BIDIRECTIONAL BASE STATION ANTENNAS WITH 4-BRANCH POLARIZATION AND HEIGHT DIVERSITY

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Introduction:

Recently, microcell mobile communication systems, such as personal handy phone systems(PHS), have received much attention over the world[1]. In urban areas, since base stations of the microcell systems is generally lower than the surrounding buildings, the communication cell follows the street, and so is usually called a 'street cell'. Moreover, since the propagation environment in microcell systems is mainly Line-of-sight (LOS), the waves radiated from base station antennas and handy phones retain their original polarization state during propagation.

Vertically polarized antennas, such as collinear antennas, are commonly used for the base station antennas in microcell systems. Whip antennas are also common for the handy phones. Since handy phones are generally inclined during use[2] and are carried at various angles, the polarization of the incident waves reaching the base station varies. Therefore the signal power received at the base station degrades due to the mismatch of the polarization state of the base station antenna and the incident wave.

This paper first shows the dependency of the signal power received by an ordinary 2-branch height diversity collinear antenna (called HCA hereafter) and a 2-branch polarization diversity antenna on the inclination of a handy phone in a street cell environment. The effectiveness of the 2-branch polarization diversity antenna for eliminating the degradation of the received signal power caused by the polarization mismatch is presented. The problem of the 2-branch polarization diversity antenna is also shown. In order to overcome this problem, the effectiveness of a 4-branch diversity configuration, which has both polarization and height diversity schemes, is investigated. Moreover a novel 4-branch bidirectional polarization and height diversity antenna of rod shape (called BPHDA hereafter) is proposed as an example of the 4-branch diversity antenna. Finally the cell lengths possible with a BPHDA and a HCA are compared by conducting measurements in a Japanese urban area.

Influence of the inclination of handy phones on signal reception:

HCA and 2-branch polarization diversity antenna

Figure 1 shows the dependency of the signal power received by a HCA and a 2-branch polarization diversity antenna on the inclination of a handy phone when the antennas were used as base station antennas. This dependency was measured at a street cell environment in a Japanese urban area (Yokohama). A sleeve antenna was used as the handy phone antenna, and was placed at the height of 1.5m. The gain of the HCA is 7.8 dBi. The upper antenna of the HCA was placed at the height of 3.5m, and the lower antenna of the HCA was spaced by 3.7 wavelengths from the upper antenna. A bidirectional narrow patch and slot antenna (BNPSA)[3] was used as the polarization diversity antenna. The gain of the BNPSA was 8dBi. The BNPSA was also placed at the height of 3.5m. The angle of 0 degrees in the horizontal axis in Fig. 1 means the sleeve antenna was vertical. The signal power in Fig. 1 is the median value of the cumulative

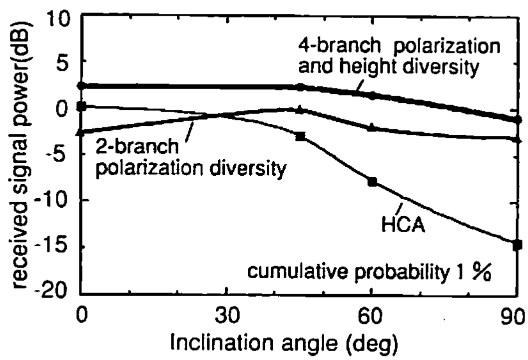


Fig. 1 Dependency of received signal power on handy phone inclination.

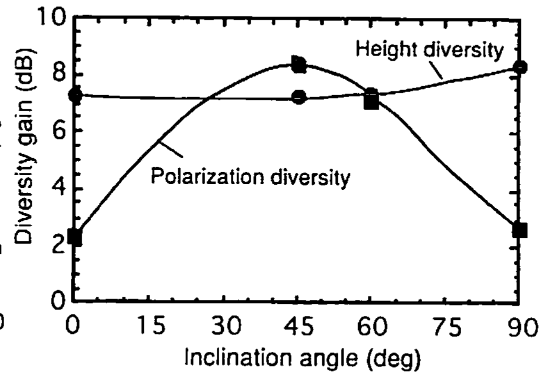


Fig. 2 Dependency of diversity gainr on handy phone inclination.

received signal power with ideal selection combining diversity reception within 230m away from the base station. The values in Fig. 1 are normalized by the value of the HCA when the inclination was 0 degrees.

