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# EFFECTS OF THE VERTICAL PLANE RADIATION PATTERN OF BASE STATION ANTENNAS ON INDOOR RADIO PROPAGATION

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## 1. Introduction

In mobile communication, so-called "high-gain antennas" (antennas whose radiation beams on the vertical plane are made sharp) are used for base station antennas on the top of buildings. Their sharp beams have large directivity, so they can enlarge the service area per base station or save transmission power. Many experimental results have been reported so far regarding the effects due to the radiation pattern on the vertical plane of a base station antenna, including the beam tilt effects, for outdoor mobile reception in a city area. However, to the authors' knowledge, there have only been a few reports concerning indoor radio communications [1].

The distance between antennas for transmission and reception on the premises is much shorter than in the outdoor case. The size, structure and arrangement of any furniture in the room also affect the indoor radio propagation environment. So, the effects caused by the radiation patterns of indoor base station antennas are probably different from the outdoor effects of the antennas placed on buildings. Reference [1] presents a comparison in an indoor field test between a 12-element Yagi-Uda antenna and a half-wave dipole antenna for a base station. The 800 MHz line-of-sight measurement showed that the difference in the received signal strength is less than the directivity difference in a multipath environment.

This paper describes 1.3 GHz indoor mobile measurement results in order to compare the propagation characteristics of three different base station antennas. These three antennas have different beam widths on the vertical plane. A typical office under a multipath environment was used for the measurement. Based on the measurement data, the authors calculated the average signal strength, the fading range, the cumulative probability profile for signal strength, and so on. Then, these propagation parameters were compared to characterize the effects due to the radiation pattern on the vertical plane.

## 2. Test Site and Measurement Apparatus

Figure 1 shows the test site and measurement courses. The site was a typical office 50 x 15 meter, with many pieces of furniture made of metal. The windows were all covered by metal shades. Metal lockers were installed on all the walls on the south side. Such furniture easily causes multipath phenomena.

Figure 2 shows the radiation patterns on the vertical plane for the three base station antennas, whose radiation fields were all vertically polarized. Type I had a 5 dB larger directivity than Type III, Type II was 1 dB larger than Type III. The beam tilt angles for these antennas were also different. All three antennas had omnidirectional patterns on the horizontal plane. The base station antenna was located at the center of the room ceiling. The ceiling was 2.5 meters above the floor.

A 1.3 GHz CW signal from the base station antenna was received by a mobile measuring vehicle [2]. The vehicle was equipped with a receiving antenna, a signal receiver, a personal computer for data recording and processing, a position and direction measuring unit using an angle velocity sensor and distance pulse generators. The receiving antenna was the same as the Type III antenna in Figure 2. However, the antenna was installed upside down, compared to the one for the base station, so that the beam was directed up from the horizontal plane. The antenna was 1.4 meters from the floor.

## 3. Average Signal Strength Comparison (Figure 3)

The average signal strength values were calculated among 501 points. The 501 points covered a 1 meter range in the course. The signal strength was measured both ways, but Figure 3 shows only the average from the one-way measurement data.

Type I antenna had the largest average signal strength in most of the courses. The minimum and maximum differences between Type I and Type III were 3 dB and 16 dB, respectively.

However, comparing Type II with Type I, there were some portions in the courses in which Types I and II were almost the same, or when Type II exceeded Type I. These portions of the course were relatively far from the base station and were located near the metal furniture surfaces commonly visible from the base station antenna and the mobile vehicle antenna. These surfaces were illuminated by the signal wave from the base station and scattered the wave. Besides, the reception points were close to the scattering surfaces. These scattered waves cause deep fading and make the average signal strength worse. Comparing the radiation pattern for Type I with that for Type II, the strong and nearly horizontal beam of Type I illuminates the surfaces more intensely than Type II, and the ratio of the the scattered wave intensity to the direct incoming wave was larger. The difference on the propagation situation probably caused the worse average for Type I.

## 4. Fading Range Comparison

The fading range is defined as the difference in dB between the signal strength values with 10 % and 90 % cumulative probabilities. The fading ranges were calculated among 250 points. The 250 points covered a 0.5 meter range for the course. In the case of a Rayleigh distribution, the value is 13.4 dB. Figure 4 shows only the fading range from the one-way measurement data. Figure 5 shows the cumulative distribution for the fading range in several courses. Figure 5(a) was calculated from the data in courses A and B in Figure 1 and Figure 5(b) in courses C, D, E, and G, which were farther from the base station than A and B.

Figure 5(a) shows that the Type I antenna gives the smallest fading range near the base station. The probability that the fading range will be less than 10 dB when using Type I was 95 %, which was 15 % larger than for Types II and III. The probability that the fading range will be less than 10 dB out of the area near the base station when using Type I antenna was 45 %, which was almost the same as for Type II.

The authors also compared the fading range calculated from measurements made when going and those made when returning. The results showed that the fading range for the going and those for the returning were considerably different near the metal lockers which were near scattering surfaces.

