

# A Phased Array Tracking Antenna for Vehicles

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## ABSTRACT

An antenna system including antenna elements and a satellite tracking method is considered a key technology in implementing land mobile satellite communications. In the early stage of land mobile satellite communications, a mechanical tracking antenna system is considered the best candidate for vehicles, however, a phased array antenna will replace it in the near future, because it has many attractive advantages such as a low and compact profile, high speed tracking and potential low cost. Communications Research Laboratory is now developing a new phased array antenna system for land vehicles based on research experiences of the airborne phased array antenna, which was developed and evaluated in satellite communication experiments using the ETS-V satellite.

This paper describes the basic characteristics of the phased array antenna for land vehicles.

## I. INTRODUCTION

An antenna system including antenna elements and a satellite tracking method is considered a key technology in implementing land mobile satellite communications. In the early stage of land mobile satellite communications, a mechanical tracking antenna system is considered the best candidate because of its characteristics such as a simple config-

uration, a wide beam coverage and an easy installation [1]. However, a phased array antenna will replace it in the near future, because it has many attractive advantages such as a low and compact profile, high speed tracking and potential low cost. On the other hand, it also has such disadvantages as lower G/T caused by complex feed lines, narrow beam coverage and so on.

Communications Research Laboratory is now developing a new phased array antenna system for land vehicles based on research experiences of the airborne phased array antenna [2], which was developed and evaluated in aeronautical satellite communication experiments using the ETS-V satellite [3].

This paper describes the basic characteristics of the phased array antenna for land vehicles.

## II. MAIN FEATURES OF THE PHASED ARRAY ANTENNA

The main features of the phased array antenna are as follows:

(1) Antenna elements are excited by electromagnetic coupling with microstrip feed lines. Because of its easy configuration, production cost will be reduced greatly enough for land vehicles including private cars.

(2) A total number of digital phase shifters will be reduced to one-half using a newly developed phase shifter. The phase shifter is printed on a substrate, which will make the present complex feed lines simple. The development of a new phase shifter is in the first stage, where a 3-bit phase shifter with having only 6 PIN-diodes have been developed.

(3) Tracking error between transmitting and receiving frequencies, which is inevitable for a phased array antenna, is potentially eliminated using a frequency dependent phase shifter [4]. The new phase shifter is scheduled to be developed on a second stage of the project.

### III. ANTENNA ELEMENT

An electromagnetic coupled antenna is adopted as an antenna element, because it will reduce procedures of assembling the antenna system and it will reduce a cost of the phased array antenna to compete with a conventional mechanical steering antenna. Figure 1 shows a configuration of the antenna element. A feed line is a microstrip line printed on a substrate, which excites a radiating element by electromagnetic coupling through a coupling aperture. A radiating element, which radiates circularly polarized waves, is also printed on a thin film substrate. Figure 2 shows a

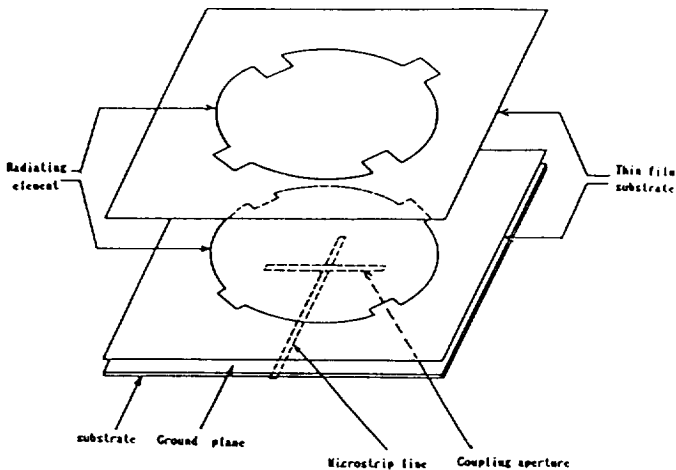


Fig.1 Configuration of Antenna Element.

frequency dependence of return loss of the element. The return loss in the frequency range of 1530-1660.5 MHz, which is required in mobile satellite communications, is found to be below 20 dB.

