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Effects of Narrowing and Tilting of Base Station Antenna Beam in Mobile Radio Delay Spread Reduction

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1. INTRODUCTION

Signals in the mobile radio communication systems are in the process of being digitalized. Clarification of the transmission performance of digital signals is an important subject in the offering of digital mobile communication systems. Some theoretical studies and experiments show a high correlation between bit error rate, which indicates the transmission performance, and delay spread [1],[2]. For a examination of reducing the delay spread, theoretical studies of narrowing and tilting of base station antenna beam have been carried out [3]~[5].

In this paper, narrowing and tilting of base station antenna beam are examined by a theoretical method for the purpose of reducing the delay spread. Further, the effects of reducing the delay spread are examined by an experimental method.

2. SIMULATION

The propagation models used here are shown in Figs. 1 and 2. The model shown in Fig. 1 is used to evaluate the effects of antenna beam narrowing of the base station, and the model in Fig. 2 is used to evaluate the effects of antenna beam tilting of the base station. In both models, location for the reflection structures which are in line of sight from both the base and the mobile stations were chosen, after careful consideration of the experimental areas. The path of the section L_0 between the base station and the mobile station is the urban or suburban propagation. The paths of the section L_1 between the base station and the mobile station via the reflection structure are the free space propagations. Furthermore, the waves are attenuated by 30 dB at the reflection structures. The antenna patterns of the base station are the ones which are used in the experiments. For the antenna beam narrowing of the base station, an antenna in which the 3 dB beam width in the horizontal direction is 38 degrees is used. For the antenna beam tilting of the base station, an antenna in which the 3 dB beam width in the vertical direction is 3 degrees is used. The mobile station antenna is an omni-directional antenna. The delay profiles are calculated using the location of the base, the mobile and the reflective structures and the propagation loss of each wave. The delay spread S, which is a multipath parameter, was computed by the following equation;

$$S=\sqrt{\Sigma t_n^2 A_n / \Sigma A_n - (\Sigma t_n A_n / \Sigma A_n)^2} \qquad (1)$$

where t_n is the excess delay and A_n is the received level at the excess delay t_n.

In the simulation of the antenna beam narrowing, the base station antenna is rotated in the horizontal direction. The antenna gain difference ($\Delta G = G_0 - G_1$) between the mobile station (G_0) and the reflection structure (G_1) is a parameter (the abscissa of the figure). Figures 3(a) and 3(b) show the sample predicted delay profiles. Figure 3(a) is for the case in which the antenna gain of the reflection structure direction is large. Figure 3(b) is for the case in which the antenna gain of the mobile station direction is large.

In the simulation of the antenna beam tilting, the base station antenna is tilted in the vertical direction. The tilt angle of the beam tilting antenna is a parameter (the abscissa of the figure). Figures 4(a) and 4(b) show the sample predicted delay profiles. Figure 4(a) is for the case in which there is no beam tilting of the base station antenna. Figure 4(b) is for the case in which there is a beam tilting at an angle of 4 degrees.

The dotted lines in Figs. 5 and 6 show the predicted results of the delay spread. These figures show the effects of reducing the delay spread by narrowing and tilting of base station antenna beam, respectively.

3. EXPERIMENTS

To evaluate the effects of narrowing and tilting of base station antenna beam, experiments with excess delay and received level were carried out in suburban (Atsugi) and urban (Yokohama) areas. Table 1 summarizes the experimental parameters. In both areas, the waves modulated by BPSK were transmitted from the base stations. The receiving antenna was mounted on the roof of the vehicle, and the waves were received with the vehicle stopped. The delay profiles were measured by the correlating detection method. The delay spread figures were calculated from these delay profiles using Equation (1).

Suburban (Atsugi): To evaluate the effect of the antenna beam narrowing, an experiment was carried out in suburban Atsugi. Atsugi is a flat area, which is located 50 kilometers southwest of the Tokyo metropolitan area. Around the base and the mobile stations, there are many fields and several structures. A few structures attain a height equal to that of the base station antenna. The mobile station is located 2,500 meters from the base station. At the base station, a Yagi-antenna with a horizontal beam width of 38 degrees was rotated in the horizontal direction. The antenna gain difference between the mobile direction and the reflection structure is a parameter. Figures 3(c) and 3(d) show the sample measured delay profiles. Figure 3(c) is for the case in which the antenna gain of the reflection structure direction is large. Figure 3(d) is for the case in which the antenna gain of the mobile station direction is large. The x symbols in Fig. 5 are the measured delay spread values calculated from the measured delay profile. The measured values agree well with the predicted ones.

