A PROPAGATION EXPERIMENT ON EARTH-SPACE PATHS OF LOW ELEVATION ANGLES IN THE 14 AND 11 GHZ BANDS USING THE INTELSAT-V SATELLITE

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1. INTRODUCTION

It is essential to investigate the propagation impairment of the Earth-space paths of low elevation angles in designing an international satellite communication link. To further such investigation, a propagation experiment using the INTELSAT-V satellite is being conducted in Japan. The subjects being studied include: rain attenuation characteristics in the 14 and 11 GHz bands; cross-polarization characteristics in the 11 GHz band ; atmospheric scintillation in the 14 and 11 GHz bands; and the site diversity effect. Some results obtained so far are described in this paper.

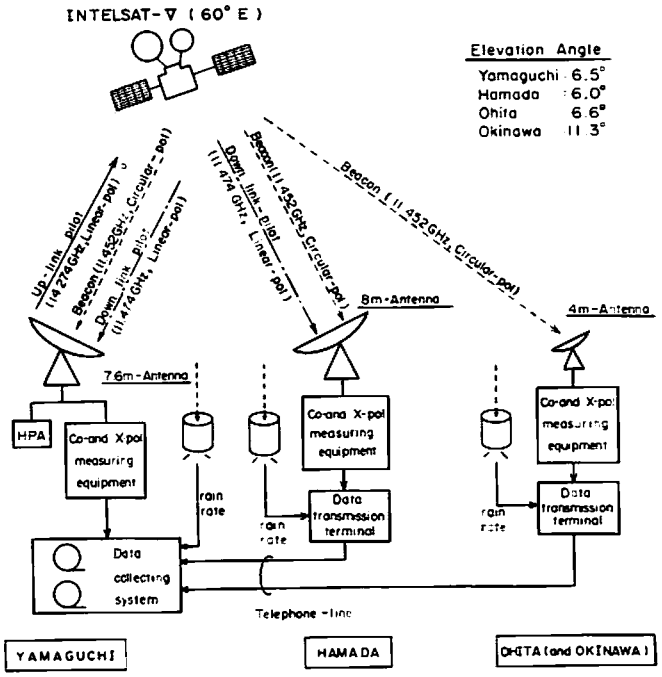

Fig. 1 Configuration of Experimental System

2. CONFIGURATION OF THE EXPERIMENTAL SYSTEM

The whole experimental system is shown in Fig. 1. The 14.274 GHz up-link pilot signal is transmitted from Yamaguchi, and the 11.474 GHz down-link pilot signal is received at Yamaguchi and Hamada. In addition to the pilot, an 11.452 GHz beacon signal is also measured at these two sites. Thus, the difference of the received level variation between the beacon and the pilot level can be considered as the level variation in the 14 GHz band. Beacon measurements were also carried out in Ohita and Okinawa as shown in Fig. 1. Concerning received signals in the 11 GHz band, co-pol, cross-pol levels and the phase between them are being measured in each site to obtain the cross-polarization degradation data. All the data, including the antenna pointing data, status of PLL-receiver, etc., were recorded on magnetic tape in Yamaguchi.

3. RESULTS OF THE EXPERIMENT

3.1 Atmospheric Scintillation

Signal level variation has been observed throughout the entire period of measurement. It is considered

to be atmospheric scintillation, based on the following facts observed under clear sky conditions:

(1) Level fluctuations vary with the elevation angle of the antennae;

(2) Level fluctuations become large in summer and small in winter;

(3) The distribution of level fluctuation is almost Gaussian;

(4) The power spectrum of signal level variation is approximately proportional to f (f: frequency) as is expected for atmospheric scintillation.

Figure 2 shows the diurnal variation of the received beacon level fluctuation (11.452 GHz, Yamaguchi) in February and August. The measured r.m.s. values of the level fluctuation clearly depend on the season and averaged r.m.s. values, 0.83 dB in August and 0.29 dB in February, are comparable to estimated value of 0.56 dB for a year.

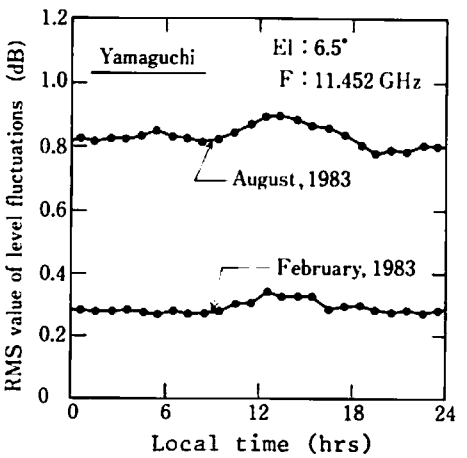

Fig. 2 R.M.S. Value of the Beacon Level Fluctuations under Clear Sky Condition in Summer and Winter

