Field Experiment on Simple Vehicle Antenna System using Geostationary Test Satellite

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***Abstract* — This paper presents a field experiment of simple developed antenna system for land vehicle use which was tested by use of the Japanese geostationary test satellite called the Engineering Test Satellite-VIII (ETS-VIII). The antenna system was mounted in a vehicle is compact, light weight, and promising for low cost system. The antenna system was built by a planar array antenna which has a simple tracking capability controlled by a personal computer (PC) as the vehicle's bearing from a navigation system (Global Positioning System (GPS) receiver) is updated in real time. The GPS receiver was constructed to provide accurate information of the vehicle's position and bearing during traveling. The PC was used as the control unit and data acquisition allowing the antenna-beam control as well as the retrieving of the received power levels and error rate. The antenna system was thoroughly examined in the field experiment and satisfactory results were obtained. Steadily received power levels and bit error rate (BER) while tracking the ETS-VIII satellite were confirmed. Yet, the developed system was tested in real environment constraints such as buildings, foliages, utility poles and pedestrian overpasses. The results showed blockage was confirmed. Additionally, the satellite signal was steadily received even it was examined at the inclined-road.**

***Index Terms* — Field experiment, land vehicle, ETS-VIII, antenna system, satellite-tracking.**

I. INTRODUCTION

In the previous decades, mobile communications provided by satellite systems had widely developed in a range of operational systems either for domestic or global communications purposes. Most of them are developed for voice, data, facsimile, and paging communications including for land, maritime and aircraft applications [1]. Concerning on the next technologies, the Japan Aerospace Exploration Agency (JAXA) has launched a huge geostationary test satellite called ETS-VIII in December 2006. The ETS-VIII was conducted for various experiments in Japan and surrounding areas to verify mobile satellite communications functions [2]. Additionally, the satellite communications system will help rescue efforts in disaster areas by allowing us to collect information more promptly, especially if ground communications facilities are damaged or in areas without advanced communications infrastructure such as rural and isolated areas. The satellite has 3 years mission test for field experiments. Here, we are concerning on field experiment which carried out using our developed antenna system mounted in a vehicle for confirming the validity of our developed system, particularly the quality of the received signal from the ETS-VIII satellite.

This paper provides a simple antenna system aimed at land mobile satellite communications. An active integrated patch array antenna was developed with no phase shifter circuit, realizing a light and low profile antenna system which has reliable operation and high-speed beam scanning performance. The antenna system was built by aforementioned antenna has a simple tracking capability controlled by a personal computer (PC) as the vehicle's bearing from a navigation system (Global Positioning System (GPS) receiver) is updated in real time. Here, the antenna system was installed in a vehicle and communicated with the satellite by tracking it during traveling as a concept of our system depicted in Fig. 1.

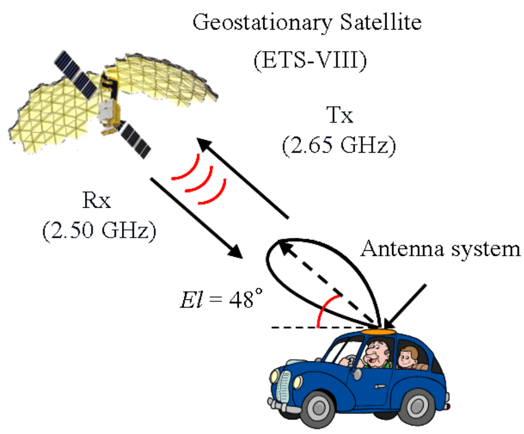


Fig. 1. Concept of antenna system aimed at vehicle communications using the satellite.

The detail of proposed system is described in Fig. 2. As for the beam-steering capability, the array antenna configuration is 120º sequentially physical rotated and set with an equal distance between each element following a circular path. With such alignment, in case each element is fed in-phase, by sequentially rotating them, their relative phase is physically shifted. Such sequential rotation ensures the generation of circular polarization. As a result, a beam is generated in the elevation direction with the direction of the created beam being shifted in the azimuth plane by -90º from the element that is turned off. By successively turning off the feeding source of each antenna element, the whole azimuth range can be scanned by step of 120º. For example, when turning off element no. 1 located in *Az* = 90º, a beam is created in the azimuth direction *Az* = 0º. Similarly, if element no. 2 and no. 3 are turned off, the beam is generated in the direction *Az* = 120º and 240º, respectively [3].

