User discrimination characteristics by terminal polarization in SDMA system adopting spatial and polarization control

Kentaro NISHIMORI, Kazuhiro KOMIYA, Keizo CHO
NTT Network Innovation Laboratories, NTT Corporation
1-1, Hikarino-oka, Yokosuka, Kanagawa, 239-0847
E-mail : nisimori@wslab.ntt.co.jp

1. Introduction

Space division multiple access (SDMA) is an attractive wireless access system that increases the capacity of cellular networks [1]. We proposed the use of dual-polarized antennas at both the base station and the terminal to increase the number of users that SDMA can achieve [2]. We also confirmed by computer simulation that the proposed SDMA improves the user discrimination performance more than does the conventional method using single polarization when the number of users is increased.

We assumed that the cross-polarization discrimination (XPD) in a propagation channel is the same among the users and the phase difference between the vertical and horizontal polarization (V.-pol. and H.-pol.) is randomly distributed in this simulation [2]. However, since the service area of a cellular system is generally Non-Line of Sight (NLOS), the amplitude and phase of the signals that are transmitted by the terminal station are distributed widely through the propagation channel even if the transmission polarization is V.-pol. and H.-pol. Thus, the user discrimination performance of the proposed SDMA using the values of the XPD and phase obtained in an actual cellular environment should be clarified in order to show the effectiveness of the proposed SDMA.

This paper first clarifies the XPD and phase characteristics in an actual cellular environment. Next, the user discrimination characteristics between two users are shown by measuring the spatial correlation [3] when the terminal polarization is selected for V.-pol. or H.-pol. Finally, we evaluate by computer simulation the SINR characteristics when applying the proposed SDMA using the measured data of the terminal polarization.

2. SDMA System Adopting Spatial and Polarization Control

Figure 1 shows the concept of the proposed SDMA system [2]. The system comprises a smart antenna base station and terminals with dual-polarized antennas including terminal polarization assignment control. The angle of arrivals (AOAs) between users that approach each other and the spatial discrimination performance are severely degraded in conventional SDMA systems because the sector-cell is applied to enhance the channel capacity in cellular systems. As shown in Fig. 1, the proposed SDMA can discriminate each terminal even the AOAs of the terminals close to each other by utilizing not only directivity, but also the orthogonal polarizations of both the base and terminal stations. Therefore, the proposed SDMA is effective in increasing the number of users in SDMA systems.

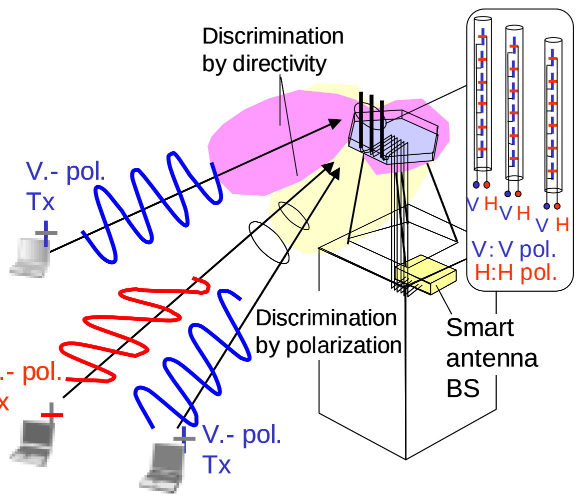


Fig.1 Concept of proposed SDMA

3. User Discrimination Characteristics by Polarization of Terminal

3.1 Measurement environment

Figure 2 shows the measurement environment. Table 1 illustrates the combinations of a base station and the terminals polarizations we evaluated. Here, Case 1 involves V-pol. base station antennas and V-pol. terminals, Case 2 involves dual-pol. base station antennas and V-pol. terminals, and Case 3 involves dual-pol. base station antennas and V-pol. and H.-pol. terminals. A 2.2-GHz band transmitter with 128-kbps QPSK modulated signals is established while changing the inclination angle of the employed sleeve antenna vertically or horizontally at a height of 2 m on a vehicle rooftop. The vehicle runs along three NLOS courses (C1, C2, and C3 in Fig. 2) at 30 to 50 km/h for 20 sec. The base station antenna is located at the top of a steel tower and its height is 60 m. The signals are measured by a 2-branch V-pol. and H-pol. patch antenna. The element spacing of the array was 0.5 wavelengths. The half-power beam width is 105 deg. in the horizontal plane and 4 deg. in the horizontal plane. The received signals are stored by a frequency converter and A/D converter, and the signal processing is performed off-line. The number of measurements is four for each course.

