to 48°. In this research, the operating frequency is fixed to 2.5025 GHz (for reception).

3. 4-element patch array antenna

Figure 1 shows the structure of the simple satellite-tracking antenna. The fabricated antenna using a conventional substrate (relative permittivity: 2.17 and $\tan\delta$: 0.00085) is shown in Fig. 2. In order to generate a circular polarization, the antenna is constituted of single-fed square patches with truncated corners. The elements of the antenna are sequentially rotated of 90° so that the feeding sources are internally located. Finally, parasitic elements are used and a stacked configuration with two layers is chosen in order to improve the gain [4]. Regarding the beam switching, the operation can be easily

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understood from Fig. 3. The switching is realized by successively turning off any of the feeding sources of patches no. 1 to no. 4. In this case, the direction of the created beam is shifted in the azimuth plane of -90° from the element that is turned off for a left-handed circularly polarized antenna. For example, if patch no. 4 is turned off, a wide beam will be created in the direction Az = 270°. Switching all the four beams in the conical-cut plane for each element can therefore scan the whole azimuth range. As for the selection of the direction of the satellite, a method of calculation based on information such as car navigation system, gyro, etc. can be used. Figure 4 shows the radiation characteristics of the antenna in the elevation plane when patch no. 4 is off. Full line, dotted line represent the results obtained by measurements in the radio anechoic chamber of the Graduate School of Science and Technology, Chiba University, Japan, and by simulation using the Method of Moment (Ansoft Ensemble Ver. 8), respectively. This figure shows the direction of maximum radiation occurs when El = 64° for the measurements.

Figure 5 shows the gain characteristics of the beam switching (measurement). By successively turning off any one of the patches, it is shown that four beams are generated in the conical-cut plane at Az = 6°, 96°, 190°, and 276°. Furthermore, the gain can reach more than 6.4 dBic on the whole azimuth range for an elevation El = 48°.

4. Outdoor experiments using a test vehicle and a pseudo satellite

In order to check the actual radiation performances of the developed antenna applied to mobile satellite communications, outdoor experiments were done. Figure 6 illustrates the outline of these experiments. In these experiments, the pseudo satellite was placed on the roof of a building at Chiba University. The antenna that has been presented in section 3 was mounted on a test vehicle with measurement systems (see Fig. 7). A main lobe of the antenna was generated in the direction of Az = 270° (patch no. 4 off). The received power level on an elevation range El = 38° - 58° was measured while the test vehicle moved away from the building. Figure 8 shows the photograph of the experiments situation. Table 2 shows the assumed and measured link budget for the downlink. The measured data representing the relationship between received power and elevation angle is shown in Fig. 9 along with the calculation data. Both are normalized by the maximum value of calculation data at an elevation angle El = 58°. The calculation data is determined from an equation relating the transmission power, the transmission antenna gain (cavity backed spiral antenna), the path loss, the reception antenna gain (4-element patch array antenna) by use of Method of Moment and the LNA gain. According to this figure, the measurements are in quite good agreement with calculation. However, the measurements value is decreased of 1~3 dB on the elevation range 46°~52°. This phenomenon is due to the influence of the reflection from the buildings around the measurements site. Therefore this fact will be investigated by including the environment condition in the next step. Figure 10 shows the experimental results of relating received power and azimuth angle for El = 48°. Although these measurements value is decreased of 1~3 dB as in Fig. 9, measurements are in quite good agreement with the calculation.

5. Conclusions

In this paper, a simple satellite-tracking array antenna for mobile satellite communications aiming at ETS-VIII applications has been discussed. The analyzed circularly polarized stacked antenna is constituted of four single-fed patches sequentially rotated of 90°. By successively turning off any one of the patches, it is shown that four beams are created in the conical-cut plane at Az = 6°, 96°, 190°, and 276°. Furthermore, the gain can reach more than 6.4 dBic on the whole azimuth range for an elevation El = 48°in Tokyo. Outdoor experiments using the developed antenna mounted on a test vehicle and a pseudo satellite are presented. In the next step, the improvement of the gain performances at low elevation angle, investigation of a dual-frequency antenna, outdoor experiments and mobile satellite communication experiments using ETS-VIII will be held.

