C-11-1 ETS-II MICROWAVE PROPAGATION EXPERIMENTS

Masaharu FUJITA*, Nobuyoshi FUGONO**, Risao HAYASHI* and Tasuku TESHIROGI**

*Kashima Branch, Radio Research Laboratories, Kashima, Ibaraki 314, Japan

**Radio Research Laboratories, Koganei, Tokyo 184, Japan

INTRODUCTION

The first Japanese geostationary satellite, Engineering Test Satellite Type-II (ETS-II: KIKU-2) was successfully launched from Tanegashima Space Center using N launch vehicle by the National Space Development Agency of Japan (NASDA) on February 23rd, 1977 and stationed at 130°E of geostationary orbit on March 5th, 1977. On this satellite, propagation experiment transmitter (PET) has been installed in compliance with the request of Ministry of Posts and Telecommunications to investigate the propagation characteristics of millimeter and quasi-millimeter wave along the earth-space link. This propagation experiments are closely related to the following communication experiments using the Experimental Communication Satellite of Japan (ECS), in which millimeter wave band is planned to be used. The satellite ETS-II has been controlled and monitored by NASDA using the VHF telemetry and command.

PET transmits three frequency radio waves of 1.7, 11.5 and 34.5GHz which are originated from a single crystal oscillator by multiplications of 96, 648 and 1944, respectively. These three frequency signals are, therefore, phase coherent to each other.

Using these signals, microwave propagation experiments have been conducted by the Radio Research Laboratories (RRL) since early May, 1977. The examples of such a high frequency propagation experiment are only ATS-5[1], ATS-6[2] and COMSTAR [3] project and this ETS-II project may give further valuable information on earth-space propagation of millimeter and quasi-millimeter wave.

RECEIVING FACILITIES

Three frequency signals from ETS-II are received by a 10mø modified Cassegrain antenna. This antenna was designed and constructed carefully for providing the high accuracy for reflector surface. Surface roughness of the main reflector was measured as 0.172mm rms at 90 degrees and 0.237mm rms at 45 degrees of elevation angle. Feedings of 34.5 GHz and 11.5GHz band are made through four-reflector beam waveguide with multi-flare horn as a primary feed. Dual polarization characteristic is provided to receive the co- (left hand circular) and cross- (right hand circular) polarization to measure the cross-polarization discriminations, which are affected by the rain-filled medium of propagation at such high frequencies. 1.7GHz is fed by the eight-element ring array of herical antennas located around the beam waist of the Cassegrain antenna. The diameter of this array has been chosen as the result of a compromize between the loss of aperture efficiency at 1.7GHz due to the spillover from the subreflector and the

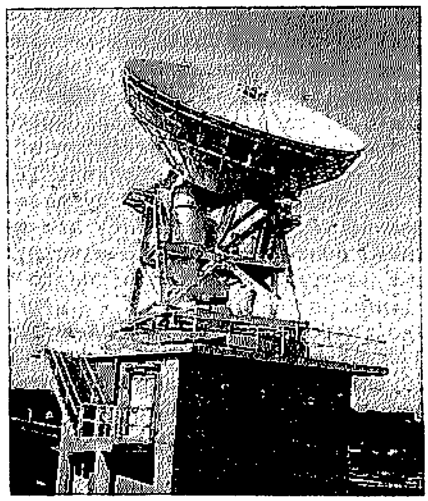

Fig.1 10mø earth station antenna.

loss of aperture efficiency at 11.5 GHz due to a blocking by the herical antennas.

The measured gains at the feeding points are 69.0, 60.1 and 40.2dB at 34.5, 11.5 and 1.7GHz, respectively. The cross polarization discriminations in the boresight direction at 34.5 and 11.5GHz are 32 and 33dB, respectively.

The autotracking of the satellite can be made at either 34.5 or 11.5GHz by use of the TM_{01} mode of a circular waveguide. The tracking frequency can be chosen automatically in accordance with the received field strength or by manual commands. The outer view of this antenna is shown in Fig.1.

The received signals (34.5GHz co- and cross-polarization components, 34.5GHz tracking error signal, 11.5 GHz co- and cross-polarization components, 11.5GHz tracking error signal and 1.7GHz co-polarization component) are introduced into frequency conversion sections, in which all signals are translated into an intermediate frequency of 140MHz with maintaining the phase relationship among them.

Receivers are prepared to measure field intensities of co- and cross-polarization components at 34.5 and 11.5GHz, and of co-polarization component at 1.7GHz. The receiver system has adopted the phase-lock-loop (PLL) technique with local oscillator signal reproduced from the received 1.7 or 11.5GHz signal by using the coherency of signals from ETS-II. Therefore, this experimental system operates under the supervision of a single crystal oscillator installed on the satellite. A wide dynamic range of level measurements are achieved over 35dB for the margin under severe attenuations due to precipitations.