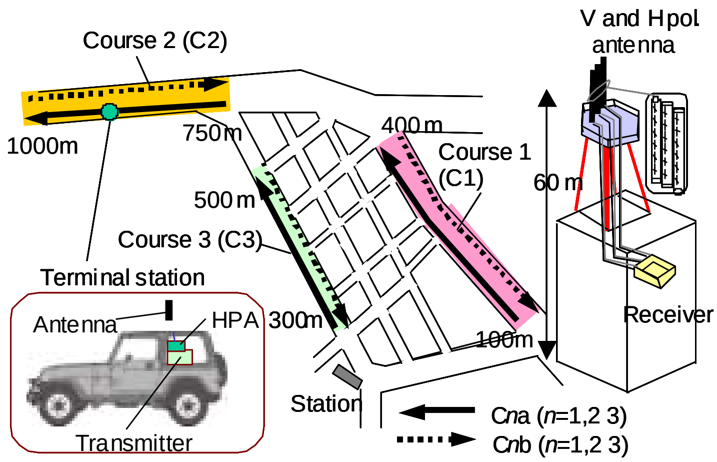


Fig. 2 Measurement environment

Tabel 1 BS and TS Combinations

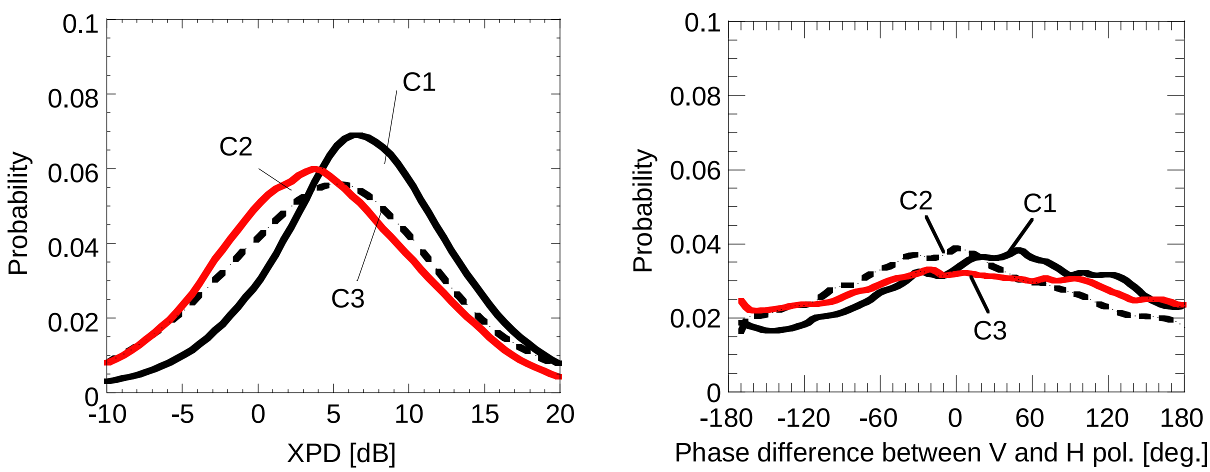
(BS: Base station, TS: Terminal station)

	TS 1	: S2	BS (2 branch)
Case 1	V. pol.	V. pol.	V. pol.
Case 2	V. pol.	V. pol.	V. and H. pol.
Case 3	V.pol.	H. pol.	V. and H. pol.

3.2 XPD and phase difference characteristics between vertical and horizontal polarization

Figure 3 shows the probability distribution of the cross-polarization discrimination (XPD) and phase difference between the V-pol. and H.-pol. of the base station in Case 3. The XPD and phase difference represent the mean values that are transmitted with both the V.-pol. and H.-pol.

As shown in Fig. 3(a), the medium values of the XPD are from 3.5 to 7 dB. This result shows that the polarization characteristics are kept to some extent in an actual cellular environment. As Fig. 3(b) shows, because the probability distribution of the phase differences is almost the same from –180 to 180 degrees regardless of the measurement courses, the phase difference between the V.-pol. and H.-pol. can be regarded as almost randomly distributed. Thus, we found that the assumption of the simulation is appropriate [2].



