FIELD EXPERIMENTS OF PHASED ARRAY ANTENNA FOR MOBILE SATELLITE VEHICLE APPLICATION

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1. Introduction

In mobile satellite communications, several types of medium gain tracking antennas have been developed to provide high quality communication services[1]. A mechanically steered antenna will be utilized in the early stage of communication services because of low manufacturing cost. However, we consider a phased array antenna to be one of promising antennas used in future mobile satellite communications, because it has many advantages such as low profile and beam agility[2]-[4].

In the case of land vehicle satellite communications, blocking effects due to buildings and trees often rise compared with the cases of an aircraft and a maritime vessel. Therefore, it is an important key technology to maintain the beam toward the satellite in such circumstances. Moreover, there are various requirements such as low profile, compact size and low cost.

Toyota Central R&D Laboratories have been developing a planar phased array antenna and a beam tracking system for cars[3]. This paper describes features of the antenna and the beam tracking system, and tracking performances of the antenna system in the field experiments with the Engineering Test Satellite Five (ETS-V).

2. Features of antenna system

Photographs of the phased array antenna and the tracking controller are shown in Figure 1. The system consists of the phased array antenna, the beam tracking system and a RF transceiver, as shown in Figure 2. Main characteristics of the phased array antenna are described in Table 1. The antenna is very low profile less than 30mm, and it is suitable for car antennas in mobile satellite communications. The beam tracking system is composed of a single-board microprocessor with an A/D converter, and an angular rate sensor. The received signal strength and the angular rate in azimuth according to the orientation of the car are referred for acquiring and tracking the satellite. For acquiring the satellite, the beam tracking system scans the 24 directions (every 15° in azimuth) and decides the beam being able to get the strongest signal. The basic tracking technique is a step track method referring to the received signal strength. The method has such problems that the received signal level is fluctuated during repeating to steer the beam, and the system loses track of the satellite when the signal is blocked. Then control routines using the angular rate sensor are added to the basic beam tracking algorithm. As a result, needless beam steering and variation of the received signal level are decreased, and reacquisition of the satellite becomes easy.

The hybrid tracking system which adopts the modified step track method with the aid of the angular rate sensor shows accurate tracking and good immunity to signal fading in various driving circumstances. The merit of this system is that the angular rate sensor does not need high accuracy.

3. Field experiments

In this chapter, we discuss about results of the field experiments with the phased array antenna and the beam tracking system. The phased array antenna was mounted on the car-roof. The antenna height was about 2m above the ground. A continuous wave at 1545MHz transmitted from the satellite was measured by the spectrum analyzer, of which the received bandwidth was 1kHz to avoid the Doppler effect frequency shift and frequency variation of the measuring system. Moreover the beam direction of the antenna, the heading direction of the car and the sampling pulse generated every 7.8cm were recorded. The geostationary satellite ETS-V is at 150° E. The elevation angle to the ETS-V is about 47° in Tokyo, Nagoya and Kyoto, Japanese cities where the field experiments were conducted. Therefore the beam was steered only in the azimuth direction and fixed at 45° in elevation.

Figure 3 shows the received signal level, the beam pointing direction and the pointing error toward the satellite which was measured on the curved road beside the buildings. The beam pointing direction represents counterclockwise angles to the heading direction of the car, and the pointing error represents the difference in angles between the beam pointing and the satellite direction. Followings are found from Figure 3. Needless beam steering for searching the satellite could hardly be observed with the aid of the angular rate sensor. The beam was maintained toward the satellite within the pointing error of 15°. The variation of unshadowed signal level due to the beam steering was less than 2dB. A C/N_0 value of the communication link was 54dBHz in the experiments. Furthermore, it was confirmed that the tracking routine worked very well down to 35dBHz.

An example of results measured in the urban area is shown in Figure 4. The beam was accurately maintained toward the satellite during severe signal fading and signal outages due to blocking effects. Figure 5 shows the probability density function of the pointing error measured on the test course (5km) in the urban area. The beam was also maintained within the pointing error of 15°.

Figure 6 shows the visibility in area in the Japanese cities where the field experiments were conducted[5]. The visibility in area is a ratio of unshadowed area to the whole area. Signals transmitted to and from the satellite are seriously affected in the urban areas of Tokyo and Nagoya, because the visibility in area is about 70%. On the other hand, such blocking effects are small in the suburban area, because of over 90% of the visibility in area. We have conducted field experiments in various circumstances, and confirmed that the antenna and the beam tracking system worked very well.

4. Conclusion

The planar phased array antenna and the new beam tracking system have been developed for land vehicle satellite communications. Furthermore, we have conducted field experiments with the ETS-V satellite to confirm that the beam tracking system functions very well. As a result, it was found that the beam was accurately maintained toward the satellite in various circumstances.