Urban (Yokohama): To evaluate the effect of the antenna beam tilting, an experiment was carried out in urban Yokohama [5]. Yokohama is a flat area on the Tokyo Bay. Around the base and the mobile stations, there are many tall buildings, structures and bridges. The mobile station is located 1,800 meters from the base station. At the base station, a 120-degree corner antenna with a vertical beam width of 3 degrees was tilted in the vertical direction. The angle of the beam tilting antenna is a parameter. Figures 4(c) and 4(d) show the sample measured delay profiles. Figure 4(c) is for the case in which there is no beam tilting of the base station antenna. Figure 4(d) is for the case in which there is a beam tilting of 4 degrees. The x symbols in Fig. 6 are the measured delay spread values calculated from the measured delay profile. Although only two measured delay spread values were calculated, they agree well with the predicted values.

4. COMPARISON BETWEEN PREDICTED AND MEASURED VALUES

Figures 5 and 6 show a reduction in predicted and measured delay spread. From the figures, the effectiveness of narrowing and tilting of base station antenna beam in reducing delay spread is confirmed.

In the antenna beam narrowing, the delay spread is large when the antenna gain difference between the mobile station and the reflection structure is small. As the antenna gain difference is increased, the delay spread is decreased. When the reflective structure is out of the sector, the delay spread is reduced at the mobile station in the sector.

In the antenna beam tilting, the received levels of the waves, which have a long delay time, show large attenuation. Therefore, the delay spread is reduced. As the tilt angle is increased, the delay spread is decreased.

5. CONCLUSION

Narrowing and tilting of base station antenna beam are examined by theoretical and experimental methods. Predicted and measured delay spread values show good agreement. As a result, the effectiveness in reducing the delay spread is confirmed.

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Table 1 Experimental Parameters

Location		Suburban (Atsugi)	Urban (Yokohama)
Frequency		1452.5 MHz	
Modulation		BPSK Modulated by 511-bit Pseudorandom Binary Sequence	
Bit Rate		5 Mbps	
Average Power		10 W	
Base Station	Ant. Type	8-Element Yagi	120° Corner
	Ant. Height	26 m	80 m
	Ant. Gain	11.4 dBi	16 dBi
Mobile Station	Ant. Type	Sleeve	
	Ant. Height	3 m	
	Ant. Gain	2.2 dBi	

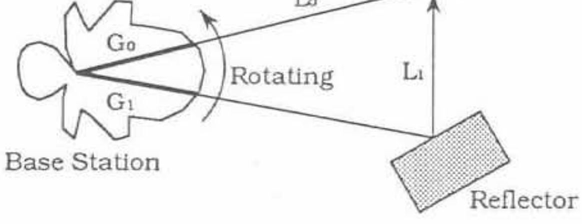

Figure 1 Propagation Model (Beam Narrowing)

Figure 2 Propagation Model (Beam Tilting)