(a) XPD (b) Phase difference

Fig. 3 XPD and phase difference characteristics (Case 3)

3.3 Characteristics of spatial correlation

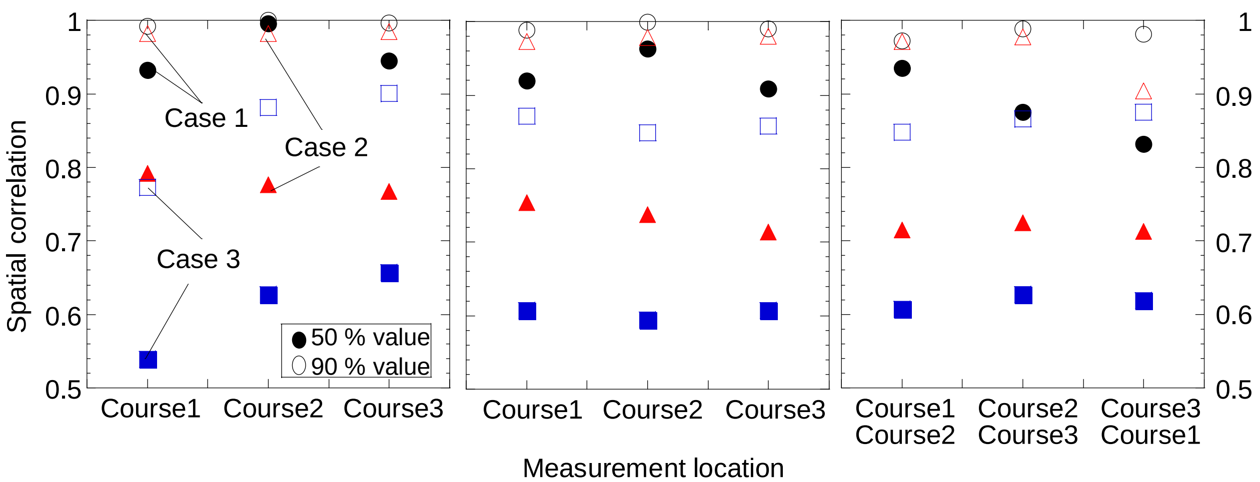
Figure 4 compares the spatial correlation characteristics of Cases 1, 2, and 3 in Table 1. Figures 4(a) and 4(b) show the conditions when the two terminals move in the same and opposite directions along the same courses, respectively. Figure 4(c) shows the conditions when the two terminals move along different courses. The 50 and 90% values of the cumulative provability are shown in Fig. 4.

As shown in Fig. 4(a), the spatial correlation at the 50% value becomes greater than 0.9 when only vertical polarization at both the base and terminal stations (Case 1) is used. These results shows that it is difficult to discriminate between users if two terminals approach each other in Case 1. When the V.-pol and H.-pol. at only the base station is used (Case 2), the spatial correlation at the 50% value can be from 0.7 to 0.8. However, the spatial correlation at the 90% value becomes greater than 0.9 in Case 2, and the degree of user discrimination is insufficient. On the other hand, the value of the spatial correlation becomes less than 0.7 and 0.9 at the cumulative probability of 50 and 90%, respectively, by using the V.-pol. and H.-pol. for both the base station and the terminal (Case 3). We also found that the result obtained in Fig. 4(b) is similar to the one in Fig. 4(a).

As shown in Fig. 4(c), the value of the spatial correlation is less than the one in Figs. 4(a) and 4(b) when Case 1 is applied because the AOAs of the two terminals separate spatially. However, the values of the spatial correlation become greater than 0.8 and these values particularly become greater than 0.9 if the two terminals move along Courses 1 and 2. This means that it is difficult to discriminate between users even if the AOAs of the two terminals are different when Case 1 is applied. On the other hand, the value of the spatial correlation becomes less than 0.65 and 0.9 at the cumulative probability of 50 and 90%, respectively, by using the V.-pol. and H.-pol. for both the base station and the terminal (Case 3) regardless of the measurement course. Considering the above results, we confirmed that the user discrimination between the two users becomes highest if V.-pol. and H.-pol. are used for the base station and the terminal.

4. User Discrimination Characteristics Applying SDMA

We evaluated the effectiveness of the proposed SDMA by computer simulation using the measured data obtained in Section 3. Table 2 illustrates the configuration combinations of a base station and terminals we evaluated. We considered the V.-pol. and H.-pol. characteristics of the terminal by obtaining the correlation characteristics between the terminal polarizations in Section 3. The element spacing of the array was 0.5 wavelengths. To account for the Doppler effect, we assumed that users move in random directions at the velocity of 50 km/h. The carrier frequency was 2.2 GHz, signals were modulated by QPSK, and the data rate was 128 kbaud. All



(a) Same courses and moving in the same direction

(b) Same courses and moving in opposite directions

(c) Different courses

Fig. 4 Spatial correlation characteristics terminals were assumed to move within a 60 deg. sector. The number of iterations of the trials for generating the terminal locations was 100,000. The input SNR was 20 dB. The angular spread was modeled by 11-element waves with equip-angle intervals, the amplitudes of which were all identical and the phases were uniformly distributed. The value of the angular spread was 10 degrees.

