Simple Switched-Beam Antenna System for Mobile Satellite Applications

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Introduction

The Japan Aerospace Exploration Agency (JAXA) has been developing Engineering Test Satellite (ETS-VIII) mission technology, which is one of the largest geostationary S-band satellites in the world to meet future requirements of mobile communications. The mobile communication technologies adopted by ETS-VIII are expected to benefit our daily life in the field of communications, broadcasting, and global positioning. In the end of 2006 year, ETS-VIII satellite has been successfully launched [1].

Various antenna systems for land mobile satellite have been developed with some kind of methods, either mechanical method [2] or electronic method using closed-loop [3] and opened-loop control [4]. However, their antenna systems were huge and weighty. To minimize a bulky system, a patch array antenna for land mobile system has been developed aimed at ETS-VIII [5]. The performances of the antenna [5] have been experimented outdoor by use of a pseudo-satellite station.

In this paper, a configuration of antenna system for land mobile system using GPS and gyroscope terminal unit as automatic-navigation system to track the ETS-VIII satellite is proposed. To miniaturize the antenna system, an electronically tracking is used rather than mechanically by use of a developed control program. With this configuration the antenna system becomes light and low profile with more in reliability and high-speed beam scanning possibility. In this research, a left hand circularly polarized array antenna integrated with an onboard switching circuit is proposed. Measured results of return loss, axial ratio and beam switching characteristics are presented.

Antenna Specifications and Targets

The specifications and targets of the antenna are shown in Table 1. ETS-VIII is conducted at orbital experiments on mobile satellite communications and high-speed packets communications, providing voice/data communications with hand-held terminals in the S-band frequency (2.5025 GHz and 2.6575 GHz for reception and transmission, respectively). The polarization is left-handed circular (LHCP) for both transmission and reception units. As this antenna is assumed to be used in Tokyo and its vicinity, the targeted elevation angle is set to 48°

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because it is the elevation angle of the geostationary satellite seen from the center of this city. In addition, the antenna should cover the whole azimuth space.

Antenna and System Configuration

Fig.1 shows a satellite-tracking system built with the beam switching method. As shown in this figure, the localization of the satellite is determined, based on the location and traveling direction of the mobile station by use of currently available car navigation systems and gyro, and the appropriate beam direction is selected. Then the signal emitted by the tracking unit is received and by appropriately controlling the activation of the feedings of each element, through the switching circuit used to control the feeding of the antenna, the beam is switched in three directions in the azimuth plane and the satellite can be followed.

Structure of the proposed array antenna is shown in Fig.2. The array antenna is composed of three pentagonal patch antennas which excited directly from the feeding network on the beneath of the construction. In the top of the construction is laid three isosceles triangular patches as parasitic elements in order to enhance bandwidth of the antenna. To match with 50Ω input feed, air gap is inserted at the area between the fed elements and the parasitic elements. The design makes possible the excitation of two near-degenerate orthogonal modes of equal amplitudes and 90° phase difference for left-handed circular polarization (LHCP) operation.

Antenna System Measurement

The measured antenna gives good return loss at the target frequency 2.5025 GHz. The impedance bandwidth ($|S_{11}| < -10$ dB) is about 9.5% as shown in Fig.3. Fig.4 shows the axial ratio is below 3 dB at frequency 2.5025 GHz for an elevation angle $El = 48°$. Moreover, the 3 dB axial ratio bandwidth gives about 1.6%.

In the system measurement, the transmitting (Tx) antenna is supposed to be a satellite and the developed antenna (as a receiving antenna) as though mounted on the rooftop of car while it is traveling and turning on the road, as described in Fig.5. Here, the capability of the antenna to switch automatically its beam pursuing Tx antenna is examined.

Fig.6 shows the beam switching characteristics of the antenna which can be manually and automatically switched. It is shown that the characteristics of each beam do not change drastically when the radome and ground plate are employed (Fig.6(b)) compared to the only antenna structure (Fig.6(a)), except the axial ratio because the scattering from the ground plate affects the incident phase onto the antenna. The effect of used radome is considerably neglected since a hemisphere shape gives minimum scattering and its thin material provides less loss. From Fig.6, it can be stated that the proposed system can control the beam of the antenna automatically in the azimuth direction which the gain more than 5 dBic and the axial ratio less than 3 dB, although when radome and ground plate employed the axial ratio rises 0.5 dB higher.

Conclusion

Antenna system for land vehicle communications aimed at ETS-VIII applications was proposed. The proposed antenna system consists of an array antenna loaded with switching circuit onto which controlled by a developed program after receiving data input from gyro sensor of GPS unit. As a result, for an elevation angle *El* = 48°, three beams are electronically created in the azimuth direction with a minimum gain more than 5 dBic and an axial ratio less than 3 dB. In addition, the antenna beam could be automatically switched with good results.