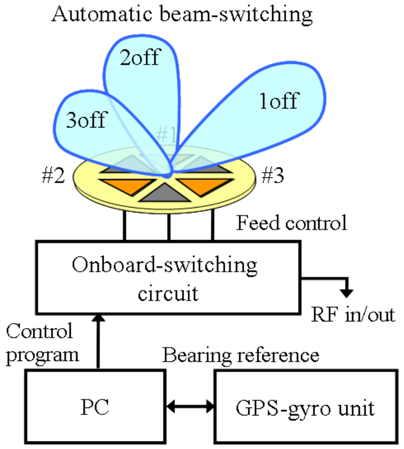


Fig. 2. Antenna system architecture which is mounted in a vehicle aimed at field experiment.

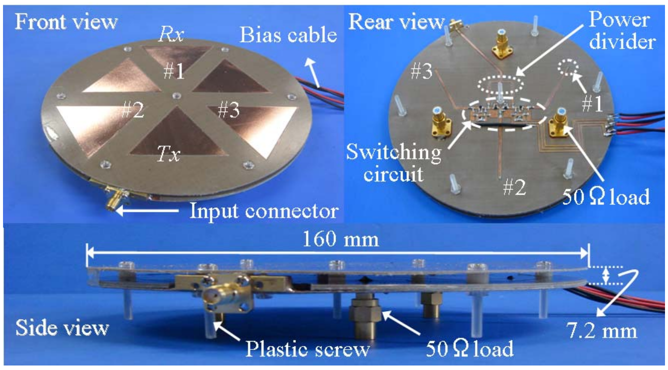


Fig. 3. Dual-band operation fabricated patch array antenna which used during field experiment.

Satellite-tracking system was created to provide a beam-steering capability for the array antenna. As illustrated in Fig. 2, the antenna system works associated with the control unit (PC), hence the tracking-algorithm is expected allowing the antenna beam automatically steered. The tracking-algorithm was simply developed regardless the signal of satellite for azimuthally-tracking. As for beam-forming of array antenna, the PC provides three bias voltages to switch on and off the P-I-N diodes of the circuit (switching circuit in Fig. 3) and thus two elements of the array are correctly fed and specified beam is created. For automatic beam switching, by considering vehicle's bearing, a control program on PC decides a correctly-generated beam among three selectable-beams. As the satellite lies at southern from Japan area, the beam is invariably controlled at the south direction [4].

The fabricated antenna is pictured in Fig. 3. It is a planar array antenna was composed of three pentagonal patch elements which excited directly from the feeding network on the beneath of the construction. In the top of the construction was put three isosceles triangular patches as parasitic elements to enhance antenna bandwidth. In order to match with 50 input feed, air gap was put in 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. Good axial ratio performance can be obtained by adjusting the feeding point, air gap height, and parasitic element dimension. In order to make compactness and to minimize the feeding losses, a power divider and a switching circuit embedded on the antenna, which is mounted on the rear of the antenna.

Due to abnormal-operation of the ETS-VIII satellite, that is impossibility for uplink connection using medium-gain antenna, we fabricated the antenna for reception of field experiment, however the antenna was actually can be operated in both transmission and reception use. For this case, each transmission patch was connected with the 50 load as pictured on rear view of Fig. 3.

In this paper, we thoroughly concerned to verify the antenna system in the field experiment using signal from the ETS-VIII satellite. We carried out the field experiment for the received power level measurement for satellite-tracking at the line of sight (LOS) environment and at the obstacles area such as buildings, roadside-trees, utility poles and pedestrian bridge in urban area. Moreover, a simple data communication experiment was performed to confirm the link quality of our antenna system.

II. EXPERIMENT SETUP OF THE MEASUREMENT

According to the report [5], the Large Deployable Reflector (LDR) antenna of ETS-VIII satellite could not be used due to improper situation at Power Supply of Low Noise Amplifier (PS-LNA). For this reason, the field experiment was conducted by using High Accuracy Clock (HAC) receiving antenna with gain 25 dBi instead of 43.80 dBi of LDR antenna. Therefore, the current experiment system was constructed for forward link from the transmission (fixed-earth station) to the reception (vehicle) through the ETS-VIII satellite even though the link budget was actually calculated in both forward and return link [6]. In this case, at the transmission side we boosted the transmitted signal by using a 22.40 dBi-gain parabola antenna (Fig. 4). We measured the received power level and bit error rate (BER) at the reception side. The received power level was measured from intermediate frequency (IF) output from handset terminal. The measurement circumstance is described in Fig. 4. With an interface board the bit error rate (BER) also could be measured.

