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MEASUREMENTS OF 11 AND 18 GHz RADIO WAVE ATTENUATION DUE TO RAINFALL AT HIGHER ANGLES OF ELEVATION

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Introduction

An 11 and 18 GHz sun tracker has been installed at the Electrical Communication Laboratory (ECL) in Musashino city and measurements of attenuation of solar radiation due to rainfall have been conducted since June 1969. This equipment has two antennas, one is directed toward the sun (for sun noises) and the other is off beamed by few degrees from the sun (for sky noises). Not only sun noises and sky noises but also rainfall attenuation which is obtained by electronical subtraction of sky noises from sun noises, are recorded on a multitrack recorder. The measuring range is about 30 dB (both 11 and 18 GHz). Ten raingauges have also been set up in Musashino, Mitaka and Chofu cities in the area south of the ECL and rainfall rate in these 10 points are simultaneously recorded on a typewriter and papertape for any time interval of from 10 to 60 seconds. For the purpose of obtaining the space correlation of rainfall attenuation, data from the 17 GHz radiometer installed at Tokyo Astronomical Observatory (TAO) 5.5 km southwest from the ECL has been used.

Rainfall Attenuation

Most heavy rainfalls occur in the summer season of July, August and September in Japan. Figure 1 shows a cumulative distribution of rainfall rate and attenuation. All attenuation data has been collected only for the daytime. Also, path elevation angles exceed more than 30 degrees from the horizon. These data have been converted into the elevation angle of 45 degrees. According to long term rainfall rate observation, heavy rainfalls occur from evening to night in the Musashino district, therefore the cumulative probability for a total summer season period rainfall attenuation will be more severe than the value of the same probability in Fig.1. Instantaneous correspondence between rainfall attenuation and path rainfall rate along the antenna beam path has not been too close, but cumulative distribution curves have been well coincided. In Fig.1, the attenuation ratio of 11 and 18 GHz at the same probability is about 1:3, and this value corresponds to the theoretically calculated rainfall attenuation coefficient ratio at 12.5 mm/hr. From weather radar observation reports of Aerological Reserch Institute (ARI), the scales of summer rainfall cells show that the average ceiling is about 5 km high and the rainfall area covers several kilometers. If horizontally stratified rainfall cells are assumed, then the antenna beam crosses about 7 km with rainfall cell at a beam elevation angle of 45 degrees. The 0.01 % value of rainfall rate is 36 mm/hr in Fig.1, and theoretical rainfall attenuation coefficient for 11 GHz is 1.2 dB/km at this rainfall rate. Therefore, rainfall attenuation of 8.4 dB derived from attenuation coefficient and path length closely agrees with observed 11 GHz rainfall attenuation of 8 dB.

Mean Absorption Temperature

It is necessary to obtain mean absorption temperature when estimating rainfall attenuation from sky noise temperature. Therefore, the mean absorption temperature has been calculated using the sun tracker's data and a value of 275°K has been obtained for the mean absorption temperature. Employing this result, rainfall attenuation at TAO have been calculated for the estimation of space diversity effect.

Path Diversity

If the probability distribution of rainfall attenuation and correlation coefficient of two propagation paths have been made clear, then the path diversity performance can be estimated from them. Probability function of rainfall attenuation X ($X=\gamma\int R^{\alpha}dx$, dB) was derived from probability distribution of rainfall rate was measured. In this derivation, it was assumed that the zero degree layer is the rainfall ceiling. Using measured data of the space rainfall rate correlation coefficient, space correlation coefficient of X (rainfall attenuation) has been calculated for any elevation angle and propagation path length. From empirical investigation of rainfall rate and theoretical investigation of two dimensional Γ-distribution (X can be closely approximated by Γ-distribution function), the relation of correlation coefficient and path diversity performance have been derived. Applying the above relation, path diversity effects were estimated for any elevation angle and propagation path. Figure 2 is an example of path diversity effects for a path separation of 5.5 km and an elevation angle of 45 degrees. The path diversity effect shown in Fig.3 has been estimated from rainfall attenuation measured at ECL and TAO August 19, 1970. The correlation coefficient of rainfall attenuation for these two places is about 0.38 (long term correlation coefficient will be about 0. 7) and path diversity gain is about 3 dB at 0.5 % of cumulative probability value. This 3 dB value coincides well with theoretically estimated values derived from rainfall rate correlation. The rainfall on August 19 was a local shower and had a maximum rainfall rate of 9 and 21 mm/hr at ECL and TAO, respectively. However, no attenuation differrence is found between these two cumulative distribution curves.

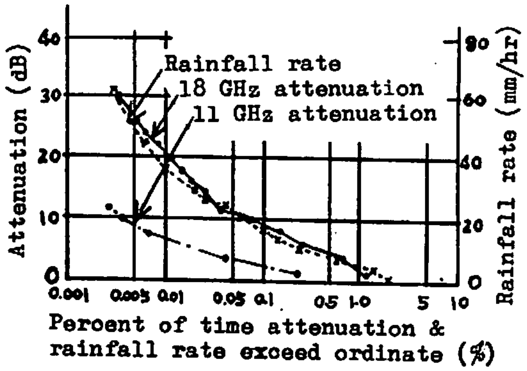

Fig.1 Cumulative distribution of rainfall rate and attenuation

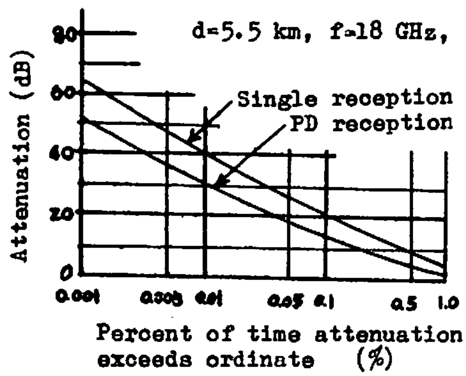

Fig.2 Estimated cumulative distribution of space diversity effect

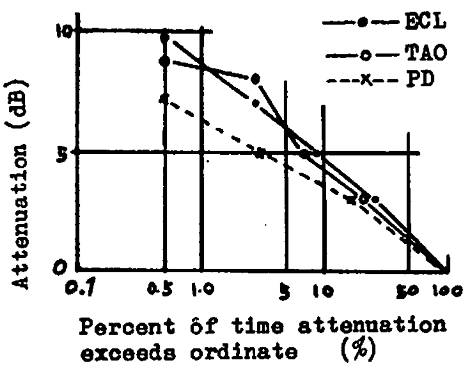

Fig.3 Cumulative distribution of space diversity effect