MILLIMETER WAVE PROPAGATION EXPERIMENT WITH GEOSTATIONARY SATELLITE ETS-II OF JAPAN

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ABSTRACT

Engineering Test Satellite Type II (ETS-II) [Kiku-2] was successfully lifted off on February 23, 1977 and stationed at 130°E of the geostationary orbit on March 5, 1977.

This paper will introduce outline of the experimental system and preliminary results using the data until end of the August, for over three thousand hours of test time.

Introduction

ETS-II is the first Japanese geosynchronous satellite launched by N-launch vehicle of National Space Development Agency of Japan (NASDA) from Tanegashima Space Center. ETS-II was planned by NASDA to acquire the technique to launch a satellite into geostationary orbit by N-launch vehicle.

A beacon transmitter in three coherent frequencies, 1.7, 11.5 and 34.5 GHz, is installed in compliance with the request of Ministry of Posts and Telecommunications (MOPT). Radio Research Laboratories (RRL/MOPT) conduct propagation experiment with the beacons as a preliminary experiment of Experimental Communication Satellite (ECS) program of Japan which is initiated by RRL/MOPT and is planned to investigate the possibility of satellite communication in millimeter wave. ECS is expected to be launched in February 1979.

Propagation Experimental Transmitter (PET)

The block diagram of PET is shown in Fig. 1. The original signal of PET is generated by a master crystal oscillator in 17.76 MHz. The signal is multiplied up to 1.7 GHz, 11.5 GHz and 34.5 GHz and fed to each mechanical despun antenna (MDA). The 1.7 GHz and 34.5 GHz signal circuits provide 100% AM modulation in 300 Hz by command to improve the margin of the receiving system for 34.5 GHz in case of a heavy rain.

Receiving System

The experimental system is located at the Kashima branch of RRL. The system is composed of a main receiving station, a rain radar, a radiometer, meteorological instruments and data processing computers as shown in Fig. 2.

The main receiving station is equipped with a modified Cassegrain type antenna of 10 meters in diameter with four reflector beam guided feeding. This antenna was carefully designed and constructed for use in the millimeter wave range. The surface roughness of the main dish of the antenna is measured as about 0.17 mm r.m.s. at 90° elevation angle and 0.25mm r.m.s. at 45°.

The calibrated gain measured with the satellite beacon is 69.7 dB for 34.5 GHz, 60.8 dB for 11.5 GHz and 40.2 dB for 1.7 GHz.

The 1.7 GHz signal is fed with the 8 element helical antennas which are arrayed around the beam waist of the higher frequencies. The two-channel auto-tracking system utillizes the radiation pattern of the TM_{01} mode at 34.5 GHz or 11.5 GHz signal.

The on-board original frequency is reproduced from the received 1.7 or 11.5 GHz signal and is used as the reference frequency of the receiving system, in order to eliminate doppler effect of the beacons, to compensate fluctuation of the on-board oscillator, to detect phase differences between the beacons of the different frequencies and to improve the rain margin of 34.5 GHz. Fig. 3 shows the block diagram of the circuit.

The summary of the characteristics of the receiving system is shown in Table 1.

From estimated link budget of the experimental system with ETS-II, the rain margin of 34.5 GHz is expected as 31 dB in the CW mode and 47 dB in AM mode.

Rain Radar

A C-band rain radar was designed to have unique functions in order to obtain more accurate information of the meteorological condition along and around the radio wave path from the satellite to the earth station. Pm-mode operation of the rain radar measures rain intesity of every 250 meters along the path between satellites and the main station. Ps-mode measures intensity of every 250 meters along the path between satellites and any other earth station within 50 Km away from the main station. CAPPI (Constant Altitude Plan Position Indication) mode shows horizontal patterns of rain intensity of any two heights within 50 Km radius range with 1 Km accuracy. RHI (Range Height Indicator) mode shows a vertical pattern of rain intensity of any azimuthal direction within 50 Km in range and 15 Km in height. The operation scheme of the rain radar is illustrated in Fig. 4.

Preliminary Reaults of Experiments

The experiment is being operated on a 24th hour/day basis, except for the time which is necessary for range measurements and for maneuvering to keep the position of the satellite. The tests of the continuous propagation experiment started on April 18, and regular operation began on May 9.

