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Mobile Antenna System for Direct Broadcasting Satellite

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1. Introduction

A television broadcasting service via a Direct Broadcasting Satellite(DBS) is already operational in Japan and there are many subscribers for a residential house. In addition, many people want to watch the DBS broadcasting even in a car, because the DBS broadcasting has advantages over terrestrial television broadcasting because of high quality, simultaneity and wide coverage. Several mobile antenna systems for the DBS have been developed vigorously[1]-[4]. However, some of the systems[1][2] have a mechanical steering unit to track a satellite in the elevational direction. These systems have a high performance for receiving, but the problem is that these systems are still tall to be mounted on a car. Some of the systems[3][4] don't have an elevational tracking unit, and a planar antenna is installed horizontally, in order to reduce the height. However, these systems don't have a wide receiving area. We have made a great effort to widen the receiving area. We have also realized a small and extremely low-profile mobile antenna system which can be mounted on a small car. This paper presents an outline and the features of the developed antenna system.

2. Requirement for Mobile Antenna System

It is necessary for a mobile antenna system for the DBS to satisfy the following requirements. Supposing that we use a broadcasting satellite for the next term(BS-4) in Japan which will be launched in 1997, a gain of more than about 21dBi is needed for the antenna system to satisfy the carrier to noise ratio(C/N) required for obtaining a clear TV picture. Horizontal installation of a planar array antenna with a large beam-tilt angle and a wide beamwidth is the most suitable way for omitting the elevational tracking unit. In this case the beam-tilt angle of about 50 degrees from zenith and an elevational beam width of more than 12 degrees are needed to be used in most area of Japan. On the other hand, a function of satellite tracking in the azimuth direction is indispensable for an automotive antenna system. Considering movements of a car, the tracking performance in the azimuth direction should be higher than 40°/s. Cost is one major factor for a practical use, therefore, the antenna system needs to be simple structure.

3. Outline of the Antenna System

Fig. 1 shows a structure of the antenna system and Fig. 2 shows a photograph of the outdoor unit of the antenna system. The antenna system consists of an antenna assembly, a motor assembly, a receiver assembly, and so on. The outdoor unit consisting of the antenna assembly and the motor assembly is mounted onto a roof top or a rear trunk top of a car ,and an indoor unit is installed inside the car. The signal from the satellite in the 12GHz band is received by a planar array antenna, and converted into a 1.3GHz band by a frequency downconverter. The converted signal is carried through a coaxial cable into the car and divided into the two signals. One is carried to a receiver, and the other is carried to a signal level detector. A controller determines a rotating angle of the planar array antenna with both the detected signal level and a gyroscope signal, and tracks the satellite according as the car moves about .

4. Features of the Antenna System

1) Planar array antenna: Fig. 3 shows a structure of a planar array antenna of this antenna system. The planar array antenna consists of a radial waveguide and circularly polarized ring microstrip antenna(RMSA) elements arrayed in concentric circles on a dielectric substrate(relative dielectric constant is 2.6). The array antenna is designed with the radial spacing of 14mm to suppress a grating lobe. The number of the concentric circles in the radial direction is 11 and the number of elements is 396 in order to satisfy the required gain. Each RMSA element has a feed pin which is connected at the center and inserted into the radial waveguide through a small hole. The signal from the satellite is received by the RMSA element and propagates to a center feed probe through the radial waveguide. The length of the feed pin of each RMSA element is adjusted in order to get a uniform amplitude distribution over the array surface. In addition, the rotation of each RMSA element around the axis of its center feed pin, which corresponds to the variation in the excitation phase of the RMSA element, is determined so as to get a desired beam pattern of the array antenna. A conventional microstrip antenna(MSA) element is excited from a feed point located slightly apart from its center. However, since the excitation phase of the antenna element is determined by the rotation of the antenna element, the spacing between neighboring MSA elements becomes unequal, in other word, it becomes narrow partly. In this case a gain and an axial ratio of the array antenna become worse because an undesirable mutual coupling increases. In order to reduce the undesirable mutual coupling, we have developed a new type of RMSA element fed at its center. Fig. 4 shows the configuration of the developed RMSA element. The RMSA element is fed by the two microstrip lines symmetrically divided from the center and is excited in the same dominant mode(TM_{11}) as a conventional MSA element.

