Active Phased Array Antenna for Mobile Multimedia Services via Satellite[1,2]

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Abstract—This paper will introduce an active phased array antenna for mobile DBS service. The main idea for the antenna is to use twelve active array elements for cost-effectiveness. For this purpose, the attractive hybrid-tracking method with two-dimensional array structure is also used. The electronic beam scan coverage of this antenna is over 24 degrees wide in elevation, and 12 degrees in azimuth. The high-speed tracking capability of this antenna for fast moving vehicles will give us other applications in satellite mobile multimedia services like mobile internet services by satellite hybrid link. Finally, this paper will also introduce recent results for developing active phased array antennas for the high-speed data communications via satellite.

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1. INTRODUCTION

The decade of the 1990s was an era of terrestrial mobile communications. Now, we expect that the next decade will be an era of mobile communications via satellite [1]. Mobile multimedia services will become more widespread. In implementing these services via satellite for vehicles especially, antennas will be one of the most important key technologies. The vehicle antenna means an antenna system that is mounted on a vehicle for satellite communications. In this case, antenna systems specially designed for cars, trains, ships and airplanes require high gain with directional pencil beam for satellite communication if the satellite is geostationary. However, such a large antenna will have difficulty tracking the satellite while the vehicle is in motion. The solution to this problem is reached with the help of several types of flat antennas established on the vehicle's roof [2][3]. The most attractive of these is an active phased array antenna technology. However, the conventional technology is very expensive, restricting its use in commercial products. To solve this, a modification in the phased array antenna is introduced, taking into account that the objective is to create an array antenna which can track a satellite with a minimum number of active and control elements, and with the required directivity gain. This antenna is designed for vehicles, and receives a satellite signal with exceptional clarity even in motion. One major application of this is for DBS(Direct Broadcasting Service) reception. Fig. 1 shows the application on a bus.

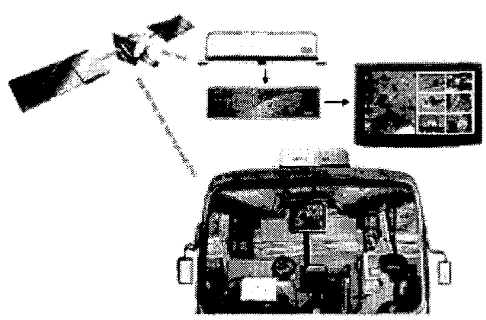

Fig. 1 Vehicle Antenna for Mobile DBS Reception

For other applications, this antenna can be used for mobile services by satellite-hybrid link. In this application, inbound signals will come via satellite and outbound signals will go through terrestrial mobile network. However, for real two-way communication, we should consider more complicated situations and more enhanced technologies to solve them.

2. ANTENNA DESIGN AND TEST

The phased array antenna with electronic beam scanning in both planes which contain radiating elements oriented vertically, and whose pattern has axis symmetrical form to ensure reception of a signal from any direction in azimuth plane depending on vehicle orientation, is a conventional type. However the phased array directivity will be decreased

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with inclined scanning, and it is necessary to use a large number of radiating elements for ensuring high gain. Herewith the more criticized point is that this antenna also requires a large number of phase shifters to scan every azimuth directions and limited elevation angles on a moving vehicle. To avoid these requirements, a modification is introduced in this conventional phased array antenna, a two-dimensional electronic beam scanning in elevation and azimuth with mechanical tracking in azimuth. In this two-dimensional electronic beam scanning with mechanical tracking in azimuth, an inclined pencil beam is used for the pattern of each element. This is shown at antenna system test results. In this case the electronic scanning area is less than the conventional type. This is attractive, because it uses a few elements. This arrangement makes it possible to use radiating elements with high directivity and to reduce strongly their number also, and, at the same time, to reduce the number of active elements. Taking into account calculation formulas, the number of elements of the proposed structure has over a hundred times less array elements than in the full two-dimensional array with the same performance [4]. If the high-speed processing in the system is not required, this approach would be the most cheap and preferable in the active phased array antenna system. The antenna with mechanical turn of antenna in azimuth plane and electronic beam scanning in elevation plane is technically competitive from a commercial point of view. The combination of mechanical and electronic scanning is the key requirement for this array structure [5]. Additionally this introduced antenna uses two beams. One is electrically tracking a satellite and the other is receiving its signal as an independent function. The second beam is very effective for the antenna because it permits an increase in tracking accuracy with its higher gain. The array design has been performed for this unique function. To scan a beam, the phases specified on the array, will be analog values. In this system, those values by discrete phase shifters instead of analog phase shifters are determined by antenna control processing.