An Example of Operation during Heavy Rain

On August 13 and 14, there was heavy rain around the main station. The occasional large attenuation of miliimeter waves up to 30 dB was observed. An example of data in heavy rain from the afternoon on 13th to the morning on 14th of August is shown in Fig. 5. From the upper raw, attenuation in 34.5 GHz, cross polar discrimination in 34.5 GHz, rain rate by specially designed high response rain gauge at the receiving antenna, sumof rain along the radio wave path below the bright band measured by Pm-mode of rain radar and that of the total path. Since it is expected that the attenuation of millimeter waves by rain occurs mainly below the bright band, the sum of rain intensity along a radio wave path below the bright band is shown as SIGMA-PM (Below B.B.) in the figure. It is observed in the figures that correspondence of attenuation in 34.5 GHz with SIGMA-PM (Below B.B.) is better than that of SIGMA-PM (Total).

The time variation of the millimeter wave attenuation agrees very well to the sum of rain intensity by

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rain radar, however, not so well to the rain intensity by rain gauge.

Correlation with the Σ-Pm Data and the Rain Gauge Data

Fig. 6 shows the scattergrams of the attenuation of 34.5 GHz signal versus Σ-Pm data below the bright band. As observed in Fig. 5, the peak for rain intensity in the rain gauge data is a few minutes after the peak of 34.5 GHz attenuation. It is observed that correlation between 34.5 GHz attenuation and rain gauge data with a 3 minutes delay is rather better than that of the 0 minutes delay data, in either case, the data are very scattered and do not greatly correlate with each other as compared with that of Σ-Pm data.

Depolarization

Results of the depolarization measurement of 34.5 GHz is shown in Fig. 7. Solid lines show theoretical curves (Ref. 1). σ is the standard deviation of the raindrop canting angle. Fairly good agreement between the theoretical curve and measured data is observed except for the data of high attenuation.

Fading Distribution

Attenuation distribution curves in 34.5 GHz of the each month are shown in Fig. 8. In the worst month, the percentage of time in which measured attenuation exceeded 20 dB and 10 dB are 0.25% and 1%, respectively. For the total observation period, the figures are about 0.07% and 0.3%, respectively.

Fig. 9 shows the distribution of fading through the day, averaged over the days.

Effects of Ionosphere

Besides above described atmospheric and meteorological related results,some results of propagation characteristics which are caused by the ionosphere, have been obtained.

As is described above, the beacons in three frequencies are transmitted in keeping phase coherency to each other and phase coherent receivers are used to eliminate the differential phase shift due to satellite motion. Therefore, the measured differential phase shift between the two frequencies is due to the characteristics of the propagation media, that is ionosphere, atmosphere and rain. The differential phase shift due to the ionosphere is far larger than that of others.

Since the range of variation of the differential phase shift by ionosphere is very large, it is expected that high sensitive measurement of total electron content of the ionosphere is available using the coherent beacons.

Scintillation of 1.7 Ghz beacon has been frequently observed at night. The peak of the occurrence appears around ten o'clock at night of the local time.

Concluding Remarks

Following to the ETS-II experiment, ECS program is under progress as described above. ECS has a K-band transponder of 35 GHz for up-link and 32 GHz for down-link. The series of program of ETS-II/ECS is planned for satellite communication experiments in millimeter wave. Data obtained by ETS-II are to be very valuable for ECS program. Data analysis which includes that of rainy season of Japan in June and July, thunder storm and typhoon in the summer are in progress.

The experiment would last in May 1978.

The data will be issued as routine reports in daily, weekly and monthly basis. Special issues will be also prepared in case of heavy rain. The data will be available to anyone who intends to use them.

Acknowledgment

The authors express their gratitude to many people of RRL, NASDA and other agencies and corporations who have co-operated to this program.