According to the calculated link budget [6], the total C/N_0 47.64 dBHz and required C/N_0 45.83 dBHz, so thus the communication between transmitter and receiver through the ETS-VIII satellite could be established with margin 1.81 dB. In addition, we performed the field experiment with built-in correction code at the receiver (handset) for 8 kbps data rate. The field experiment was conducted in some different areas i.e. in line of sight area and blockage (such as buildings, towers, utility poles and foliages) area namely in urban area. The measurement was carried out by mounting the planar antenna on the vehicle's roof and setting the system inside. The field experiment circumstance is represented in Fig. 5.

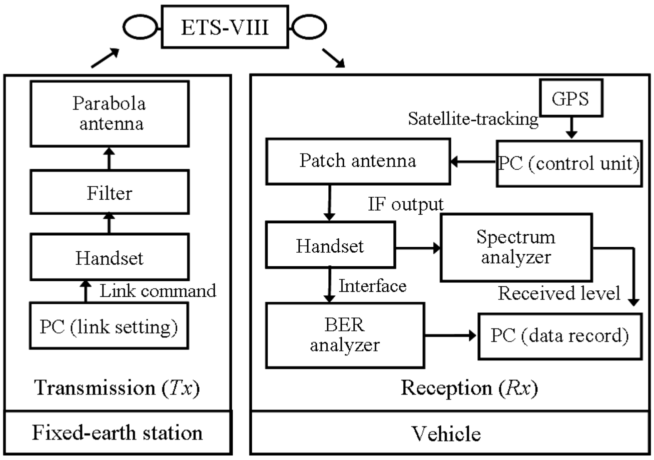


Fig. 4. Field experiment setup.

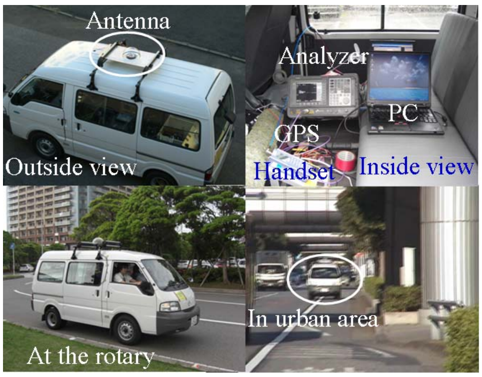


Fig. 5 Field experiment photographs.

III. Measurement Results

The field experiment was mainly tested to evaluate the satellite-tracking of antenna system. The result is shown in Fig. 6. While the vehicle was traveling at the rotary area, the beam of the antenna electronically steered pursuing the ETS-VIII satellite associated with vehicle's orientation. Three antenna beams are smoothly switched to the satellite for each beam-coverage in the azimuth direction. The bit error rate (BER) performance has also been tested. In this case, a pseudorandom noise sequence (PN sequence) was transmitted by a binary phase shift keying (BPSK) modulation. With a data transmission analyzer (Anritsu MD6420A) at the receiver, the BER performance could be obtained. As a result, the BER performance was steadily obtained in range 4 to 6 × 10^{-4} when the beam-switching was carried out at the rotary place which is depicted in Fig. 7. Additionally, measured results of the received signals showed that C/N_0 is averaged by 47.77 dBHz and thus the link margin achieved 1.94 dB close to the predicted value. Moreover, in the following sub-section we report the measurement results in urban and inclined-road areas, particularly the received power levels.

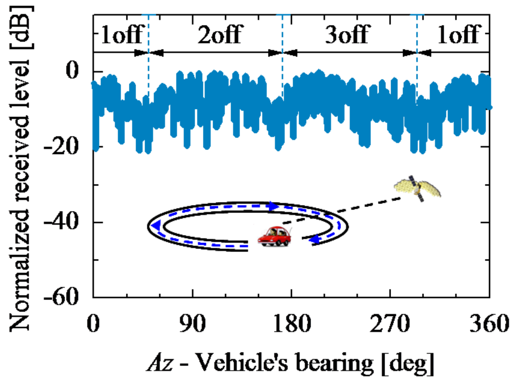


Fig. 6. Received power levels of satellite-tracking when the vehicle moved at the rotary.