2) Wide beamwidth: In order to be used in most area of Japan, a beamwidth is widened by using the pattern synthesis technique[5]. Fig. 5 shows the elevational radiation pattern of the developed array antenna at 11.85GHz. The half power beam width is 13 degrees. Fig. 6 shows the frequency characteristics of the gain and the axial ratio of the array antenna. The gain for the maximum direction of main beam is more than 23.9dBi within the 11.7 to 12.0GHz band for the DBS broadcasting. The axial ratio of the array antenna is suppressed below 1dB.

3) Satellite tracking: Only the azimuth tracking is needed for satellite tracking since the elevational beam width is wide enough. The satellite tracking is performed by using both the gyroscope signal and the received signal level. While the received signal level is higher than a predetermined threshold signal level, the controller turns the array antenna to the counter direction of a turn of a car using only the gyroscope signal. Usually a drift error is included in the gyroscope signal. If only the gyroscope continues to be used for the satellite tracking, the beam direction is off the direction of the satellite, then the receiving signal level comes down. Therefore if the received signal level becomes lower than the threshold level, the controller intentionally generates a fluctuation of the received signal level by rotating the array antenna right and left slightly to search the satellite, and adjusts the beam direction as the receiving signal level goes up. A field test was conducted to confirm the tracking performance with the above algorithm. Fig. 7 shows the measured data for C/N and yaw-rate. It can be seen from the measured data that the satellite tracking system works very well, and a deterioration of C/N is less than 3.5dB even when the value of yaw-rate is higher than 40°/s.

4) Specifications: Specifications of the antenna system are shown in Table 1. The antenna system has the height of 29mm, the diameter of 400mm and the weight of 3.3kg. The array antenna has a gain of larger than 21.2dBi from 34 degrees to 47 degrees elevation angle.

5. Conclusion

We have developed the extremely low-profile DBS antenna system for a small car. The outline and features of the developed antenna system have been presented in this paper. The antenna system has a wide receiving area, a small size, an extremely low-profile, and a sufficient performance for the satellite tracking. Low manufacturing cost is expected because of the very simple structure. The antenna system will be used widely in passenger cars.

6. Acknowledgment

The authors greatly acknowledge the collective effort of many diligent colleagues. These colleagues include Mr. Y. Minami and Mr. S. Aoshima of Toyota Motor Corporation. They also wish to thank Mr. N. Takahashi, the Division manager of Toyota Central R&D Labs., Inc. for his helpful advice, and colleagues of Communications Laboratory for their valuable discussions.

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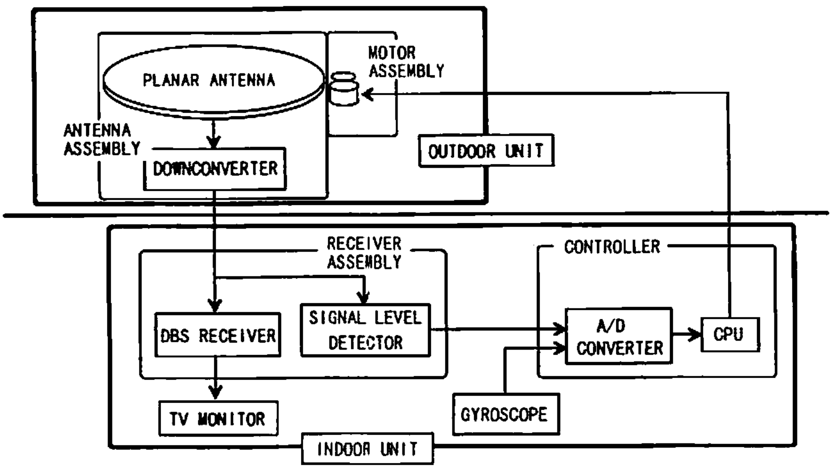

Fig. 1. Structure of antenna system.