Reference

1. Laws J.O. and Parsons D.A.,The relation of raindrop-size to intensity, Trans. Am. Geophys. Union, vol. 24, 1943.

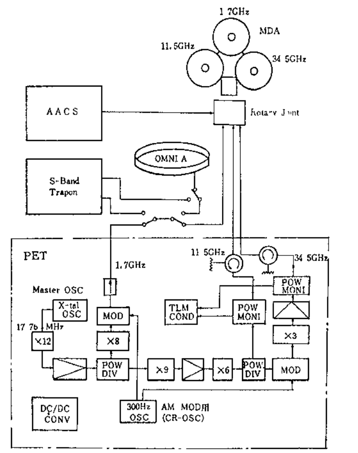

Fig.1

Block Diagram of Propagation Experiment Transmitter

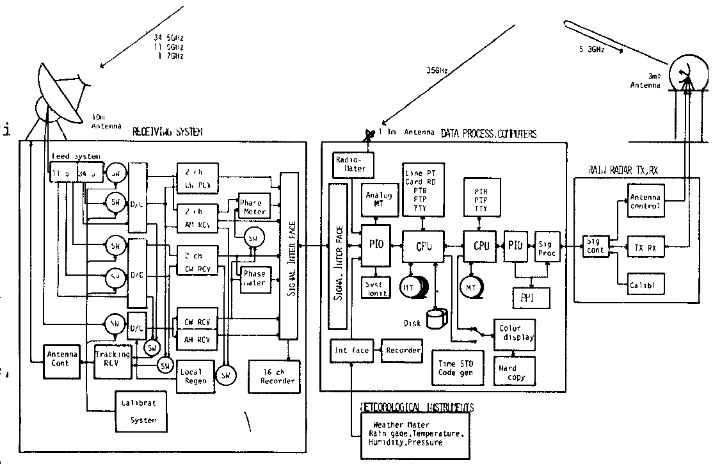

Fig.2 Block Diagram of Earth Station

Table 1

Summary of Characteristics of Receiving System

Items		34 5 GHz ch	11 5 GHz ch	1 7 GHz ch	Remarks
Receiving Freq (MHz)		34562 5±3 5	11508 75±1 15	1705 0±0 70	
Antenna	Gain (dB)	69 5	60 8	40 2	Feeder loss is inclded
	Noise temperature(K)	64	57	142	El angle 45° Feeder loss is included
	Disclim of X-pol (dB)	32	33		
	3 dB Beam width ( )	0 06	0 15	1 03	34 5, 11 5 4 Ref Beam Feed 1 7 6 Elem Hel Ant
High Sens Receiver	Rec Level (dBm)	CW -90~-131	CW -90~-134	CW -110~-142	Min Values are equal to threshold level
	Noise Figu (dB)	Co-pol ch 7 85 X-pol ch 7 56 Error ch 7 72	Co-pol ch 5 3 X-pol ch 5 7 Error ch 5 6	Co-pol ch 1 9	
	Gain Stb	0 1 dB/hr 0 3 dB/day	0 1 dB/hr 0 3 dB/day		
	In-Out Stb	less than 0 2dB	less than 0 2dB		Input level -90 -130dBm
	Band Width (Hz)	CW 500,1K,3K AM 1 or 5	CW 100,500,1K	CW 50,100,1K AM 1 or 5	