Antenna Design

For the radiation pattern design, it was performed for frequency of 12 GHz and the its parameters of the structure. The observation point was determined by variables of geostationary orbit of the KOREASAT located in E 116 degrees from the Korean peninsula. The center of the beam corresponds to 43.6 degrees. The antenna pattern calculations were done using the specified data about the azimuth and elevation pattern of the radiator array element. By the design with the structure of only 12 active phase control elements, the antenna has a pencil beam of 32.6 dBi directivity gain under other service requirements and a minimized scanning loss of 1.4dB at scan edge angle. The electronic beam scan coverage of the antenna is over 24 degrees wide in elevation, and 12 degrees in azimuth. The mechanical tracking is used only for coarse tracking. More accurate tracking performance is accomplished using this electrically steered beam at two-dimensional area. The frequency band of the array antenna is from 11.7 GHz to 12.0 GHz. The subarray has sixteen EMC microstrip patch antennas which are circularly polarized. The antenna system consists of active channel blocks with radiators, a driver module, a satellite tracking module, and a power supply module. The system is protected by a radome structure. The radiator and active channel blocks are for dual beam forming and beam scan. The driver and satellite-tracking module is for azimuth satellite tracking. The power supply module is adapted to unstable vehicle power. The radome of aerodynamic structure has low-loss. Fig. 2 shows the experimental model of the active phased array antenna system before developing commercial model that is shown in Fig. 3.

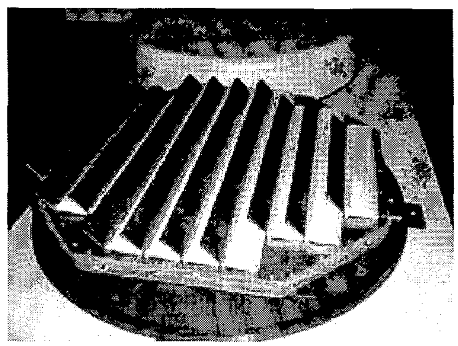

Fig. 2 Experimental Model Antenna System

Fig. 3 Commercial Model Antenna System

Antenna System Test

The indoor tests like pattern tests were performed at first. The tested inclined pencil beam pattern for each element is shown in Fig. 4. There was a good coincidence between measurement and designed gain value. Fig. 5 shows test result at 12 GHz by near-field measurement. Other several outdoor tests were performed for receiving DBS signals on vehicles like cars, buses, and boats in Korea.

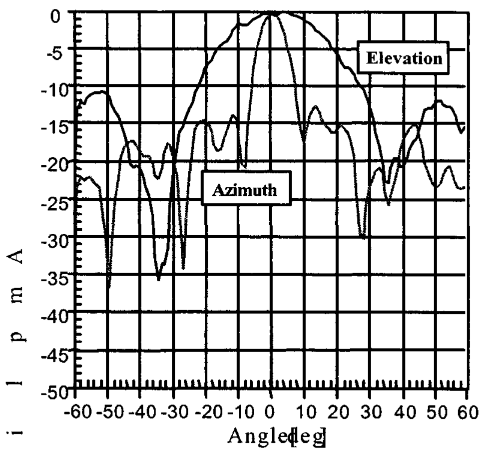

Fig. 4 Tested element pattern of the antenna

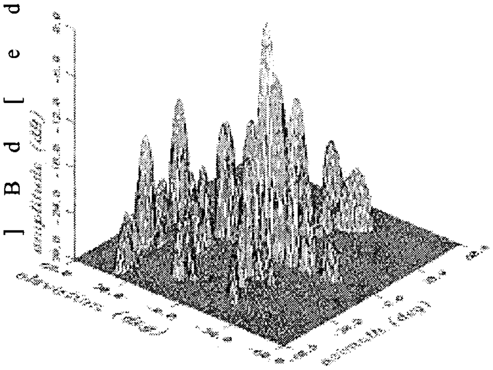

Fig. 5 Antenna Pattern Test Result (11.85 GHz)

Table 1 shows the summarized specification of the active phased array antenna system after the pattern test.