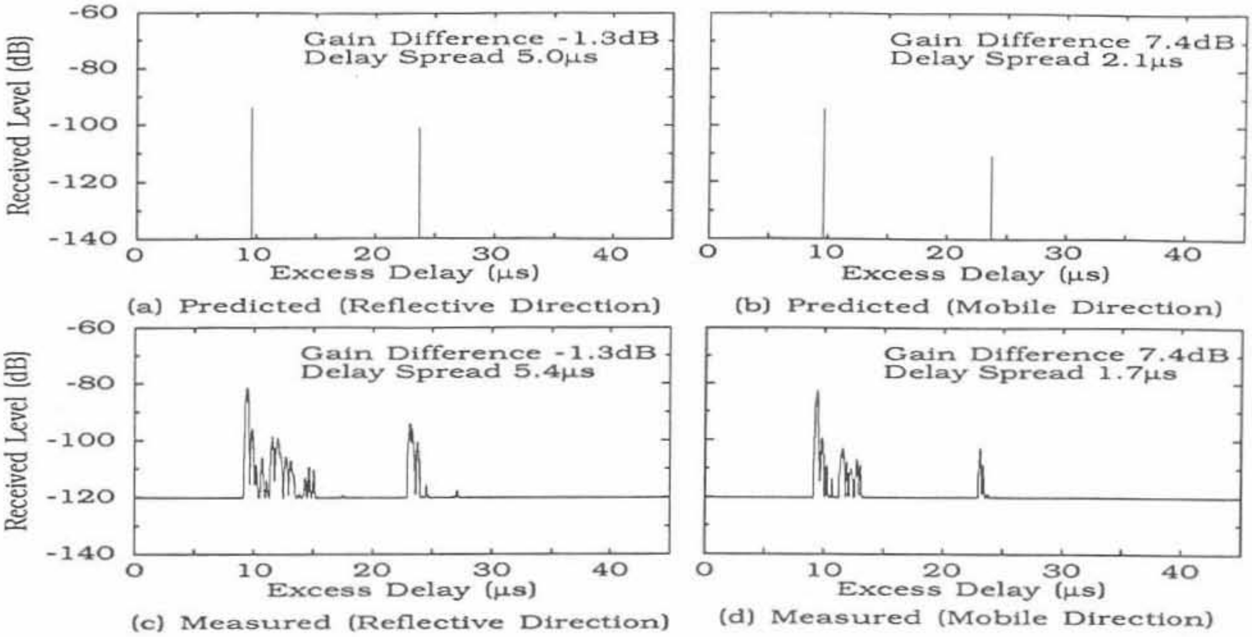

Figure 3 Delay Profile (Beam Narrowing)

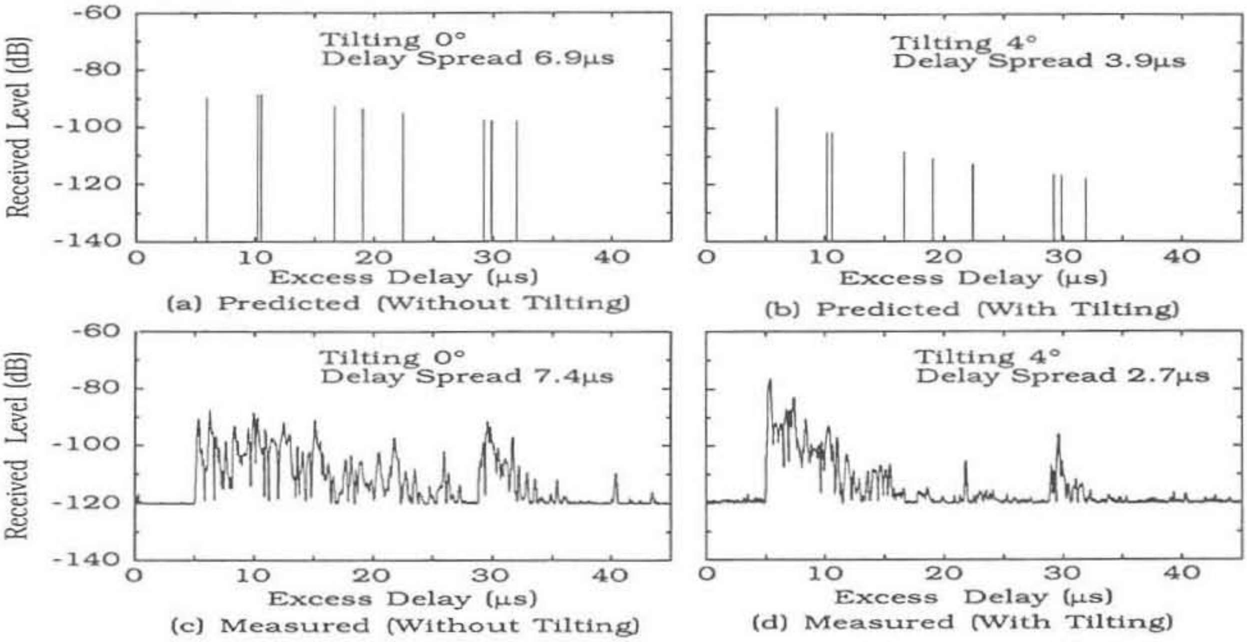

Figure 4 Delay Profile (Beam Tilting)

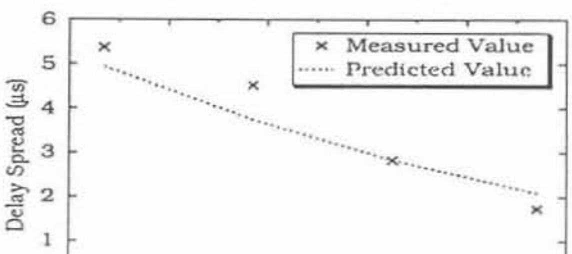

Figure 5 Delay Spread (Beam Narrowing)

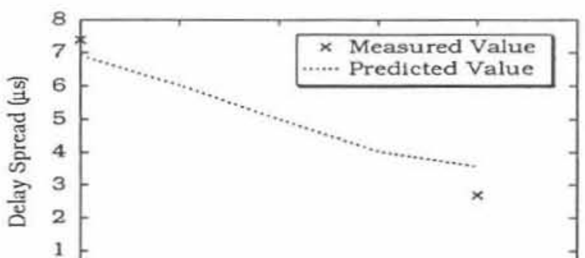

Figure 6 Delay Spread (Beam Tilting)