6. Acknowledgement

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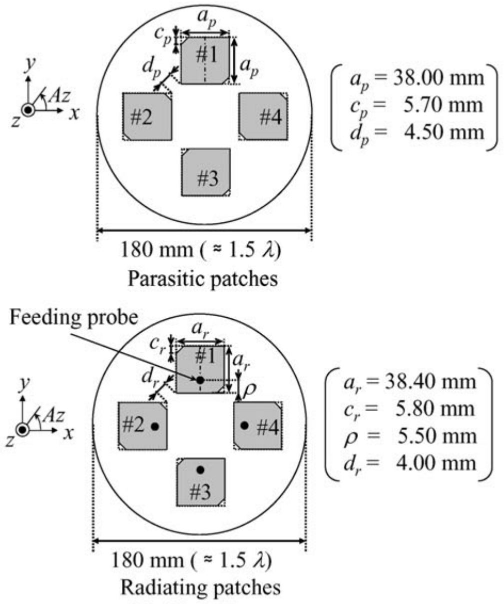
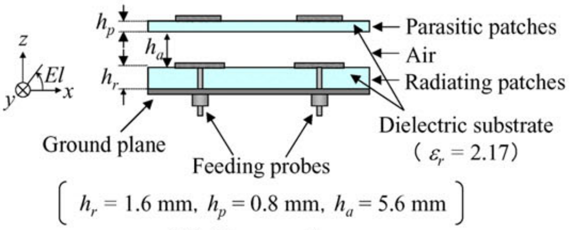
Table 1 Specifications on the antenna for mobile satellite communications (Engineering Test Satellite - VIII).

Specification		
Frequency bands	Transmission (Tx)	2655.5 to 2658.0 MHz
	Reception (Rx)	2500.5 to 2503.0 MHz
Polarization	Left-Handed Circular Polarization (for transmission and reception)	
Target		
Angular ranges	Elevation angle (*El*)	48° (Tokyo)
	Azimuth angle (*Az*)	0° to 360°
Minimum gain		6 dBic
Maximum axial ratio		3 dB



(a) Top view



(b) Cross section

Fig. 1 Configuration of the antenna.

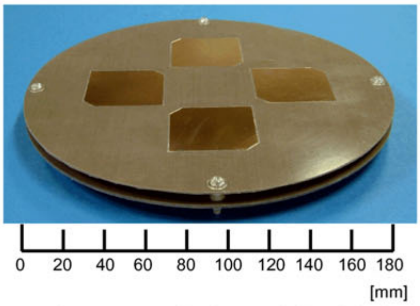


Fig. 2 The External view of the fabricated antenna.

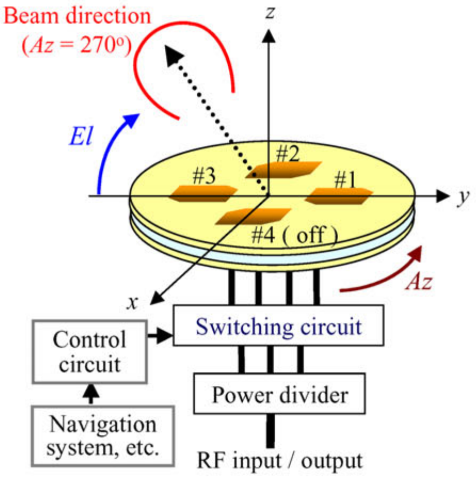


Fig. 3 Outline of the system.

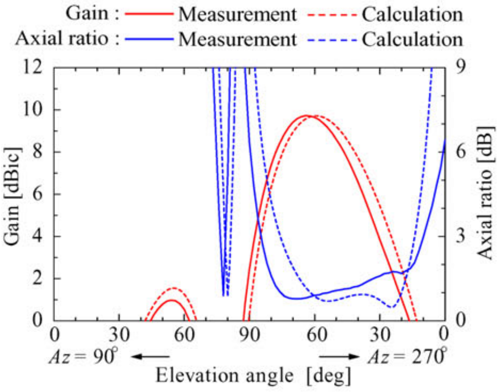


Fig. 4 Radiation characteristics in the elevation plane.

