Experimental APAA for Satellite Communications

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Abstract — **In this paper, an APAA(Active Phased Array Antenna) for X-band satellite communications is introduced. The APAA can electronically steer its beam with wide range, +/-37 degrees. The system was designed experimentally before practical model design. It will be installed on the ship finally. To confirm its functional performance, it was tested on the motion simulator with the satellite RF simulator. The motion simulator can operate with the wide range 3D movement. The APAA has its M&C(monitoring and control) functions, which show the beam directions as well as the other status during its operating.**

I. INTRODUCTION

The APAA technology has been used for military applications like radar systems. Recently, the technology is applied for civilian applications, like DBS reception. [1] In this paper, a new trial with APAA system technology for satellite communications is introduced, which are X-band services.

As like other APAA, the designed system is for fast beam steering. The function is suitable especially for mobile applications. [2] Here, it is considered that the system is used on shipboard. To satisfy ship movement under maritime conditions, its beam steering capability should be +/- 37 degrees at least at the elevation direction. To do that, there are several obstacles like scan blindness by mutual coupling effect. Technically, there are also other issues like integration of array units, isolation of transmission and reception, beam steering control, tracking control, and system performance management.

This system was designed experimentally to testify its functional performances. For the test, the system was located in an anechoic chamber. The satellite RF simulator was used as function of the satellite payload. The motion simulator was also used for shipboard movement in the chamber.

II. SYSTEM DESIGN

The key design specifications of the APAA systems are shown in Table 1. The antenna gain requirement is 25 dBi min. Tx antenna gain will be more than 25 dBi. The system EIRP is 38 dBW with the gain. The system noise figure is 1.0 dB. 16 subarrays are used in the antenna.

TABLE I

KEY SPECIFICATIONS OF EXPERIMENTAL APAA

Items	Specifications
Frequency Band	X-band
Antenna Gain	25 dBi min
Elevation Range	+/-37 °
Azimuth Range	360 °
EIRP	38 dBW
Recovery Time	1sec max
Tracking Speed	10 ms max
Tracking Loss	3 dB max
System Noise Figure	1.1 dB min

Each subarray has four antenna elements. The scan loss is estimated as 3 dB with 4 bits digital phase control. [3]

The ship movement under maritime condition is considered as +/-12 degrees at pitch, +/-35 degrees at roll. Because the system has hybrid tracking mechanism, its heading condition is not considered. The electrical tracking range is calculated by the movement condition. The calculated ranges are +/-36.7 degrees at the elevation direction and +/-56.32 degrees at the azimuth direction. The system beam steering is required to be +/- 37 degrees to meet the requirement at the elevation direction. That is wide enough to make scan blindness within beam coverage range. To avoid this, the antenna element with modified cavity backed is used.

For the satellite tracking, the system has two level beam forming mechanism, one for its communication and the other for its tracking. The antenna has separated parts of transmission one and reception one to avoid high power interference.

Finally, the APAA has monitoring and control function to monitor beam steering by visual. The function also gives the information of the status of active elements, and controls their power On/Off remotely.

III. FABRICATION

The system was integrated at the ETRI antenna center. At first, the antenna array and its active components were fabricated, and then its initial phase measurement was done for each side of Tx and Rx parts. The output power

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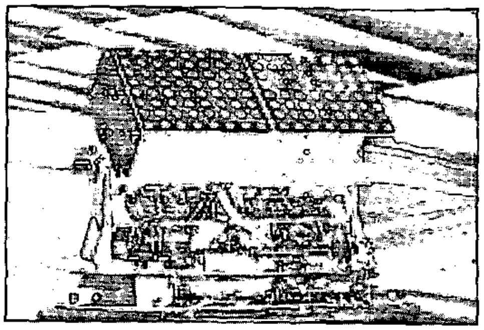

Fig. 1. Integrated experimental APAA system

of each Tx SSPA was measured as 3 dBW, which is enough to meet the EIRP specification.

The mechanical driving part was integrated below the antenna part. The part has a rotary joint unit where RF signals, control signals, and DC power are passing.

More complicated control units were installed at the backside of the array antenna to control its beams electronically. The fully integrated APAA system is shown in Fig.1.