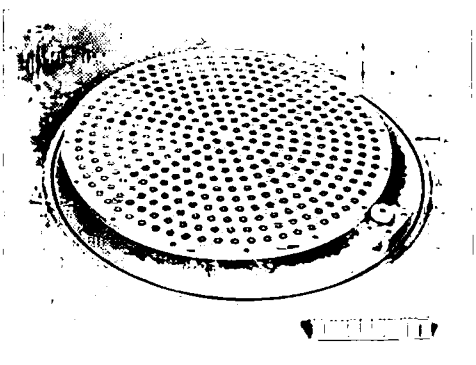

Fig. 2. External view of antenna system (outdoor unit).

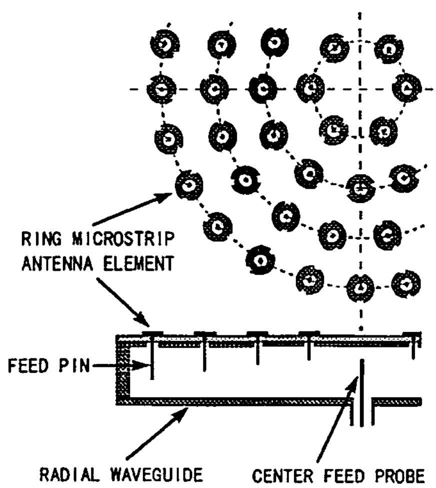

Fig. 3. Planar antenna.

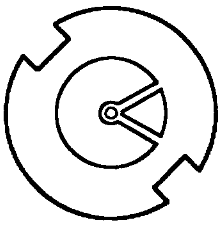

Fig. 4. RMSA element.

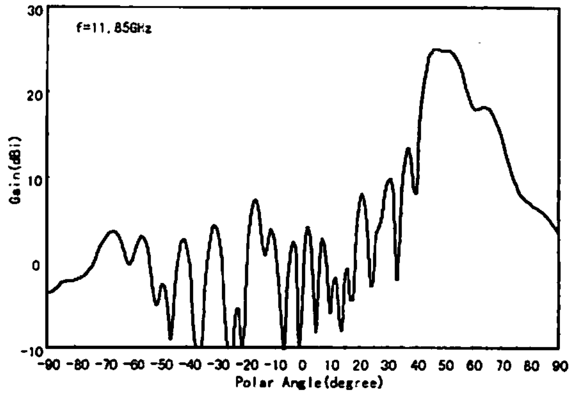

Fig. 5. Radiation pattern in elevational plane.

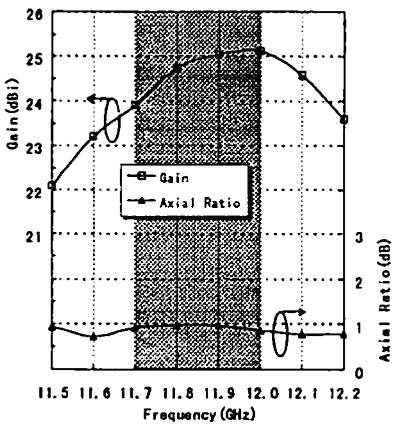

Fig. 6. Gain and axial ratio.

Table 1
Specification of antenna system.

Size	Diameter 400mm Height 29mm
Weight	3.3 kg
Gain	21.2 dBi min. (from 34° to 47° elevation angle)
Polarization	RHCP
Axial Ratio	1.0dB max.
Tracking speed	40 °/s
Frequency	11.7-12.0 GHz

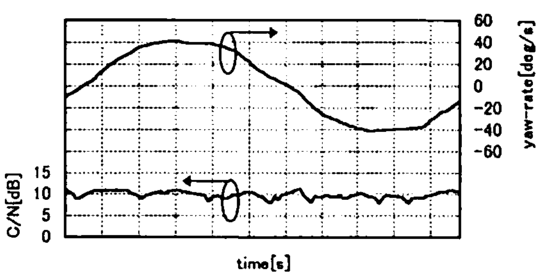

Fig. 7. Measured data of a field test for C/N and yaw-rate.