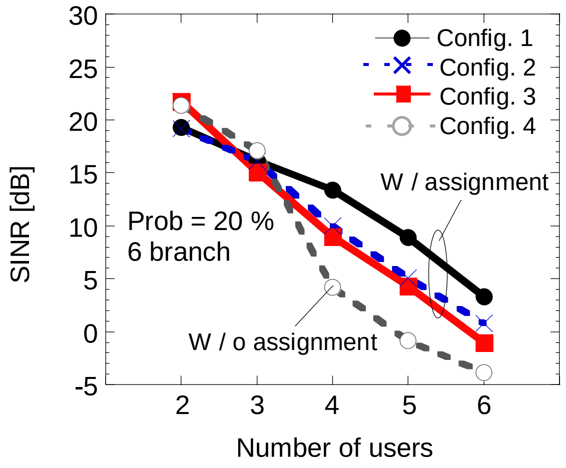
Figure 5 shows a comparison of the output SINR when applying SDMA using the configuration given in Table 2. The vertical axis in the figure represents the 20 and 50% values of the cumulative probability of the output SINR of the user with the worst transmission quality. As the figure shows, the output SINR of the proposed SDMA (Config. 1) is from 7 to 10 dB higher than that of the conventional SDMA (Config. 4) when the number of users is greater than 4. Moreover, the proposed SDMA improves the output SINR from 2 to 5 dB compared to the SDMA with using only vertical polarization at the terminal station (Configs. 2 and 3). Therefore, the effectiveness of the proposed SDMA using the V.-pol. and H.-pol. in both the base and terminal station is confirmed if the number of users increases.

5. Conclusion

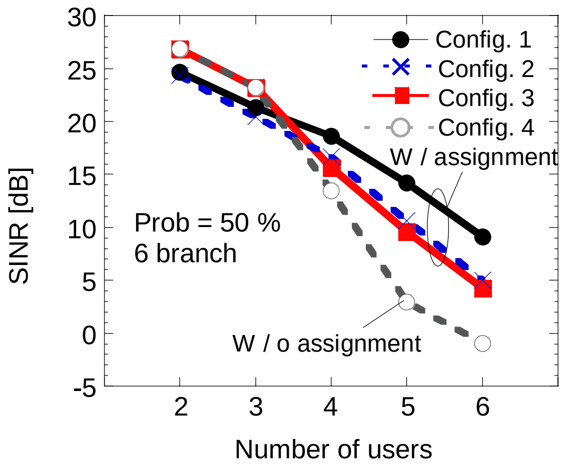
This paper evaluated the user discrimination characteristics due to the terminal polarization of the SDMA adopting spatial and polarization control with the terminal polarization assignment in a cellular environment. As a result, even if the AOAs of the two users is the same, the value of the spatial correlation becomes less than 0.7 and 0.9 at the cumulative probability of 50 and 90%, respectively, by using vertical and horizontal polarizations for both the base and the terminal station. Moreover, we confirmed by computer simulation that the proposed SDMA improved the output SINR from 2 to 5 dB compared to the SDMA using only vertical polarization at the terminal station using the measured data in a cellular environment.

Tabel 2 BS and TS Configurations

	Terminal station	BS (6 branch)
Config. 1 (Proposed)	V. and H. pol.	V. and H. pol.
Config. 2	V. pol. 2 branch	V. and H. pol.
Config. 3	V. pol. 2 branch	V. pol.
Config. 4	V. pol. 1branch	V. pol.



(a) 20 % values



(a) 50 % values

Fig. 5 Output SINR vs. the number of users

Acknowledgements

The authors thank Dr. Masahiro Umehira of Nippon Telegraph and Telephone Corporation (NTT) for his constant encouragement.

References

[1] K. Cho and T. Hori, Proc. of ISAP2000, pp. 1485-1488, Fukuoka, Japan, 2000.

[2] K. Komiya, K. Nishimori, K. Cho, and T. Hori, Proc. of VTC 2001-Fall, pp. 1447 -1451, Atlantic City, Oct. 2001.

[3] H. Lin, IEEE Trans. AP-30, no. 2, pp. 212-223, 1982.