PROPAGATION CHARACTERIZATION FOR LONG-SPAN OVER-WATER DIGITAL MICROWAVE SYSTEMS

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1. Introduction

In a long-span over-water path where a reflected wave exists, fading occurs frequently because of the long distance, the radio climate, and the interference between the direct and reflected waves. As circuit quality is provided by time percentage for the worst month, it is important to predict received power distribution of that month for designing systems.

In digital radio systems a wide frequency band is used and in-band linear amplitude dispersion is an important parameter to estimate the bit error rate. This parameter has been studied for propagation paths the lengths of which are about less than 60km and the following result is obtained that the calculated and measured distributions of this parameter are in close agreement.(1) However, when a path length is longer and an effect of a reflected wave is strong, a distribution of this parameter has not been clear.

As digital radio systems also use dual polarizations, cross-polarization amplitude characteristics and XPD characteristics become important, as do co-polarization amplitude characteristics for designing a cross-polarization interference canceler. However these characteristics has not been clear.

This paper describes the received power distribution for the worst month, in-band amplitude characteristics and in-band linear amplitude dispersion characteristics, which are based on data measured on a long-span over-water propagation test.

2. Outline of propagation test

The propagation test was conducted on a 93.8km over-sea path from August, 1982 through July, 1984. In this propagation test span, the reflected wave from the sea exists and propagation conditions are very severe. Transmitting antenna height and receiving antenna height above sea level are so high that the path difference between the direct and reflected waves is considerable. When the effective Earth's radius factor k is assumed to be 4/3, it is about 7.7m.

From a transmitting station, a 4550±30MHz frequency swept signal and a 4610MHz continuous wave (CW) signal were transmitted by a 3.3m diameter parabolic reflector antenna at a horizontal polarization. The frequency swept signal was scanned by a 25Hz sinusoidal wave.

At a receiving station, two receiving antennas, which were the same as the transmitting antenna, were used with a 2.5m vertical interval. 60MHz band horizontal polarization (co-polarization) and vertical polarization (cross-polarization) amplitudes were measured for each antenna by four phase-locked type receivers. The CW signal was received at dual polarizations and XPD was measured using a network analyzer. Measurement blockdiagram is shown in Fig.1.

3. Received power distribution for the worst month

The co-polarization received power distribution for the worst month, observed through August, 1983, is shown in Fig.2. The solid and broken lines correspond to the upper and lower antennas, respectively. The slopes of distributions are almost equal to the slope of the Rayleigh distribution (10dB/decade).

Cumulative probability at the received power level, 30dB lower than the median level, is about 0.03% and the ratio of cumulative probability to the Rayleigh distribution is about 0.3.

4. In-band amplitude characteristics

4.1 In-band amplitude pattern

Examples of in-band co-polarization and cross-polarization amplitudes are shown in Fig.3; the path difference is so long that two notches are observed in the co-polarization amplitude pattern. The frequency interval between these notches corresponds to the path difference.

An example of notch frequency distribution during fading observed for two hours on May 17, 1983, when the CW signal received power level became 30dB lower than the median level frequently, is shown in Fig. 4. Notch frequency varies uniformly such that the phase difference between the direct and reflected waves can be understood to distribute uniformly.

The cross-polarization amplitude pattern is different from that of co-polarization and shows characteristics which are affected by many waves.

4.2 Frequency correlation of received power and XPD

The frequency correlation of co-polarization received power is an important parameter for estimating the cumulative distribution of in-band linear amplitude dispersion.(1)

Figure 5 shows an example of the frequency correlation of co-polarization received power during the same fading as shown in Fig. 4. Clear cyclical characteristics are observed and the frequency pitch of this cycle corresponds to the path difference between the direct wave and the reflected wave.

Figure 6 shows the frequency correlation of cross-polarization received power during the same fading. This frequency correlation shows weak cyclical characteristics. But the pitch of the cycle is smaller than that of co-polarization and the correlation coefficient at the pitch frequency interval is low. This means that there is an inclination such that the path difference between cross-polarization incident waves is longer than that of co-polarization but the variation is complex.

Figure 7 shows the XPD frequency correlation during the same fading; it is low and can be understood that the XPD has no correlation at the frequency interval larger than 10MHz.

4.3 In-band linear amplitude dispersion

In-band linear amplitude dispersion is closely correlated with the bit error rate and is an important parameter for designing digital systems. In order to reduce the effect of amplitude dispersion, the multi-carrier system has been studied.(2) So it is necessary to estimate the amplitude dispersion for various bandwidths.

Figure 8 shows cumulative distributions of in-band linear amplitude dispersion during the same fading as shown in Fig. 5, when bandwidths are 6.25, 12.5, 25, and 50MHz. Cumulative distributions of in-band linear amplitude dispersion, calculated by using frequency correlation coefficients,(1) are also shown in Fig. 8, when frequency correlation coefficients are 0.7, 0.8, and 0.9. There is close agreement between calculated and measured distributions.

5. Conclusion

Propagation characteristics of a long over-water path, where the reflected wave exists, has been described; the following points have been made clear:

- -the slope of received power distribution for the worst month of a severe propagation span, where an effect of a reflected wave as well as Rayleigh fading exists, is almost equal to that of the Rayleigh distribution.
- -the in-band amplitude and the frequency correlation of the co-polarization have clear cyclical characteristics, the frequency cycle of which corresponds to the path difference between the direct and reflected waves.
- -the variations of in-band amplitude of cross-polarization and XPD are

complex and therefore the frequency correlations of them are low.

