電子的なビーム切り換えのための追尾型アレーアンテナシステムの開発

Development of electronically beam-steerable array antenna system

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I. Introduction

The Japan Aerospace Exploration Agency (JAXA) has been developing ETS-VIII satellite mission technology, which is one of the largest geostationary S-band satellites in the world to meet future requirements of mobile communications. The ETS-VIII conducts various orbital experiments in Japan and surrounding areas to verify mobile satellite communications functions, making use of a small satellite handset similar to a mobile phone. The mobile communication technologies adopted by ETS-VIII are expected to benefit our daily life in the field of communications, broadcasting, and global positioning. Quick and accurate directions for example, can be given to an emergency vehicle by means of traffic control information via satellite in the event of a disaster [1].

In the end of 2006 year, ETS-VIII satellite has been launched successfully by the H-IIA Launch Vehicle No. 11 from the Tanegashima Space Center, in the south of Kagoshima Prefecture. The satellite has been moved to the initial functional verification phase and has been injecting into the planned geostationary orbit at an east longitude of 146° from the drift orbit [2].

Up to now, various antennas for land mobile system have been developed aimed at ETS-VIII [3]-[5]. The performances of the antenna [5] have been experimented outdoor by use of a pseudo-satellite station. Moreover, the array antenna integrated with a separately switching circuit has been experimented indoor to test the beam switching mechanism of the array antenna, was reported in [6].

In this paper, a configuration of antenna system for mobile ground terminal using a gyroscope sensor of the Global Positioning Satellite (GPS) terminal unit as an automatic-navigation system aimed at satellite tracking of ETS-VIII is proposed. In this system, a circularly-polarized array antenna loaded with switching circuit is used. The performance of the antenna is numerically analyzed and experimentally investigated by using a Visual Basic v.6 (VB6) user interface program.

II. Configuration of Antenna System

Figure 1 depicts an antenna system configuration aimed at ETS-VIII experiment. In this configuration, data from the navigation system using GPS terminal unit is retrieved via serial cable (COM’s port) of the computer. Then, the GPS sentence data is processed in the computer by use of the VB6 applet to generate three bias voltages. These bias voltages control the onboard switching circuit to keep the generated-antenna beam is always directed to the east longitude of 146° where the ETS-VIII satellite is orbited. In this case, the switching circuit is biased according to the beam mechanism’s rule of the VB6 code program (applet), with the result that each of the antenna elements is fed correctly. Notebook PC is used in order to ease the connection in the antenna system because the devices construction is possibly connected and removed independently.

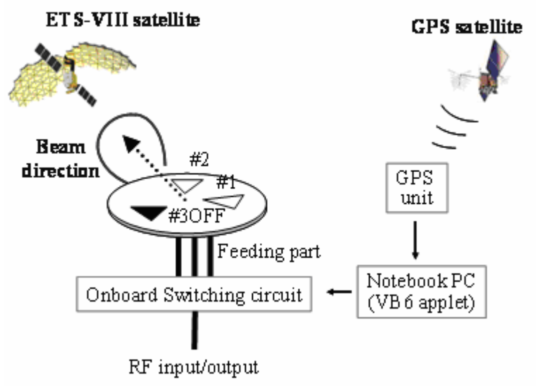

Figure 1. Configuration of the antenna system aimed at ETS-VIII experiment.

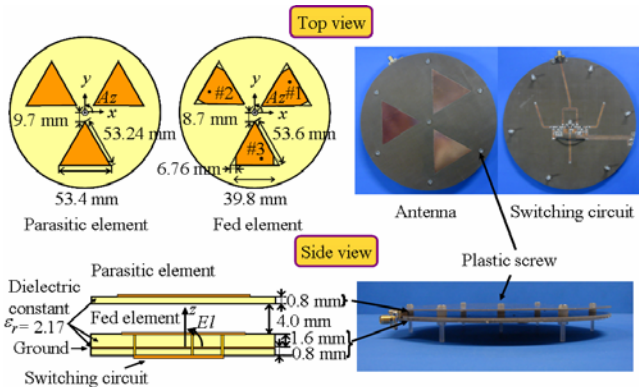

Figure 2. Geometry of array antenna loaded with switching circuit.

III. Indoor Experiment

In this research, the array antenna performance is evaluated in the indoor experiment. To set up the indoor measurement, three main components are used i.e. the array antenna attached with switching circuit, GPS unit with gyro sensor, and VB6 applet as user interface to control the switching circuit from the notebook computer.

A. Geometry of array antenna

Geometry of the antenna is shown in Figure 2. The antenna is composed of three pentagonal patch antennas which fed directly from the switching circuit on the beneath of the construction. In the top of the construction is laid three triangular patches as parasitic elements. With this geometry the antenna becomes simple, compact and low loss, because no need a power divider to distribute power signal to the antenna element. The dimension of the construction is 160 mm and 7.2 mm in diameter and height, respectively.