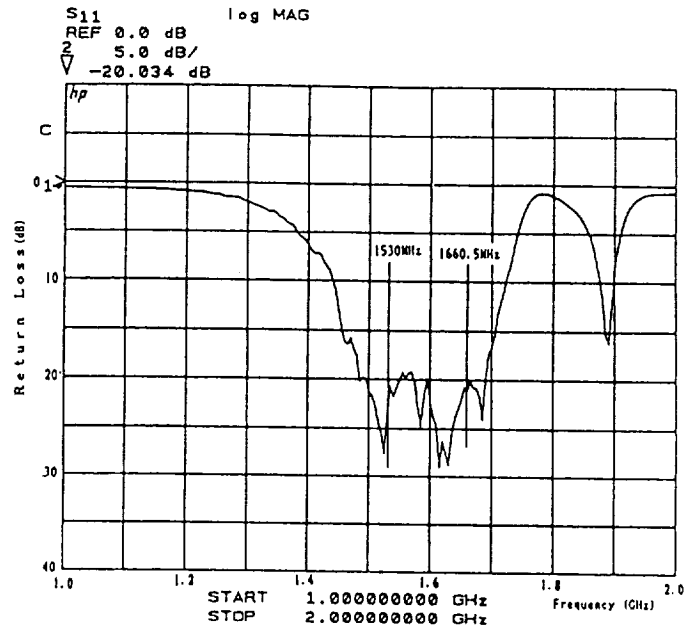


Fig.2 Return Loss of Antenna Element.

### IV. PHASED ARRAY

The phased array antenna is under development and a prototype is assembled as shown in Fig. 3. A gain of the array antenna is designed to be 18 dBi in a non-scanned direction (Elevation angle: 90 deg.), and 10 dBi in a scanned angle of 60 degrees (Elevation angle: 30 deg.), which is determined by a system requirement of the ETS-V experiment. Main characteristics of the array antenna are shown in Table 1. The array consists of 19 elements, which are fed by microstrip feed lines as shown in Fig. 4. A theoretical calculation of gains and radiation patterns of the array antenna is shown in Fig. 5, where 0 denotes a scanned angle from the boresight direction (Elevation angle: 90 deg). The gain is shown in a directive gain, which does not include losses of feed lines including phase shifters.

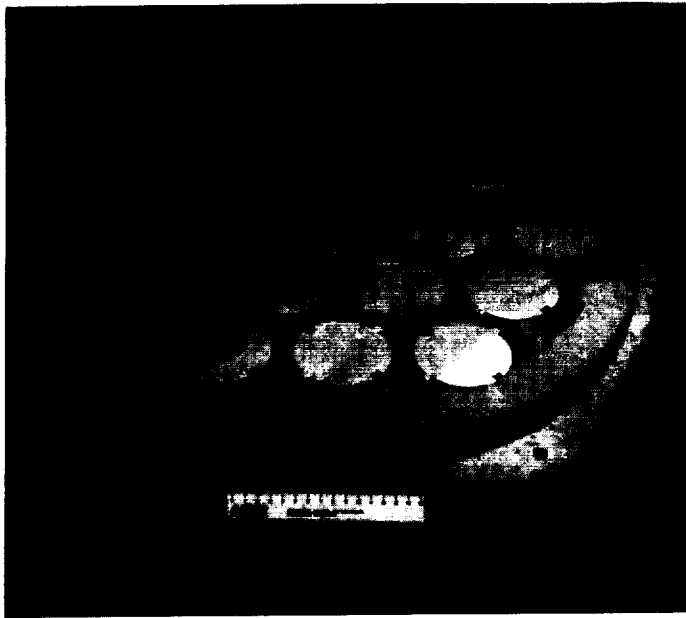


Fig.3 Prototype of the Phased Array Antenna.

Tabel.1 Main Characteristic of the Array Antenna

Frequency	$f_R$ 1530.0MHz~1559.0MHz $f_T$ 1826.5MHz~1160.5MHz
Polarization	Left Hand Circular
Scanned Angle	Ele. $30^\circ \sim 90^\circ$ Az. $0^\circ \sim 360^\circ$
Gain	18dB: (Ele. $90^\circ$ ) 10dB: (Ele. $30^\circ$ )
System Temp	200K
Axial Ratio	4dB(Ele. $=30^\circ$ )
Volume	60cm $\phi$ $\times$ 4cm(H)
Weight	5kg

## V. TRACKING METHOD

A tracking method of a phased array antenna is a very important key technology in land mobile satellite communications, and two different methods and an integrated method will be evaluated in the ETS-V experiment. First method is a closed loop system, which can track a satellite by receiving a signal from a satellite. Second