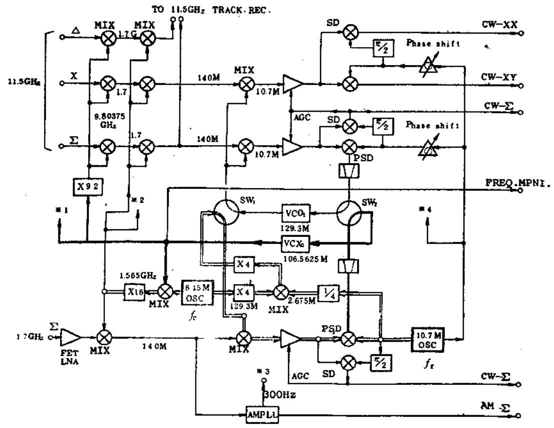

Fig. 3 Block Diagram of Local Signal Reproducing Circuits

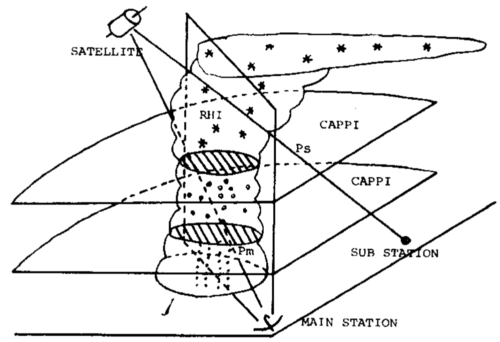

Fig. 4 Operation Mode of Rain Radar

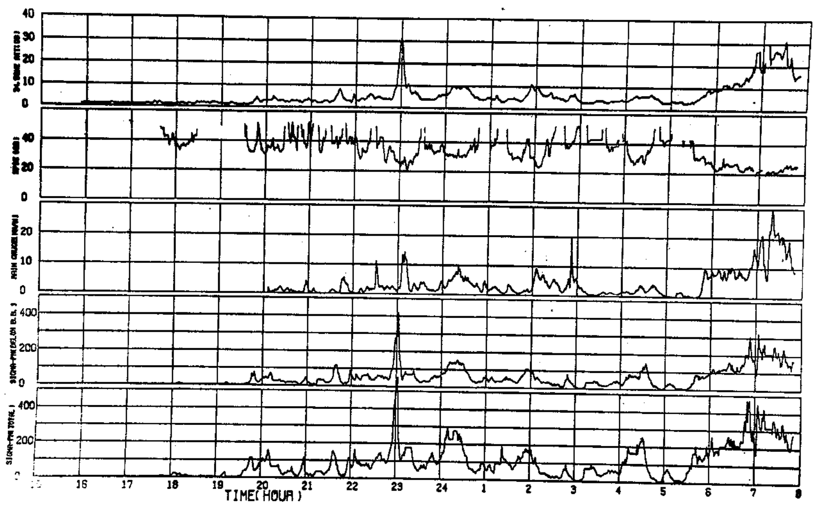

Fig. 5 Experimental Results

34.5 GHz Level and Rain Distribution (Σ-Pm) From Aug. 13 to Aug. 14

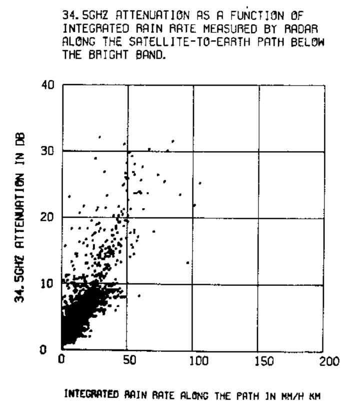

Fig. 6

34.5 GHz Attenuation versus Σ-Pm (below B.B.)

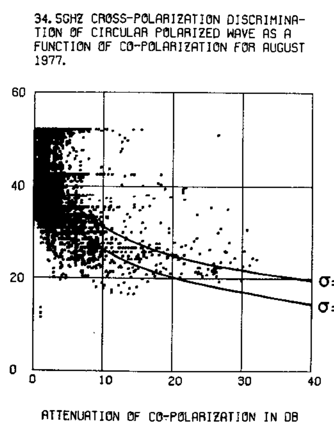

Fig. 7 34.5 GHz Cross-polalization Discrimunation versus 34.5 GHz Attenuation

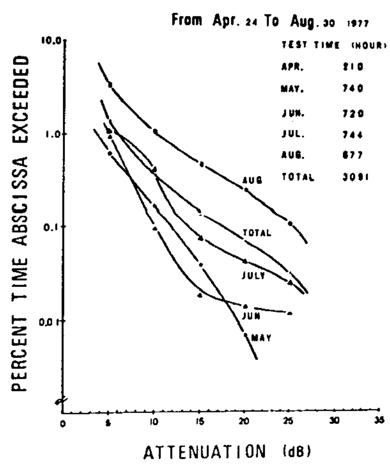

Fig. 8 Distribution curve of Attenuation of the each Month

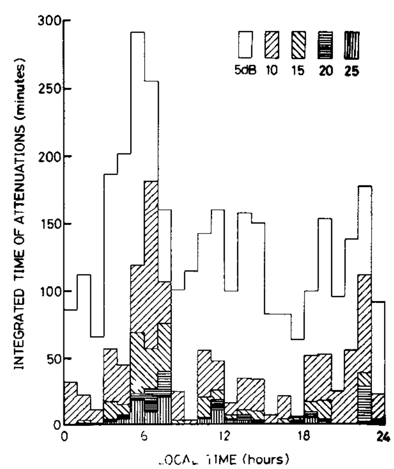

Fig. 9 Distribution of Fading through the Day