The phase differences between co- and cross-polarization component at 34.5 and 11.5GHz are also measured to investigate the influence of precipitations on propagation characteristics. In addition, differential phase shift between the received signals of different frequencies are also measured by using the coherency among them. By this technique, total

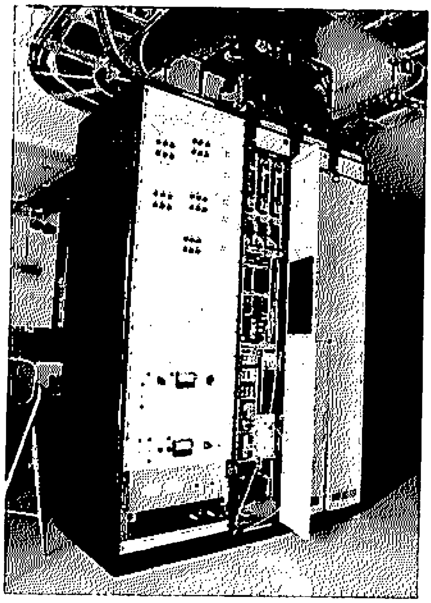

Fig.2 Frequency conversion sections (right) and Calibrator (left).

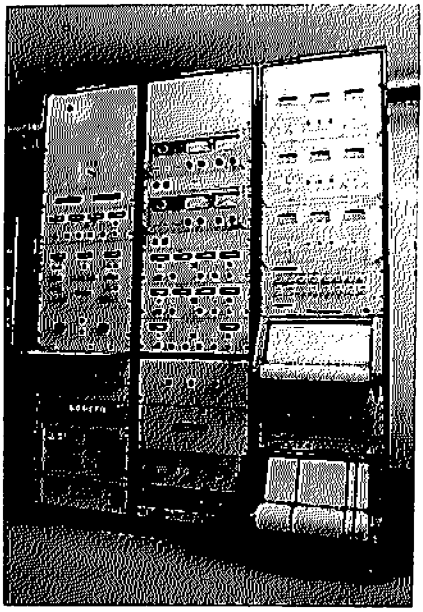

Fig.3 High sensitivity receivers (right and middle) and antenna control system (left).

electron content of the ionosphere along the propagation path can be measured without the influence of the geomagnetic field[4].

The levels of cross-polarization components are relatively measured to those of the co-polarization components by means of the AGC (automatic gain control) technique.

Calibrations of the received signals are made automatically by the command from the data processing computer.

The outer view of the frequency conversion sections and the calibrator is shown in Fig.2. Fig.3 shows the high sensitive receiver system and the antenna control system.

RAIN RADAR

To investigate the propagation characteristics of millimeter and quasi-millimeter wave in relation to the meteorological phenomena, especially precipitations, the rain radar has exhibitted the effective feature which is avairable to measure distributions of precipitations along and around the propagation path. To complete the propagation experiments using geostationary satellites, the specially designed rain radar has been introduced at the Kashima Branch, RRL. This radar is operated at 5.33 GHz with peak power of radiation of 250kw. Pulse width is 0.5μsec and radiation is made in 900pps. The control of an antenna (3mø parabolic reflector type) scanning is made by the computer, with which data processings of the radar are also made to calculate the rainfall rates from radar echo intensities. The data modes are CAPPI (constant altitude plan position indicator), RHI (range height indicator), Pm (path along a satellite and the Kashima earth station) and Ps (path along a satellite and a point other than Kashima).

The concept of these data modes is shown in Fig.4. These data are recorded on magnetic tapes, and also displayed on a color CRT. Computer control of the radar system makes the various data collection functions to be possible. The outer view of the radar system is shown in Fig.5.

OTHER INSTRUMENTS

In addition to the direct measurements of the satellite signals and the radar measurements of precipitations, other instruments have been prepared to investigate the correlations between the propagation characteristics and the meteorological phenomena.

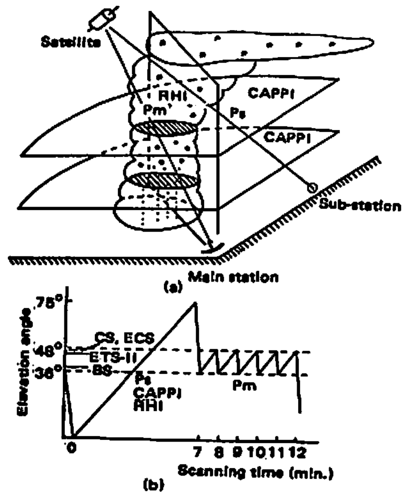

Fig.4 Rain radar scanning mode.