Acknowledgement

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Table 1 Specifications and targets for ETS-VIII applications

SPECIFICATIONS		
Frequency bands	Transmission	2655.5 MHz to 2658.0 MHz
	Reception	2500.5 MHz to 2503.0 MHz
Polarization	Left-handed circular polarization for both transmission and reception	
TARGETS		
Elevation angle *(El)*	48^{o} (Tokyo)	
Azimuth angle *(Az)*	0^{o} to 360^{o}	
Minimum gain	5 dBic	
Maximum axial ratio	3 dB	

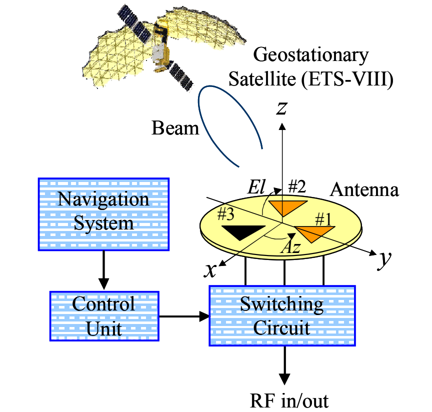


Fig.1. Antenna system configuration

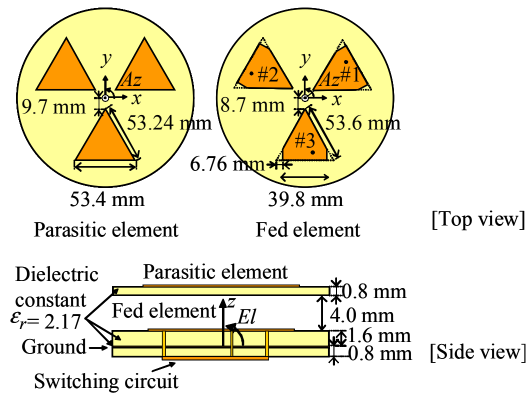


Fig.2. Structure of proposed antenna

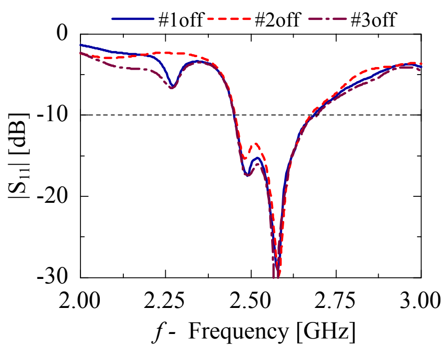


Fig.3. S parameter

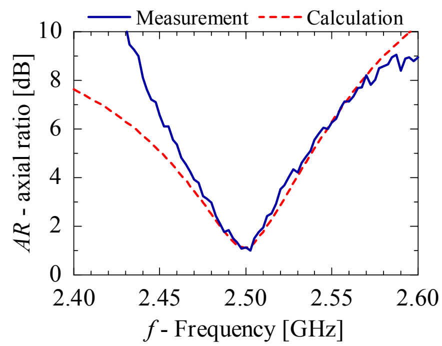


Fig.4. Axial ratio characteristics

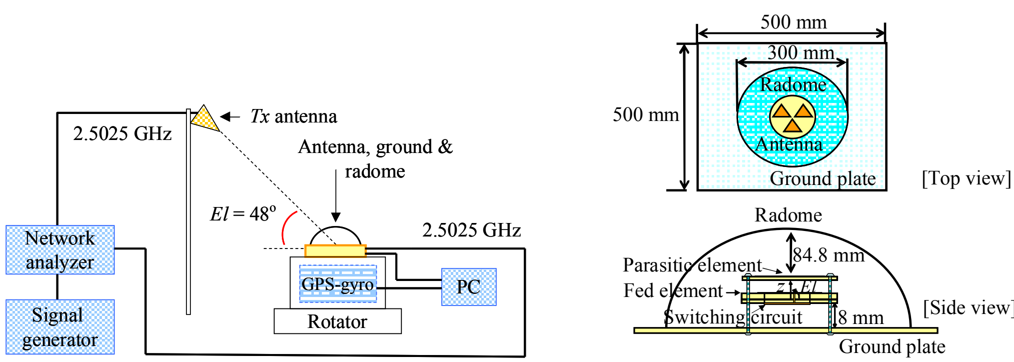
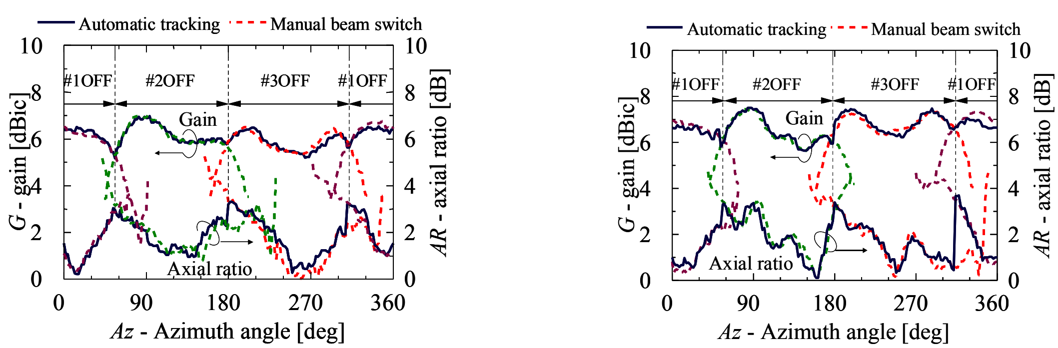


Fig.5. Antenna system experiment configuration



(a) (b)

Fig.6. Switchable-beam characteristics of the antenna:
(a) with no ground and radome (b) with ground and radome