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PATH LOSS DEPENDENCE OF DELAY SPREAD AT 5 GHz IN INHOMOGENEOUS SUBURBAN ENVIRONMENTS

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1 Introduction

Demands for outdoor high-speed digital wireless communications that will operate at several tens or hundreds megabit-per-second rates are rapidly emerging. Such systems, as mobile radios and wide area wireless access, encounter multipath degradation that is source of radiowave echos having different propagation delays [1]. Therefore delay profiles have been measured and analyzed to seek for anti-multipath methods [2, 3, 4, 5, 6, 7].

A delay spread is defined by the square root of the second central moment of the power delay profile and has been used for the description of the propagation channel outline. Distance dependence of delay spread has been derived for various environments and frequencies [2, 3, 4, 7]. In these issues, each measurement was performed in a homogeneous environment to obtain general relationship between the distance and delay spread. It has been proved that a delay spread increases with an increase of distance between transmitting and reception antennas.

For real mobile radios and wide area wireless access applications, terminals are located in both line-of-sight and non line-of-sight conditions, and there is no clear boundary between them in an actual complex environment. The terminal has potential to move among inhomogeneous environments within the service area. The delay spread characteristics even in inhomogeneous environments are expected to design the radio parameters of wireless systems.

In this paper, delay spread characteristics over inhomogeneous environments is shown with wideband measurement campaign result at a microwave band. The result showed significant correlation between path loss and delay spread.

2 Delay Profile Measurement

Delay profiles were measured in a suburban area of Fukushima prefecture in Japan. In the area, almost all buildings are three stories though there are several ten-story buildings.

A frequency of 4.95 GHz was used with a maximal-sequence pseudo random noise (PN) at a chip rate of 40 Mchip/s. The PN length was 511. The transmission antenna was vertically-arranged rectangular microstrip array antenna attached at top of a seven-story building. The vertical beamwidth was 6 degrees, the tilt angle was 6 degrees, and the horizontal ripple was within 5 dB.

The reception antenna was a six-element vertically-polarized collinear antenna attached to a car-borne receiver. The car ran streets within 3 km × 1.5 km area. There are both line-of-sight and non line-of-sight streets, and the building density is site-dependent. The reception signals were correlated with the transmitted PN sequence replica to obtain the delay profiles. The FPGA-based correlator in the receiver produced a delay profile every 10 ms. The complex amplitude of the delay profile was recorded to a 2-Gbyte memory in the receiver. The reception car also equipped a GPS receiver to determine the location and the distance between transmission and reception antennas.

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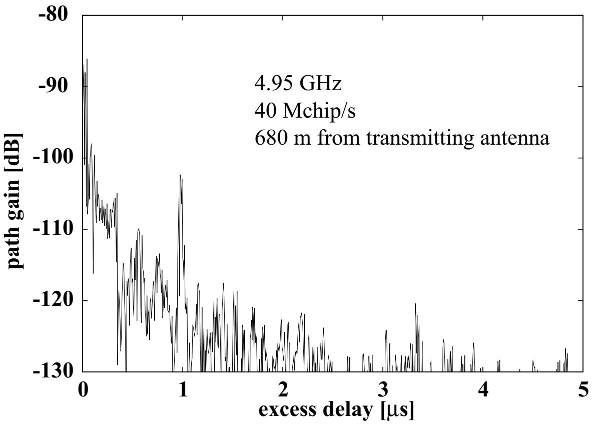

Fig. 1. An example of measured delay profile.

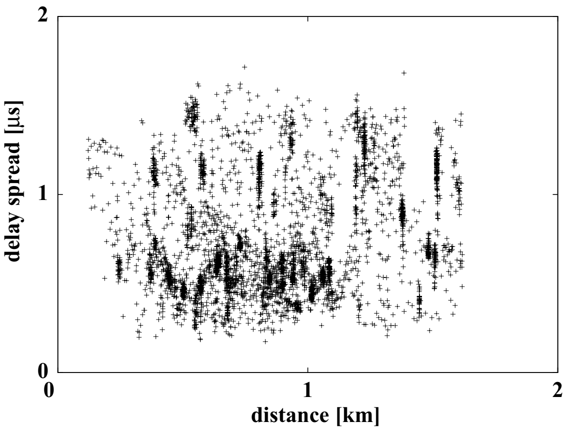

Fig. 2. Distance dependence of delay spread.

The excess delays of the profiles were adjusted after the measurement. Both the transmitter and receiver equipped a rubidium frequency standard to synchronize the frequencies and PN chips between the transmitter and receiver. Nevertheless a profile gradually moves with an increases of the elapsed time because the stability is at most 10^{-10}. It is possible that a strong radiowave follows after a weak radiowave in non line-of-sight conditions. For obtaining the time origin of the delay profile, a peak of the measured delay profile is assumed to be the signal of the provisional earliest received radiowave. Then the time origin of the real earliest received radiowave is derived by scanning the earlier time that the maximal of the delay profile are within an excess delay threshold. We chose the threshold as 10 dB by observing the measured delay profiles. A delay profile is shown in Fig. 1.