B. GPS unit with gyro sensor

The gyro sensor data of the GPS is acquired and processed in the VB6 program to yield the bias voltages by which the performance of the switching circuit can be controlled. The acquired gyro sensor data is a direction of the GPS bulk unit. Here, with 0° of the north way reference, the direction increases while moving around in clockwise rotation. For example, 90°, 180°, and 270° means east, south, and west, respectively. To simplify the circumstance of the measurement, the direction way is regarded same as the azimuth angle *Az*.

C. User interface

In the experiment, a VB6 application program is used to control the switching circuit in the antenna system. The applet is made to perform easily the experiment and to control automatically the beam of the antenna.

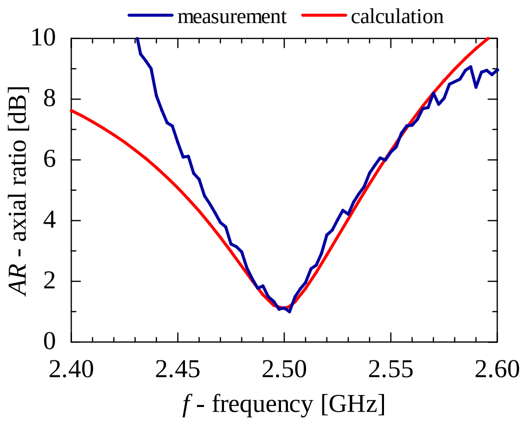

Figure 3. Frequency characteristics performance of the array antenna.

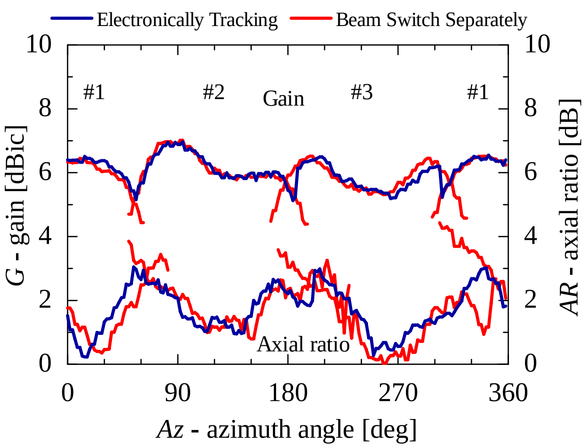

Figure 4. Beam switching mechanism: by switching each beam separately and by use of the VB6 applet for electronically switching.

IV. Experiment Result

A key feature of the developed array antenna is the beam of the antenna can be generated towards a certain azimuth direction electronically using an ON-OFF mechanism. This paper provides the performance of the antenna not only covering the gain and the axial ratio in the whole of azimuth angles as well as the beam can be switched smartly orientated to the transmitting antenna.

Figure 3 describes the frequency characteristic of the antenna when element #1 is switched OFF at the target elevation angle *El*=48°. The minimum axial ratio occurs exactly at the target frequency 2.5025 GHz with 0.9 dB, meets to the calculation result.

The beam of the antenna is generated by a mechanism that consists of switching OFF one of the radiating elements. By considering the mutual coupling between fed elements, their phase and distance, the beam direction can be varied. Theoretically, the generated beam is shifted of -90° in the conical-cut direction from the element that is switched OFF, in the case of a LHCP antenna. For example, when Rx element 1 (refers to Figure 2) placed at *Az* = 90° is switched OFF, the beam is theoretically directed toward the azimuth angle *Az* = 0°. The other two beams can be generated in the same manner, switching each element OFF successively (Rx2 and Rx3 is switched OFF, each beam is directed to *Az* = 120° and 240°, respectively).

As we discussed aforementioned, the antenna generated the beam in three states to cover the whole of the azimuth angles. Figure 4 describes the beam switching mechanism performance of the antenna at *El*=48° in the target frequency 2.5025 GHz. By switching each beam separately (Figure 4, red solid-line) the gain and the axial ratio meet the target more than 5 dBic and 3 dB, respectively, for the whole of the azimuth angles. To examine the tracking performance, here, the antenna electronically switched in order to cover the whole of the azimuth angles with the gain more than 5 dBic and the axial ratio less than 3 dB. It is shown in Figure 4 (blue solid-line) that the variation of the gain value more than 5 dBic and the axial ratio less than 3 dB in the azimuth direction is confirmed.

V. Conclusion and Future Work

A configuration of an antenna system for land vehicle communications aimed at ETS-VIII applications is proposed. The configuration of antenna system uses a gyroscope sensor of the GPS unit as an automatic-navigation system is presented. The proposed antenna system consists of an array antenna loaded with switching circuit onto which controlled by a VB6 applet. Then, the array antenna is experimentally performed in the indoor measurement, is confirmed. As a result, for an elevation angle *El*=48° (as assumed in Tokyo area), three beams are created in the azimuth direction with a minimum gain more than 5 dBic and an axial ratio less than 3 dB. Moreover, by use of the VB6 applet three beams of the array antenna alternatively can be switched and steered to the *El*=48° of the elevation target. In the next step, the effect of radome package and ground plate is experimentally investigated in order to prepare the real outdoor experiment.

Acknowledgment

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