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Reference

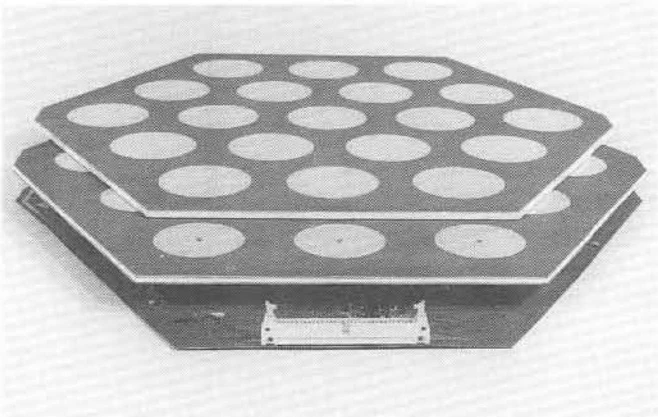
[1] K.Woo et al., "Performance of a family of omni and steered antennas for mobile satellite applications", International Mobile Satellite Conference IMSC'90, pp.540-546 ,Ottawa (1990).

[2] J.Huang, "L-band phased array antennas for mobile satellite communications", 37th IEEE Veh. Technol. Conference Rec., pp.113-117 (1987).

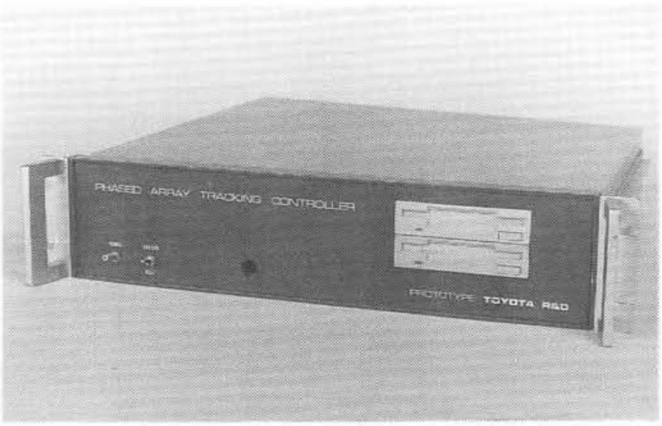
[3] K.Nishikawa et al., "Phased array antenna for land vehicle satellite communications", IEEE Denshi Tokyo No.29, pp.87-90, (1990).

[4] S.Ohmori et al., "A phased array tracking antenna for vehicles", International Mobile Satellite Conference IMSC'90, pp.519-522, Ottawa (1990).

[5] Sato et al., "Propagation measurements for mobile satellite communications", IEICE Technical Report, AP91-59, pp.53-60, (Aug. 1991).



(a) Phased array antenna.



(b) Tracking controller.

Figure 1 Photographs of developed antenna system.

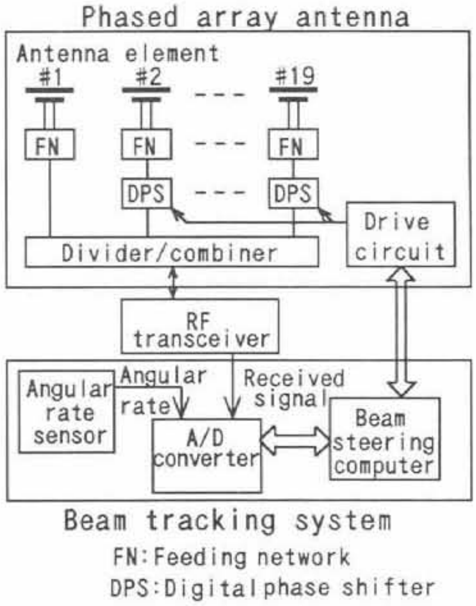


Figure 2 Block diagram of antenna system.

Table 1 Characteristics of phased array antenna.