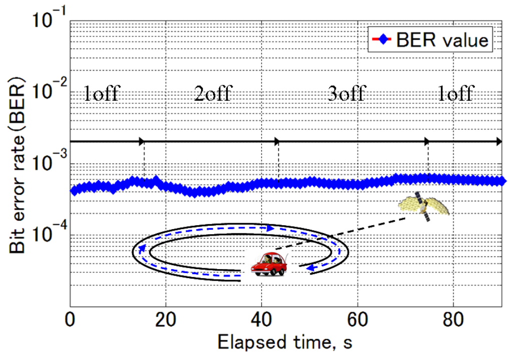
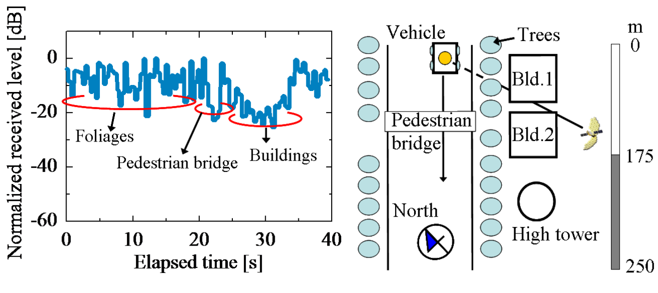


Fig. 7. Measured bit error rate (BER) of satellite-tracking when the vehicle moved at the rotary.

A. Measurement in urban area

Evaluation in the real environment condition particularly the influences of obstacle objects like buildings, towers and foliages of trees to the received level qualities of the antenna, was carried out in urban area. The vehicle passed on the street with some high buildings, roadside-trees, utility poles and pedestrian overpasses in the surrounding area. As described in Fig. 8 (b), the satellite position was situated at the left side from the vehicle thus the signal from the satellite was attenuated by roadside-obstacles and received the reflected signal from the surrounding objects. As a result, the decayed-signal was confirmed as shown in Fig. 8 (a).



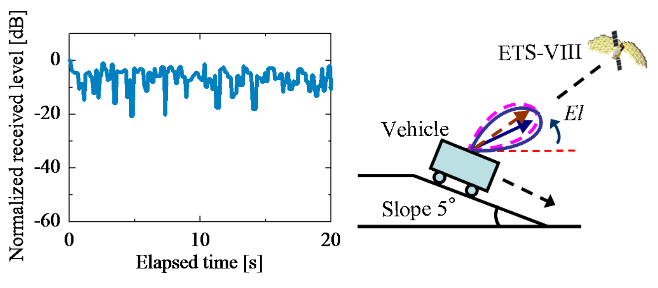
(a) (b)

Fig. 8. Received power level in urban area (a) measurement result (b) measurement circumstance

B. Measurement in inclined-road area

The antenna system was designed for only azimuthally electronic-tracking since the radiation characteristic in the elevation direction was sufficiently satisfied the targeted-gain in the chamber measurement [4], so thus the inclined-road measurement was carried out to confirm the received signal for different elevation angles. We tested the antenna system in Chiba prefecture area (El = 48° from the satellite position) where the vehicle passed on the 5°-inclined road at bearing 222° relative to the North. The vehicle passed for downward-movement on speed 40 km/h. Since the satellite was lying at bearing 170º, the satellite was situated in the left side of the vehicle for downward-movement.

Fig. 9(a) shows the received power level for downward-measurement. From the result, the signal was steadily received even though the inclination changed the antenna position in the elevation direction to the satellite as described in Fig. 9(b).



(a) (b)

Fig. 9. Received power level in inclined-road (a) measurement result (b) measurement circumstance

IV. Conclusion

The field experiment of simple antenna system for vehicle satellite communications using a geostationary test satellite was conducted for verifying the developed antenna system. The developed antenna system discussed was composed of a planar array antenna which has a simple tracking capability controlled by a PC as the vehicle's bearing from a navigation system (GPS receiver) is updated in real time. The antenna system was mounted in a vehicle for the measurement. We thoroughly evaluated the antenna system using the ETS-VIII satellite in some areas i.e. in line of sight area and blockage (such as buildings, towers, poles and foliages) area. The steadily received power level was obtained and the satisfactory bit error rate (BER) as well when the tracking was performed in the line of sight area. Furthermore, the antenna system was examined in real environment constraints such as buildings, foliages, utility poles and pedestrian overpasses. The results showed blockage was confirmed. Additionally, the satellite signal was steadily received even it was examined at the inclined-road.

The overall our designed and developed antenna system has been effectively small, light and possibility in low cost for implementation, so it is expected the antenna system will be promising contribution in the future mobile satellite communications.

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