Table 1. System Specification

Item	Specification
Input Frequency	11.7 – 12.0 GHz
Gain	32.6 dBi
Elevation Scan	24 degrees
Azimuth Scan	360 degrees
Output Frequency	950 – 1250 MHz
Power Supply	12 VDC(30W)
Dimension	540(W)x579(D)x133(H)
Weight	13.5 kg

The antennas were installed on the place visible to the satellite. The power supply, the satellite receiver, the TV monitor, and the spectrum analyzer including the monitoring notebook PC to acquire the tracking data were installed inside of the vehicle. Fig. 6 shows a van on which the antenna is installed, and Fig. 7 shows test equipment in the vehicle.

Fig. 6 Test Antenna System installed on a Van (circle)

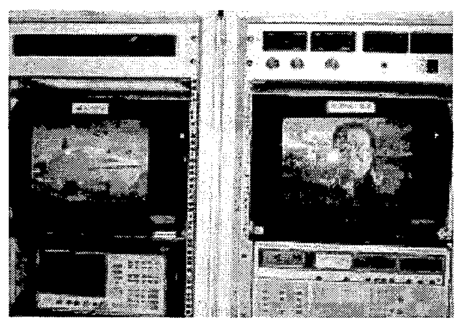

Fig. 7 Test Equipment Set-up in a Van

The tested antenna on the car showed very stable DBS reception on the highway. During the test, the car speed was up to max. 110 km/h. There was no loss of satellite and no serious distortion of TV signal just after passing very short blockage area. Fig. 8 shows the tracking field test results on the highway. These results showed that the designed active phased array antenna had good tracking performance except the signal blockage areas like buildings, bridges and others in the downtown area. Although there were such blockages, the worst recovery time was only within 0.8 sec after the signal blockage in the situation of high-speed turning. Fig. 9 shows this test result.

In the field, the antenna systems after outdoor tests were successfully installed on a domestic vessel carrying natural gas and the SNG car for a broadcasting company, KBS (Korea Broadcasting Service). Seen in Fig. 10 and Fig. 11.

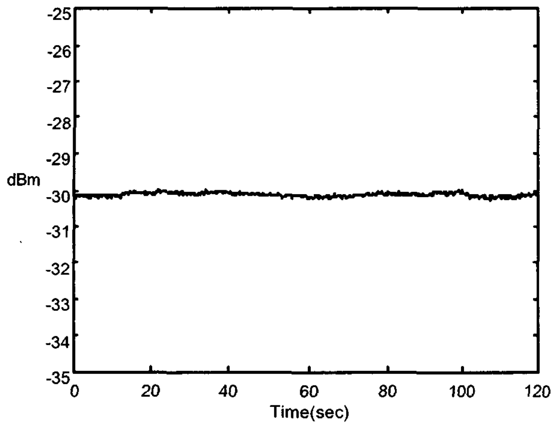

Fig. 8 Tracking Field Test Result on the Highway

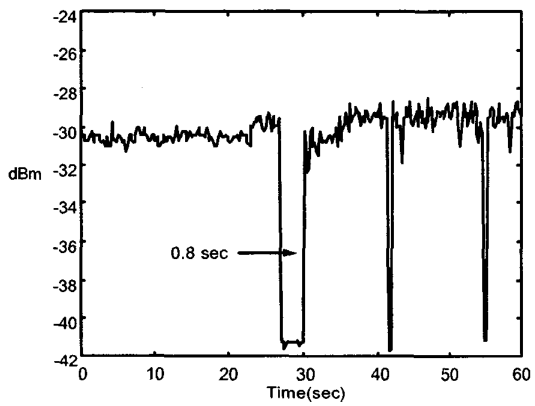

Fig. 9 Tracking Field Test Result at the Downtown

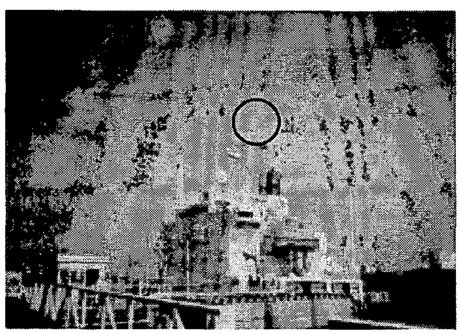

Fig. 10 Antenna System installed on a Vessel (circle)