A delay spread S is defined by

$$S = \sqrt{\frac{1}{P_{\mathrm{m}}} \int_0^{t_1} \tau^2 f(\tau) d\tau - T_{\mathrm{d}}^2}$$

where P_{m} is the mean reception power defined by $P_{\mathrm{m}} = \int_0^{t_1} f(\tau) d\tau$, $f(\tau)$ is the delay profile when the excess delay time is τ, t_1 is the excess delay threshold that the profile is below the measurement limit, and T_{d} is the mean delay defined by $T_{\mathrm{D}} = \int_0^{t_1} \tau f(\tau) d\tau$.

3 Path Loss Dependence of Delay Spread

Delay spreads through a single measurement are plotted in Fig. 2 as a function of the distance between the transmission and reception antennas. No obvious correlation can be seen between them in contrast to ones in homogeneous environments [2, 3, 4, 7]. The figure also shows that the distance dependence of delay spread in inhomogeneous environments is not the simple superpositions of the dependence in the involved environments since the figure does not show clear clusters: there is no clear boundary among these homogeneous environments.

On the other hand, the delay spreads with respect to the path loss (or an inverse of the path gain obtained from P_{m}) are plotted and shown in Fig. 3. There is an apparent correlation between reception power and the delay spread: the delay spread decreases with increasing of the path gain. From Fig. 3, we can see that path loss, rather than the actual distance, represents the major traveling distance of the radiowaves. In Fig. 3, there is a cluster with relatively high delay spread (around 0.8 μs) in high path gain (around -82 dB) region. An extensive measurement was carried out to know about this cluster.

Figure 4 shows the dependence when the transmission antenna was substituted a sector antenna for the microstrip array antenna. The beamwidth was 6 degrees for vertical and 70

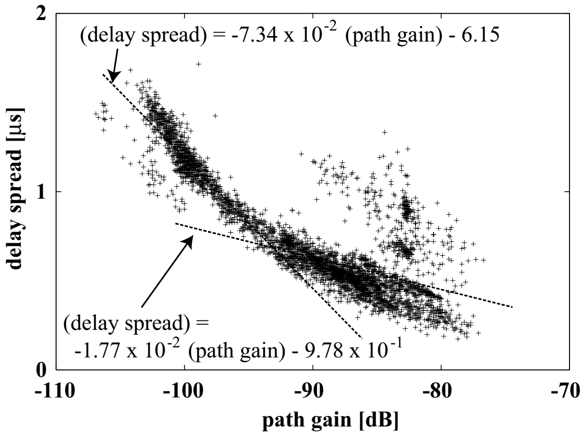

Fig. 3. Path loss dependence of delay spread.

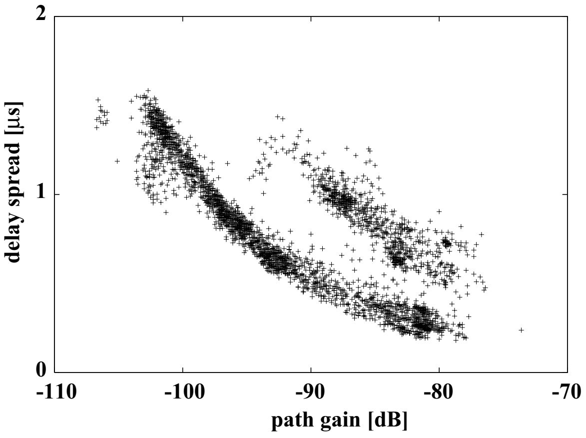

Fig. 4. Path loss dependence of delay spread when a sector antenna was used for transmission.

degrees for horizontal, and the tilt angle was 4 degrees. Two apparent correlations can be seen in Fig. 4: the cluster in Fig. 3 is corresponded to a correlation curve in Fig. 4. If the curve is assumed to be for out of sector beam, the path loss dependence of delay spread has two correlations in nature.

A knowledge of statistical delay-spread characteristics of path loss is rather more useful for a performance improvement of wireless communication systems than for cell designing. The characteristics can be used for determination of adaptive modulation and time sharing assignment such as the dynamic parameter control method [8].

4 Conclusion

Delay spread characteristics over inhomogeneous environments was discussed. For real mobile radios and wide area wireless access applications, the terminal has potential to move among inhomogeneous environments. The distance dependence of delay spread is not sufficient for describe over inhomogeneous environments. In contrast path loss and delay spread showed apparent correlation. With our measurements, the path loss dependence of delay spread had two correlation clusters: one is for in-service and another is for out-of-serve by transmission antenna directivity. The characteristics can be used for performance improvement for wireless communication systems employing adaptive modulation.

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