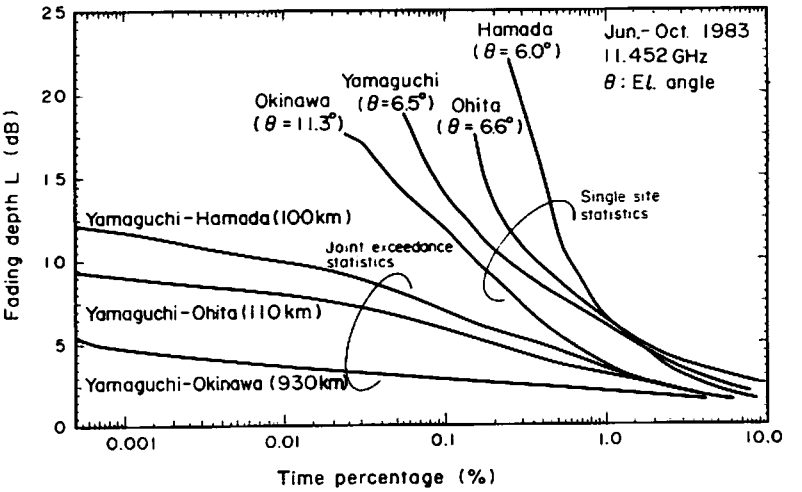

Fig. 3 Cumulative Distributions of 11 GHz Fading at Yamaguchi, Hamada, Ohita and Okinawa (Single Site Statistics and Joint-exceedance Statistics)

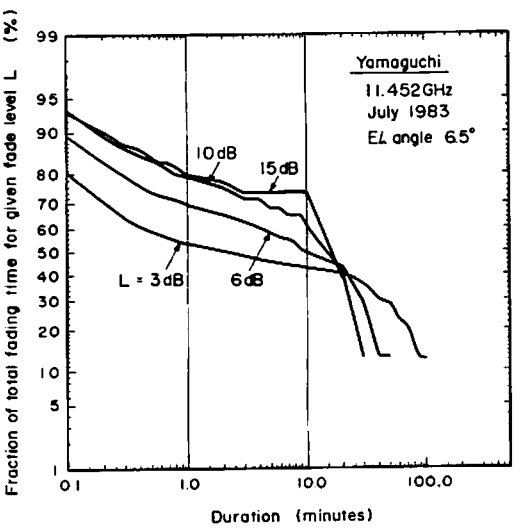

Fig. 4 Duration Statistics of 11 GHz Fading in the Worst Month

3.2 Rain Attenuation

Rain attenuation and atmospheric scintillation were frequently observed occurring simultaneously in the measurement. Hereafter, they are called 14 or 11 GHz fading.

The cumulative distributions of 11 GHz fading are shown in Fig. 3. Five months data, which have been reduced here, include almost all the large rain attenuation in the year of 1983. The record-breaking heavy rain at Hamada during the period from 23 - 26 July, 1983 appears clearly in the cumulative distribution curve.

Duration statistics of fading of the Yamaguchi beacon level in the worst month are given in Fig. 4. In that month, the total fading times of the fading depths L of 3, 6, 10 and 15 dB were 2912, 862, 238 and 75 minutes, respectively. The fraction of total fading times (%) of small durations is rather large because of the influence of atmospheric scintillation.

It will be necessary to investigate the detailed characteristics of rain attenuation and atmospheric scintillation separately. Several methods, such as the moving average procedure, by which the fluctuation component due to atmospheric scintillation is smoothed, seems to provide good results.

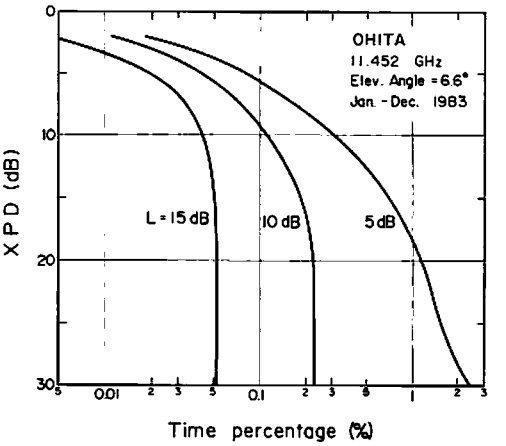

Fig. 6 Cumulative Distributions of 11 GHz XPD for Copolar Attenuation of 5, 10 and 15 dB (Polarization: Circular)

3.3 Cross-polarization

Figure 5 shows the results of cross-polarization measurement in the 11 GHz band (circular polarization) at three sites. The top three curves in the figure represent the cumulative distributions (single-site statistics) of XPD for Yamaguchi, Ohita and Okinawa, respectively. In the experiment, severe reductions in XPD to about 0 dB were frequently observed, which indicate that circular polarization may be distorted to a linear polarization, or even to a slender ellipse with the opposite sense of rotation. The values of XPD for 0.01% of a year are -2, +2 and +2 dB for Yamaguchi, Ohita and Okinawa, respectively.