-measured distribution of in-band linear amplitude dispersion is in close agreement with the calculated distribution.

References

(1) S. Sakagami and Y. Hosoya:Some Experimental Results on In-Band Amplitude Dispersion and a Method for Estimating In-Band Linear Amplitude Dispersion.,IEEE Trans. Commun.,vol.Com-30, No.8,pp.1875-1888, August 1982.

(2) T. Yoshida, S. Komaki and K. Morita:System Design and New Techniques for an Over-Water 100km Span Digital Radio.,IEEE ICC'83, C2.7, June 1983.

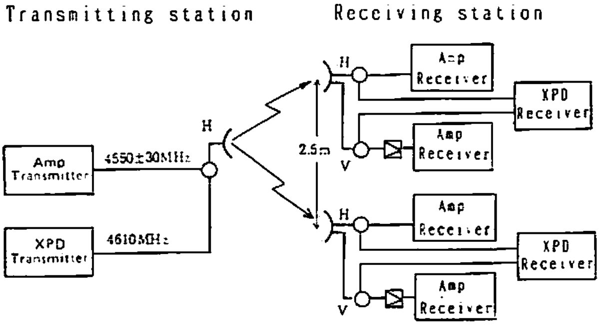

Fig. 1 Measurement blockdiagram.

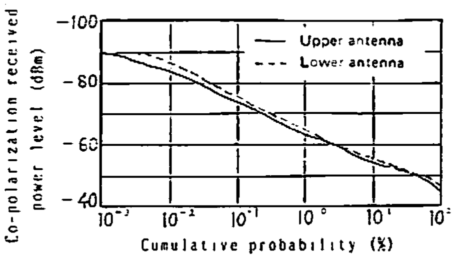

Fig. 2 Cumulative distributions of co-polarization received power for the worst month.

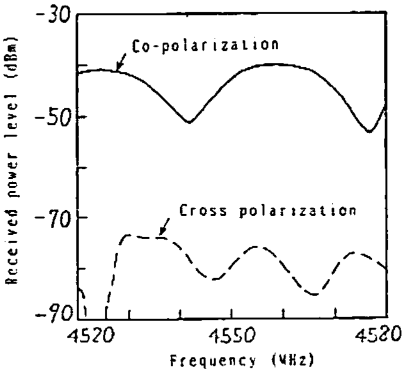

Fig. 3 Examples of in-band amplitude characteristics

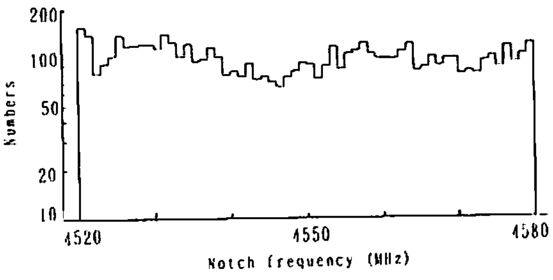

Fig. 4 Distribution of notch frequency

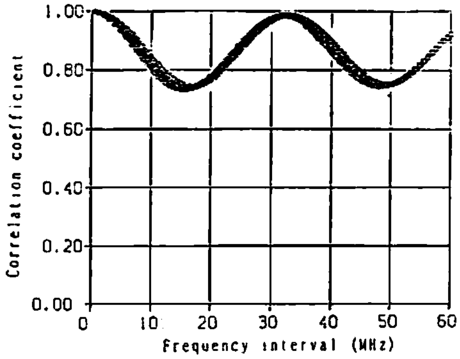

Fig. 5 Frequency correlation of co-polarization received power

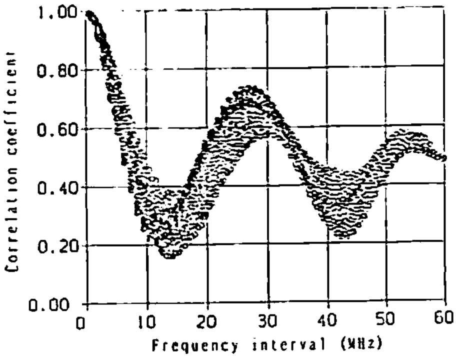

Fig. 6 Frequency correlation of cross polarization received power

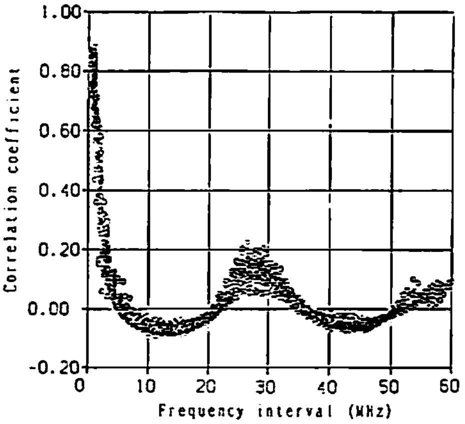

Fig. 7 Frequency correlation of XPD.

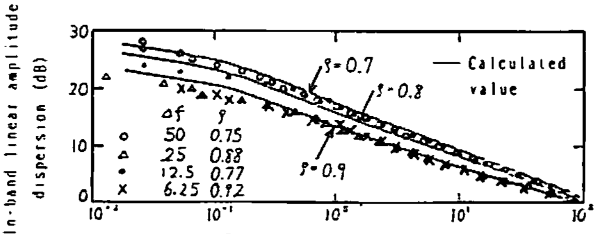

Fig. 8 Cumulative distributions of in-band linear amplitude dispersion.
(Δf is a band width in MHz and ρ is a correlation coefficient.)