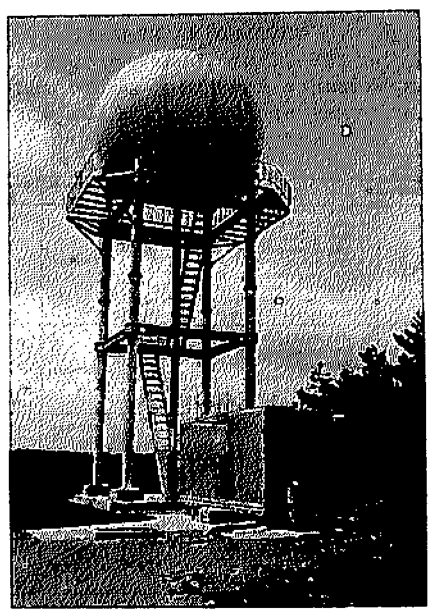

Fig.5 Outer view of the radar system.

These are 35.2GHz radiometer, quick response rain gauge, tipping backet rain gauge and other meteorological instruments.

DATA PROCESSING SYSTEM

The all data obtained are collected by the computer and recorded on magnetic tapes. The data on the satellite signals are sampled in 200msec interval. The quantization of the level data is made to be 1dB step. The phase difference data are also quantized to be 2 degrees step. The radiometer data are recorded with variable quantized level according to the observed quantities. The distributions of rainfall rate along the propagation path of the ETS-II and the Kashima earth station are also recorded, which are measured by the rain radar.

The other data from meteorological instruments are recorded on the same magnetic tape in one minute interval. In addition to them, the conditions of the antenna and status signals are written on the same magnetic tape for the benefit of the following data analyses.

The data recorded on magnetic tapes are shown in Table 1.

CONCLUDING REMARKS

The ETS-II microwave propagation experiments have been performed since early May of 1977 and which will be continued till early May of 1978. The experimental facilities described above are well functioned and some valuable data have been obtained not only for the tropospheric effect but also for the ionospheric effect on propagation characteristics of microwaves.

The facilities of the earth station (the antenna, the receiving system and the data processing system) are planned to be modified for the following communication experiments by use of the ECS of Japan after the completion of the ETS-II project.

Apparatus		Data	Measurement interval	Measurement range	Quantity unit
Receiver	PLL Receiver	34.5GHz co-pol. 34.5GHz cross-pol. 11.5GHz co-pol. 11.5GHz cross-pol. 1.7GHz co-pol. 34.5GHz co-/cross-pol. phase diff. 11.5GHz co-/cross-pol. phase diff. 1.7GHz co-/34.5GHz co-pol. phase diff. 1.7GHz co-/11.5GHz co-pol. phase diff.	200msec	0 ~ -40dB 0 ~ -40dB 0 ~ -30dB -180°~+180°	1dB 1dB 1dB 2°
	AM Receiver	34.5GHz co-pol. 34.5GHz cross-pol. 11.5GHz co-pol. 11.5GHz cross-pol. 1.7GHz co-pol. 11.5GHz co-/cross-pol. phase diff.	200msec	0 ~ -50dB 0 ~ -40dB 0 ~ -30dB -180°~+180°	1dB 1dB 1dB 2°
Radio-meter		35.2GHz atm. noise temperature	200msec	160°K~70°K 70°K~40°K 40°K~ 0°K	5°K 3°K 1°K
Rain radar		Pa mode CAPPI mode RHI mode Pe mode	1min. 12min.	0~150mm/hr	0.1mm/hr 10 steps 0.1mm/hr
Meteoro-logical instru-ment		Wind speed and direction Ground temperature Humidity Atmospheric temperature Precipitation rate	1min.	0~100mm/hr	

Table 1. ETS-II Observation data.

ACKNOWLEDGEMENTS

The authors wish to express their thanks to Mr.K.Ikushima, director of the Kashima Branch, Dr.T.Ishida, chief of artifitial satellite research division for their supports and encouragements. Thanks are also given to Drs.H.Tanaka, K.Yoshimura and Messrs.H.Komuro, S.Kimura for their efforts in planning the facilities.

REFERENCES

[1] L.J.Ippolito, Proc.IEEE, 59, pp.189-205, Feb. 1971.

[2] L.J.Ippolito, IEEE AES-11, pp.1067-1083, Nov. 1975.

[3] J.M.Harris and G.Hyde, COMSAT Tech. Rev., 7, pp. 599-624, Fall 1977.

[4] J.Awaka and M.Fujita, J. atmos. terr. Phys., 39, pp.1441-1446, Nov./Dec. 1977.