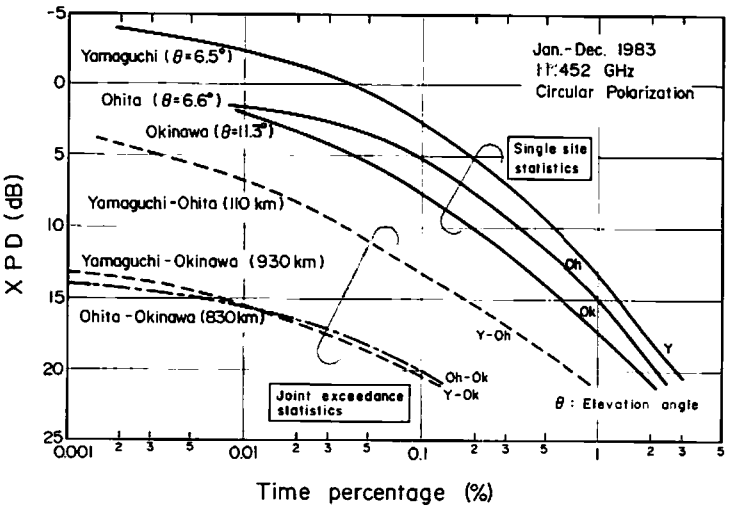

Fig. 5 Cumulative Distributions of 11 GHz XPD at Yamaguchi, Ohita and Okinawa (Single Site Statistics and Joint-exceedance Statistics)

Joint statistics for attenuation and XPD will be required to provide fundamental information for designing a dual-polarized operation at

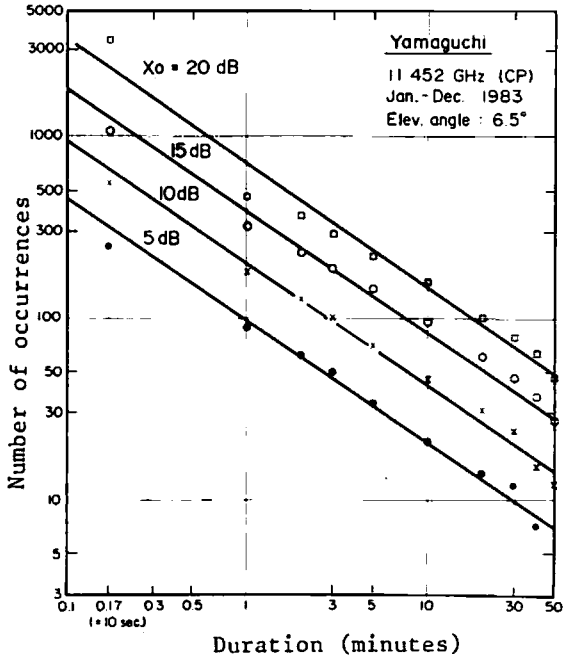

Fig. 7 Duration Statistics of 11 GHz XPD (Polarization: Circular)

frequencies of about 10 GHz. The XPD-attenuation joint statistics presented here are derived from the 11 GHz data at Ohita. Figure 6 shows the cumulative probability of XPD under the condition that the fading depth L at 11 GHz exceeds 5, 10 or 15 dB. The curve for L ≧ 5 dB is somewhat different from other two curves in that it indicates the predominance of a small depolarization with XPDs greater than 20 to 30 dB. This may be due to the fact that severe atmospheric scintillation exceeding several decibels frequently occurs at such a low elevation angle condition, which does not necessarily induce severe XPD degradations.

Figure 7 shows the duration statistics of 11 GHz XPD for the values of XPD (X_0) = 20, 15, 10 and 5 dB.

3.4 Site Diversity Effect

Joint-exceedance statistics of the 11 GHz fading are shown as the three curves in Fig. 3. The three curves at the bottom of Fig. 5 represent the joint-exceedance statistics of XPD between Yamaguchi, Ohita and Okinawa. By employing the site diversity with such a long separation, the residual depolarizations are greatly reduced. Values of XPD for 0.01% of a year are about 7 dB in the joint XPD statistics between Yamaguchi and Ohita, and 15 to 16 dB between Yamaguchi and Okinawa and between Ohita and Okinawa.

4. CONCLUDING REMARKS

Concerning the propagation experiments in the 14 and 11 GHz bands under low elevation conditions, results such as the cumulative time distributions of 11 GHz rain attenuation and XPD, duration statistics, joint statistics of fading and XPD and site diversity effect were described here. Though the reduction of data is being undertaken, more effort as to the 14 GHz fading statistics, atmospheric scintillation characteristics as well as the analysis performed so far seems to be important to clarify the propagation impairments under low elevation conditions.