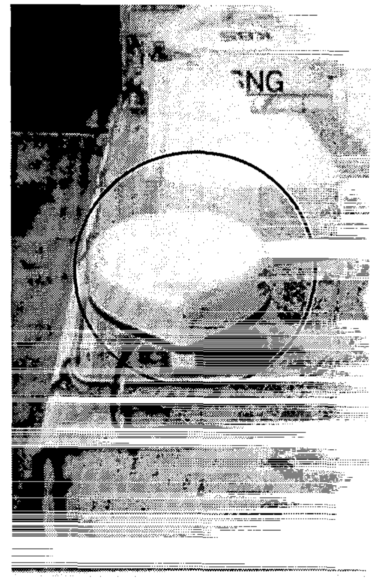

Fig. 11 Antenna System installed on a SNG car (circle)

3. MULTIMEDIA APPLICATIONS

Multimedia services including Internet is requiring a high data throughput, thus demanding broadband rather than narrow band networks for efficient traffic distribution. However, many terrestrial networks, often designed for narrow band traffic, have limited capability associated with increased Internet usage. In these cases, a satellite can offer many advantages over wire-line networks in delivery and development of Internet services [6]. Satellites are ideal for handling the asymmetrical characteristics of most Internet traffic, typically inbound or downstream traffic (downloading large files) exceeding the outbound or upstream traffic (such as requests, sending e-mail) from the user in terms of data rate and capacity. One example is 5 Mbps inbound and 512 kbps outbound. To do this, two-way communication equipment is needed. For mobile application of this Internet service, the user should install a two-way communication antenna system on his vehicle. Another configuration for this application is hybrid links. These are more convenient by using broadcasting satellites in Ku-band and reception only terminals with low cost. Generally the outbound path from the subscriber is relatively low volume and can be handled by terrestrial networks. The active phased array antenna can be used for these type mobile Internet services with the existing terrestrial mobile network that can support data communications.

4. ANTENNA FOR COMMUNICATIONS

However, for real two-way communication, we should consider the more complicated situations and the more enhanced technologies to solve them. Some activities are already announced for research [7]. This paper also introduces the recent results for developing X and Ka-band active phased array antennas to realize the high-speed mobile multimedia data communications via satellite. The X-band experimental module of 4x4 elements array was integrated for the transmission test. The test module antenna has cavity-backed microstrip antenna elements array for 110 degrees scanning range at elevation. It has 21dBi directivity gain. Fig. 12 shows the X-band antenna module.

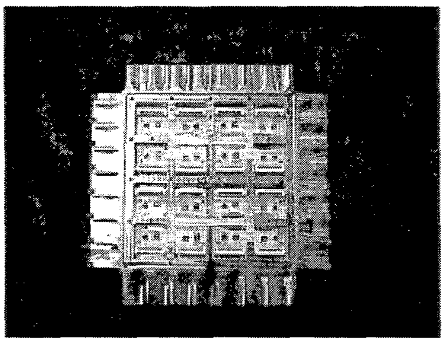

Figure 12 4x4 Array X-band Antenna Module

The other experimental module for developing Ka-band active phased array antenna was tested. The module has 16 elements array for the receiving test. Fig. 13 shows the Ka-band antenna module.

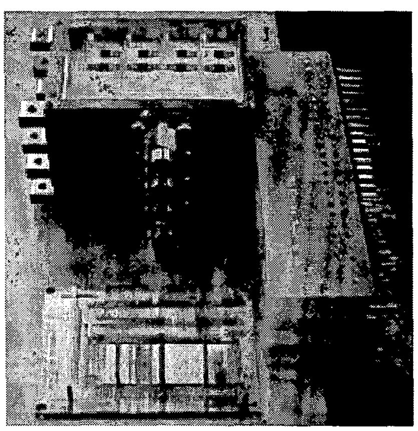

Figure 13 16 Array Ka-band Antenna Module

5. CONCLUSIONS

This paper described the active phased array antenna system with its attractive structure. This antenna has only 12 active phase control elements for 32 dBi directivity gain. This antenna used dual beams for its tracking algorithm with improved tracking performance. The test results show stable tracking performances on the highway. In the downtown area, although there were frequent signal blockages, the active phased array antenna recovered the satellite signal quickly just after passing the zone with 0.8sec delay as the worst case. The antenna will be used for mobile DBS reception. It will be also used for mobile multimedia services via satellite like Internet with hybrid link configuration. This paper also introduced the experimental antenna modules for satellite communications. To realize full scan array for wide range and broadband, there are many technology challenges and issues for us to solve like scan blindness, scan loss, cross-polarization, and frequency scanning effect etc. However, the major item will be the isolation of the transmitted power from the other part in the full duplex communications antenna system.

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