As indicated in Fig. 1, the signal power received by the HCA degrades with sleeve antenna inclination. When the angle of the sleeve antenna is 90 degrees, the signal power degrades up to about -15dB. On the other hand, the polarization diversity antenna holds the received signal power almost constant against inclination. However, when the inclination angle is 0 degrees, the signal power output by the BNPSA is lower than that by the HCA. This is caused by the difference of the diversity gain between polarization diversity and height diversity in street cell environments.

Figure 2 shows the dependency of the diversity gain(4) obtained by the 2-branch polarization diversity and the 2-branch height diversity configurations on the inclination of the handy phone. The diversity gain in Fig. 2 is also the median value of the cumulative diversity gain within 230m from the base station. In LOS scenarios like street cell environments, when a BNPSA receives vertically polarized wave, the horizontally polarized element of the BNPSA receives the 15dB lower signal power than the vertically polarized element as indicated by the curve of the HCA in Fig. 1. Therefore, the diversity gain of the BNPSA is degraded up to 2dB by the difference in signal power received by both elements as shown in Fig. 2. On the other hand, since there is no difference of the received signal power between the HCA branches, it attains 7 dB diversity gain with no influence of the handy phone inclination so the signal power received by the HCA becomes higher than that possible with the BNPSA when the incident wave is vertically polarized.

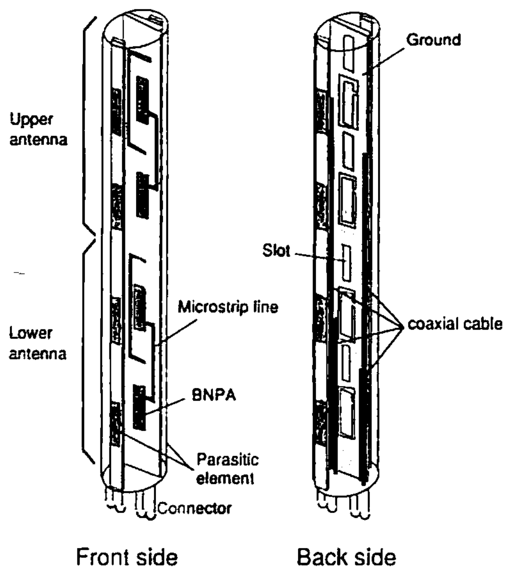
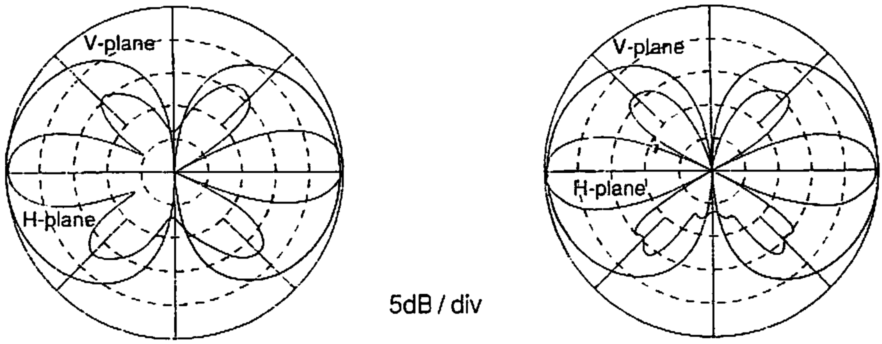


Fig. 3 Configuration of BPHDA

4-branch polarization and height diversity configuration

Taking the above results into consideration, the 4-branch diversity configuration, which is the height diversity configuration of two 2-branch



(a) Vertically polarized antenna (b) Horizontally polarized antenna

Fig. 4 Radiation pattern of BPHDA.

polarization diversity antennas, should eliminate the received signal degradation and the diversity gain degradation caused by the handy phone inclination. The dependency of the signal power received by the 4-branch diversity configuration is also shown in Fig. 1. The upper polarization diversity antenna was placed at the height of 3.5m and the lower antenna was spaced by 2.2 wavelengths from the upper antenna. As we expected, the 4-branch diversity configuration holds the received signal power constant against inclination, and it yields 2 dB higher signal power than the HCA when the inclination is 0 degrees.

