2-IV C3

# EXPERIMENTAL STUDIES FOR MICROWAVE PROPAGATION ON OVERSEA LINE-OF-SIGHT PATH

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## Introduction

Synthetic measurements on microwave propagation were carried out in summer of 1970 on a 37.2 km oversea path between Oshima Island and the Izu Peninsula in south-western area of Tokyo. This paper is concerned with statistical analyses of the transmission loss at frequencies of 4 and 7 GHz, effective reflection coefficient of the sea surface, and equivalent earth's radius factor over the test path. The results of measurements at the same time about thermal and distortion noise are reported in another paper.

## Test path

The test path is completely over the sea as shown in the path profile of Fig.1. Transmitting and receiving antenna heights are about 190 and 30 m above the sea level respectively. The calculated value of the path-length difference between direct and reflected wave is 21.4 cm, height-pattern pitch of the received signal is 5.8 m at 7 GHz, and the difference of incident angles between direct and reflected waves at transmitting and receiving antenna are 0.09 and 0.44 degree respectively, under the propagation condition in the standard atmosphere.

## Experimental Arrangements

Measurements were carried out from July 22nd to August 31st in 1970. The transmission loss at frequencies of 4 and 7 GHz were continuously recorded during the whole test period. Characteristics of the reflected wave from the sea surface were measured using two methods, height-pattern of the received signal and frequency-sweep technique over the range of 18-22 GHz. The height-pattern was recorded in each hour and the photographs of frequency-pattern was taken in each minute. Transmitting and receiving antennas were paraboloids with the diameter of 3.3 m for 4 GHz and 1.2 m for 7 GHz.

## Results

Cumulative distribution curves of the transmission loss at 4 and 7 GHz during the whole test period are shown in Fig.2. These distributions are different from each other at the lower levels of transmission loss. The distribution at 7 GHz is approximately same as Rayleigh distribution, but that at 4 GHz shows larger attenuation than Rayleigh fading. In order to make clear these phenomena, the distributions of the transmission loss of 7 GHz at three antenna heights with the interval of 3 m are compared. These results are given in Fig.3. It is seen in this figure that the distributions of the transmission loss received at each antenna are different. Furthermore, close correlation could not be found between the daily fading range and daily average of the effective reflection coefficient of the sea surface. With the results mentioned above, if we consider the nonuniformity of statistical received signal distributions with antenna height due to variation of the refractivity gradient of the atmosphere, it is seen that this nonuniformity is more effective to the variation of the transmission loss than the frequency dependence of the effective reflection coefficient.

Statistical analyses about diurnal fading range shows that occurrence of deep fading was relatively high in the daytime. Cumulative distribution of fade duration is approximated by log-normal distribution.

Fig.4 shows the distribution of the effective reflection coefficient, $\rho_e$, at 7 GHz during the whole test period. $\rho_e$ is dispersed in a wide range from 0.15 to 0.95 and the median value was 0.69. The sea surface roughness in regard to the median value is equivalent to 0.75, taking into account of the divergence factor of spherical earth's surface and specular reflection coefficient. On the other hand, $\rho_e$ measured at 20 GHz band varies from 0.05 to 0.9 with a median value of 0.31. The ratio of these median values which represents the frequency dependence of $\rho_e$ is equal to about 2. In the windy periods the effective reflection coefficient was usually smaller than the median value due to effect of the surface roughness.

Cumulative distribution of the effective earth's radius factor, $K_e$, obtained from the height-pattern of received signal is shown in Fig.5. $K_e$ is distributed over a wide range from 0.5 to -1.5 and has the median value of 1.6. This median value agrees with the value estimated from the investigation on radio meteorology in Japan. When $K_e$ was negative, height-pattern of the received signal usually kept regular feature due to interference of two components of radio waves. This result shows that the test path was covered by surface ducts. It is also found that there is no close correlation between $\rho_e$ and $1/K_e$.

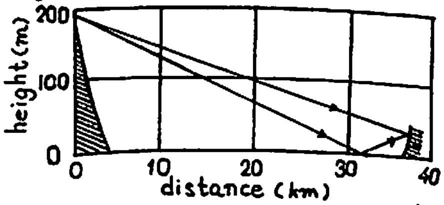


Fig.1 Profile of Test Path (K=4/3) (transmitting and receiving antenna heights are 190 and 30 m, path distance is 37.2km).

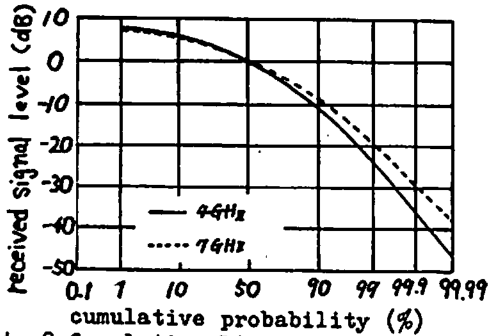


Fig.2 Cumulative Distributions of Transmission Loss.

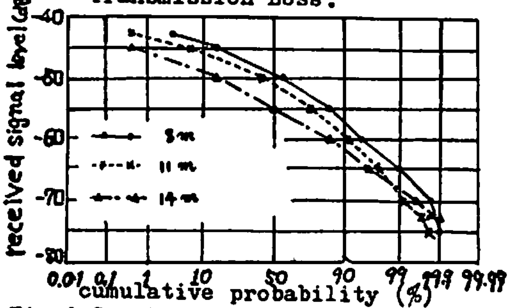


Fig.3 Cumulative Distributions of Received Signal at Each Antenna.

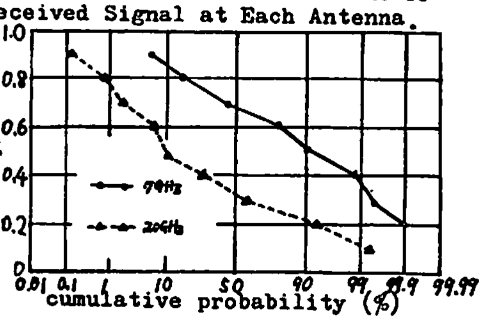


Fig.4 Cumulative Distributions of Effective Reflection Coefficient, $\rho_e$.

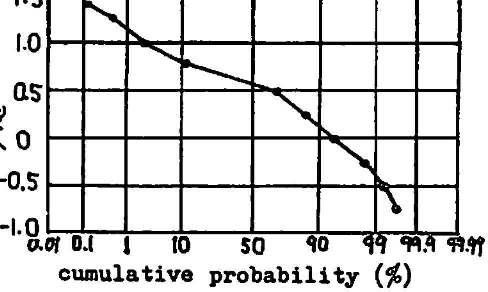


Fig.5 Cumulative Distribution of $1/K_e$.