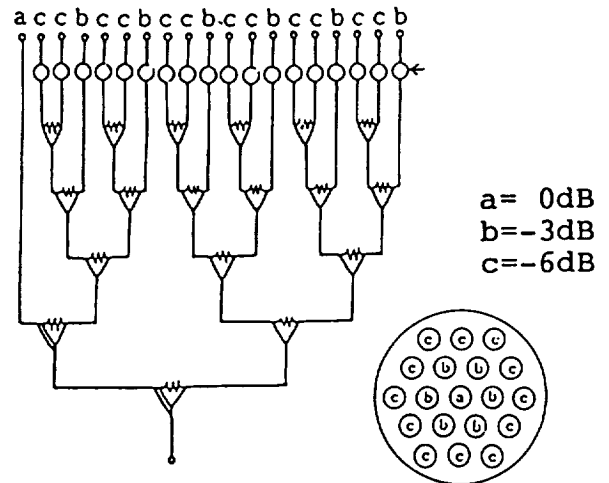


Fig.4 Configuration of Feed Lines.

system is an open loop method, which uses output signals from sensors such as magnetic compass and/or optical gyro. Table 2 shows comparisons of sensors which will be evaluated in the ETS-V experiments. An integrated method using mixture of open and closed methods is also evaluated.

Table.2 Sensors used in the Experiment

Sensor	Accuracy	Resolution	Cost
Optical Gyro	$\pm 0.05'$ /sec	0.025' /sec	¥1,000,000
Magnetic Sensor	$\pm 0.1'$	0.1'	¥420,000
Magnetic Compass	$\pm 10'$	0.25'	¥9,000
Inclination Detector		0.8'	¥340,000
Angular Velocity Detector		0.02' /sec	
Vehicular Speed Detector	400pulses at 60km/h	1pule/6.28cm	

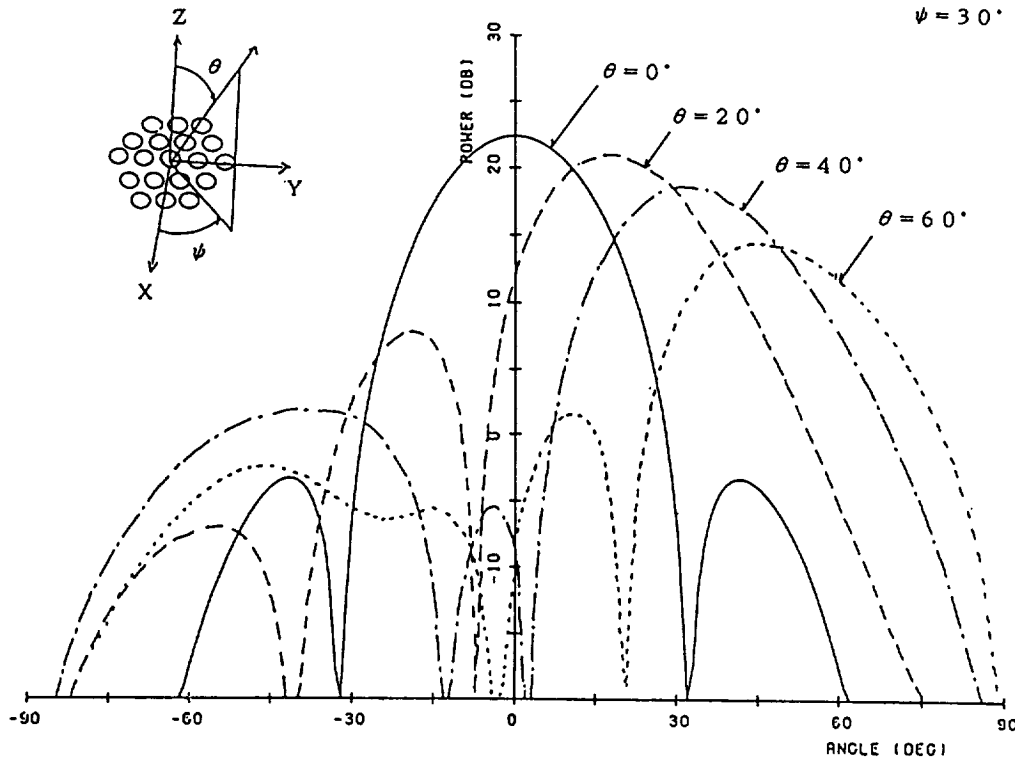


Fig.5 Calculated Radiation Patterns and Gains.

## VI. CONCLUSION

The phased array antenna for land vehicles is under development, and basic characteristics of a prototype are shown. The main aims of developing the phased array antenna are (1) to reduce the tracking error between receiving and transmitting frequencies, (2) to reduce a number of phase shifters in the feed lines and (3) to realize an array fed by electromagnetic coupling.

## REFERENCES

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