Frequency	1540-1660MHz
Coverage	Elevation: 30°-90° Azimuth : 0°-360°
Gain	10.5dBi minimum within coverage region
Polarization	LHCP
Axial ratio	3dB maximum within coverage region

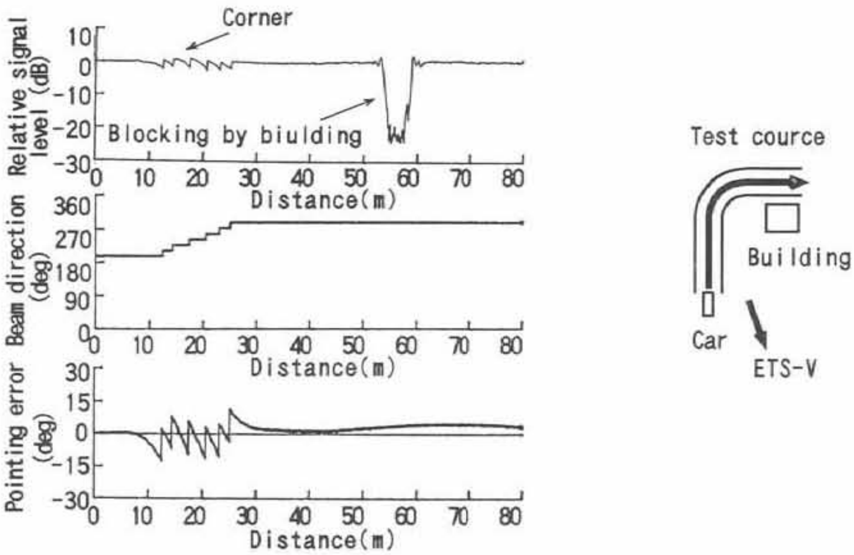


Figure 3 Received signal level, beam direction and pointing error.

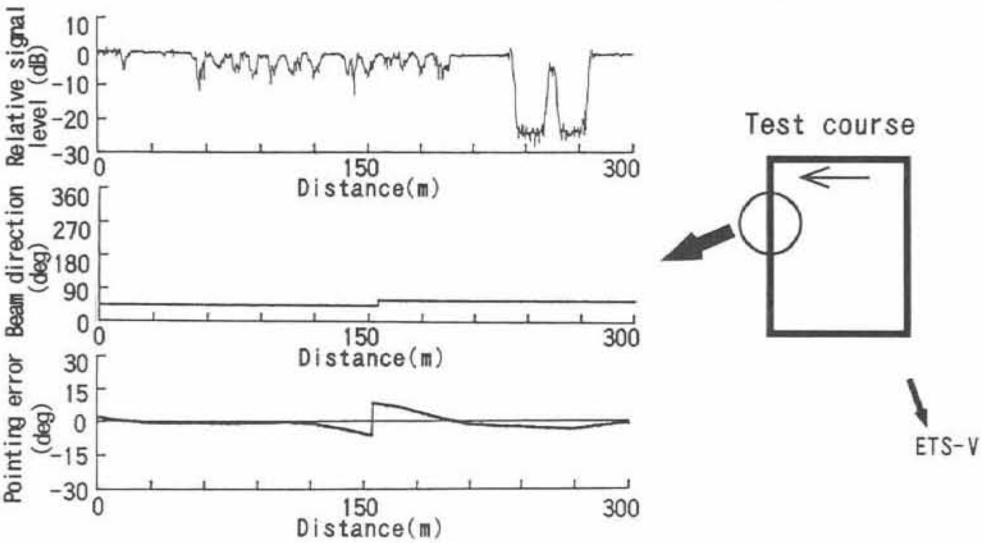


Figure 4 Received signal level, beam direction and pointing error measured in urban area.

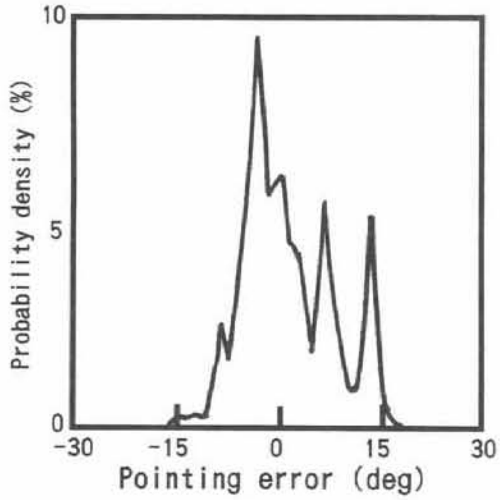


Figure 5 Probability density function of pointing error.

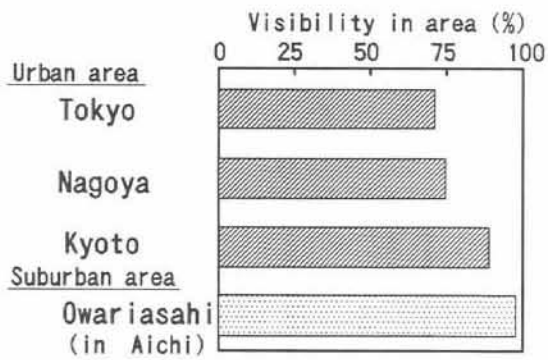


Figure 6 Visibility in area in various circumstances.