IV. SYSTEM TEST

The antenna pattern measurement was done by the near field measurement system. The measured patterns with steering are shown in Fig. 2 and Fig. 3. The measured scan loss was 3 dB. The test result showed that it had 27.3 dBi min gain with 8 degrees HPBW. The steering range was satisfied as +/-37 degrees without any scan blindness. Input and output return loss was over 12 dB in the system. The system noise figure was measured as 1.0 dB

After the pattern test, the fabricated and calibrated system was moved to the anechoic chamber for the system function test. In the chamber, the satellite RF simulator and the motion simulator, shown in Fig. 4, were installed for the test. The APAA system was loaded on the rotating platform of the motion simulator. The movement of the simulator was three axis controlled by its separated PC. The test set-up could give data information of its motion speed, and rotating angles. The inclined angle from the motion simulator to the satellite RF simulator was selected to 45 degrees.

The test result showed its tracking speed 2 msec, which was faster than its specification. This could be monitored by the M&C display, and measured by the tracking signal detection unit. Fig. 5 shows the M&C display, which

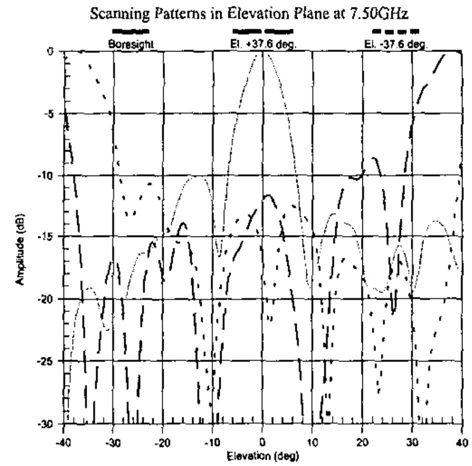

Fig. 2. Elevation beam steering patterns at -37 degrees, 0 degrees, and +37 degrees(from left to right)

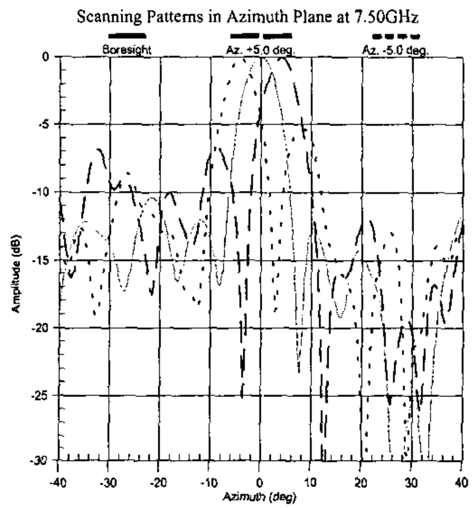

Fig. 3. Azimuth beam steering patterns at -5 degrees, 0 degrees, and +5 degrees(from left to right)

gives information of beam directions and system status. The advantages of the function are not only its original M&C function but also the monitoring function of beam steering test status with the simulator's motion.

V. CONCLUSIONS

After the DBS reception antenna with APAA technology was developed by ETRI, the institute has tried to develop its communication antennas for several applications. With the effort, the experimental APAA for GEO satellite communications was developed for shipboard application. Although the system is for experimental test with small gain, 25 dBi, some specification will be enough to be used in a practical model. At the anechoic chamber test, the system was proved with its functional performance. The fast beam steering was within 2 msec. The steering range was wide enough to +/-37 degrees. The simulators were used for the anechoic chamber test. They were fully operated well at the inside of the chamber.

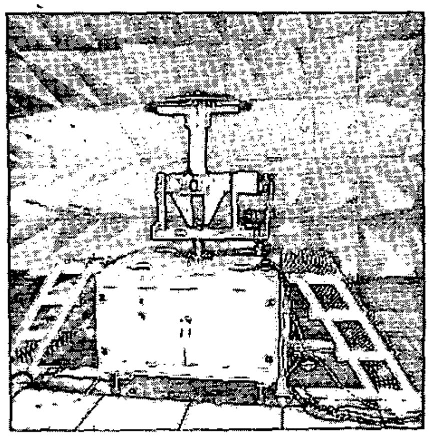

Fig. 4. Motion simulator for experimental APAA system test

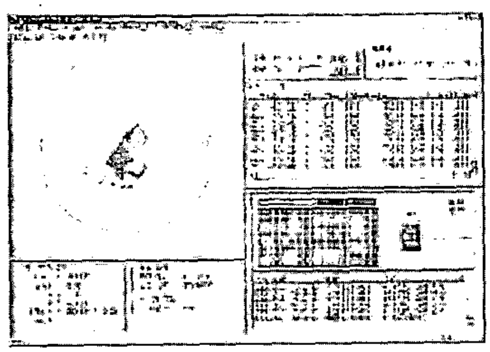

Fig. 5. Monitoring display for beam direction and system status report

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