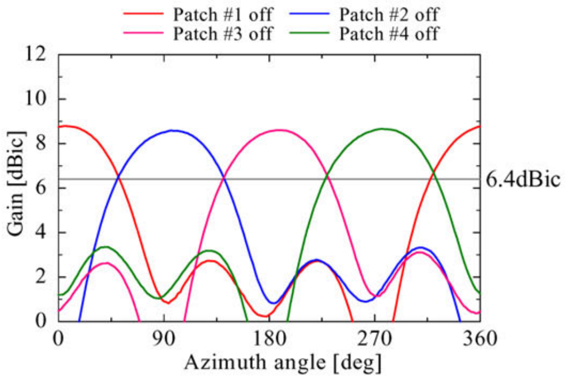


Fig. 5 Radiation characteristics in the conical-cut plane ($El = 48°$, measurements).

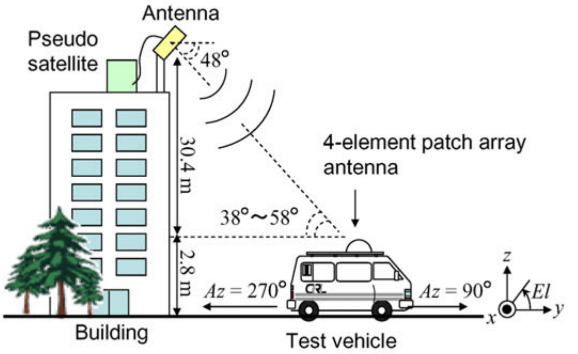


Fig. 6 Outline of the outdoor experiments.

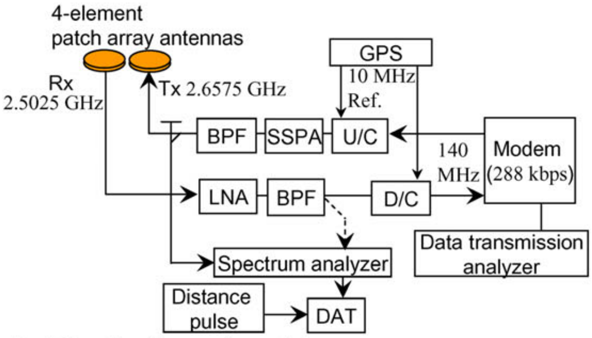


Fig. 7 The Configuration of the measurement system.

Pseudo satellite

4-element patch array antennas (Tx and Rx)

Fig. 8 Photograph of the outdoor experiments.

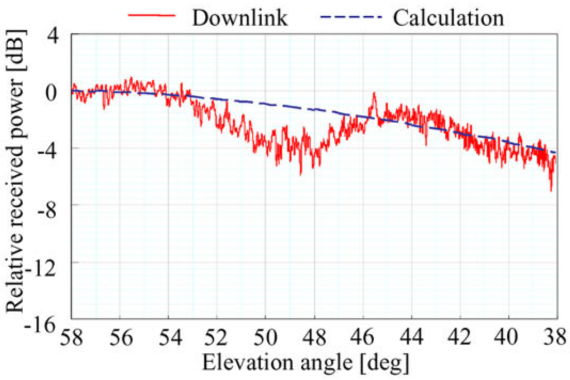


Fig. 9 The Relationship between received power and elevation angle.

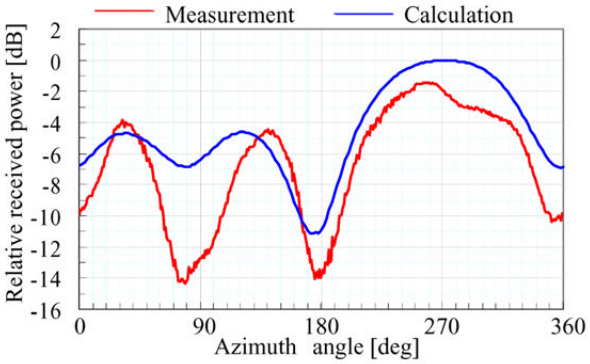


Fig. 10 The Relationship between received power and azimuth angle.

Table 2 Link budget.

	Unit	Assumed link using ETS-VIII	Measurement value
Frequency	GHz	2.5025	2.5025
Transmission power	dBW	16.99 (50W)	-42.5
Feeding loss	dB	1.8	18.0
Tx antenna gain	dBi	40.40	0.30
EIRP	dBW	55.59	-60.20
Distance	km	37207.83	0.041
Path loss	dB	191.8	72.67
Polarization mismatch loss	dB	0.2	-
Fading margin	dB	2.50	-
G/T (measurement)	dB/K	-17.60	-17.60
C/N_0	dBHz	72.09	75.80