Configuration and characteristics of 4-branch diversity antenna:

As an example of the 4-branch diversity antenna, a rod shape 4-branch bidirectional polarization and height diversity antenna (BPHDA), which is suitable for street cell environments[5], is proposed. Figure 3 shows the BPHDA configuration. The BPHDA is composed of two BNPSA arrays[3], which are arranged vertically as shown in Fig. 3. Bidirectional Narrow Patch Antennas(BNPA)[6], which are printed antennas on a substrate with parasitic elements, are used as the vertically polarized elements of the BNPSA shown in Fig. 3. The feeding networks for the elements are printed circuits on the substrate. The excited patches of the back side are surrounded by the ground. The ground makes it easy to form the beamforming network on the substrate, and sharpens the beam in the vertical plane. 1.1 wavelength is selected as the spacing between the adjacent BNPAs in order to maximize the gain. Slot antennas, which are formed on the ground side of the substrate, are used as the horizontally polarized elements. Each slot is located between adjacent BNPAs. Thus the BNPSA is a dual polarized antenna that has almost the same antenna length as a single polarized antenna. Coaxial cables are used for connecting the beamforming networks to the connectors located at the bottom of the BPHDA. These cables are placed at the back side and contact the ground to eliminate the influence of the cables on the radiation characteristics.

Figure 4 shows the radiation patterns of the upper antennas in the BPHDA, which has 2 elements for each antenna. Figure 4 (a) shows the patterns of the vertically polarized antenna in the vertical and horizontal plane (E-plane and H-plane), and Figure 4 (b) shows those of the horizontally polarized one. As indicated in Fig. 4, the patterns in the horizontal plane of both antennas are bidirectional, and the patterns of both antennas are almost identical. The 3dB beamwidth of both patterns is about 90 degrees. The measured gains of the BPHDA are 7.8dBi and 8.1dBi for the upper vertically and horizontally polarized antennas, 8.0dBi for the lower vertically and horizontally polarized antennas.

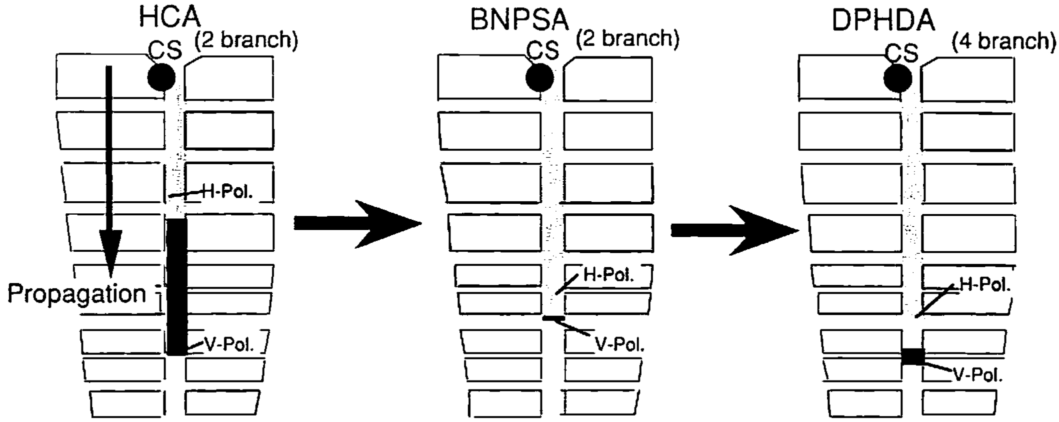


Fig. 5 Comparison of the cell lengths offered by HCA, BNPSA and BPHDA

Comparison of the Cell length:

Figure 5 compares the measured cell lengths offered by a BPHDA, a BNPSA and a HCA when those antennas were used as the base station antenna to receive the waves transmitted from the sleeve antenna previously described. As indicated in Fig. 5, when the sleeve antenna is vertical, the BPHDA cell length is the longest of the three. When the sleeve antenna is horizontal, the HCA cell length is reduced by almost half. On the other hand, the BNPSA and the BPHDA can achieve almost the same cell length as that of the vertically polarized incident wave. Therefore the BPHDA offers the longest cell length of the three without any significant dependency on the handy phone's inclination.

Conclusion:

The effectiveness of a 4-branch polarization and height diversity configuration was investigated as the base station antenna of microcell mobile communication systems, and a 4-branch rod shaped bidirectional polarization and height diversity antenna (BPHDA) was proposed as one implementation example. Measurements in a Japanese urban area clarified that the proposed BPHDA achieves longer cell lengths than the ordinary 2-branch height diversity collinear antenna while eliminating the received signal degradation caused by the inclination of the handy phones.

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