Figure 6 shows the difference between measurements made on both ways. Figure 6(a) shows Type I antenna's data for course A both ways, and Figure 6(b) shows course E, near the metal lockers. Figure 6(b) shows that the variations in the signal strength for both ways for course E were different, while the variations in Figure 6(a) were close. The scattering wave from the lockers was dominant for course E. So, the standing wave caused by the direct-incoming wave and the scattered wave made notches in signal strength along the course. If the paths for the measuring vehicle both ways were several inches apart, one path would probably be located nearly on the notches, while the other would not be. This causes a difference in both the signal strength variations and the fading ranges.

## 5. Conclusion

A "high-gain antenna" for the base station improves the average signal strength and fading near the base station. In some portion outside the area near the base station, however, the improvement in the average signal strength decreases or fading becomes worse.

In an ordinary case, the service area edges are points to judge whether the good quality radio transmission is available in the area, while there are almost no problems regarding quality near the base station. Besides, general "high-gain antennas" are physically larger than antennas with wide beams on the vertical plane. Considering compactness and appropriate performance in indoor radio communication, the best choice is sometimes a base station antenna with an optimal beam width, such as a Type II antenna in this experimental study, instead of "the highest-gain antenna" like Type I.

Acknowledgement

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Reference

[1] T. Tsuruhara, T. Suzuki and A. Akeyama, "Indoor Propagation Characteristics in the 800 MHz Band," Papers of Tech. Group on Antenna and Propagation, IECE Japan, AP79-40, Jul. 1979.

[2] S. Obayashi and T. Maeda, "Development of an Indoor Mobile Radio Propagation Measurement System with a Function of Measuring its Own Position and Direction," Proc of 1989 International Symposium on Antennas and Propagation (ISAP89), 3D3-1, Aug. 1989.

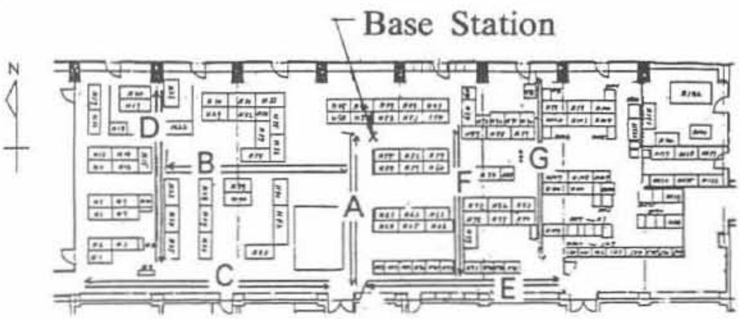
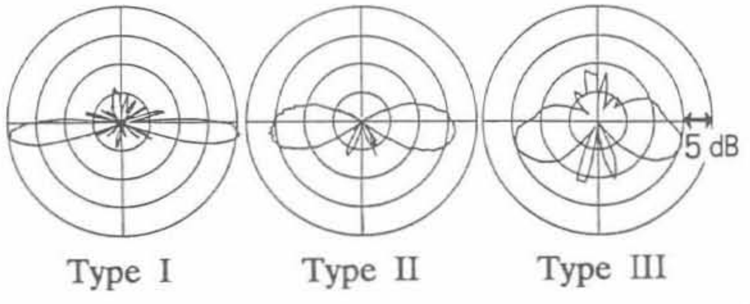


Figure 1
Test Site and
Measurement Courses



Type I Type II Type III

Figure 2
Radiation Patterns
on the Vertical Plane
for Base Station Antennas

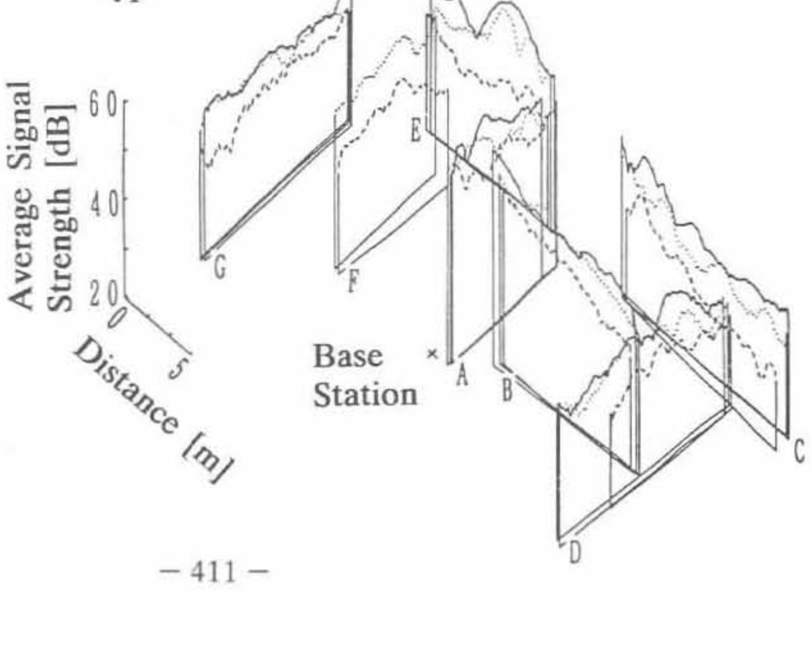


Figure 3
Average Signal Strength
Comparison

——— : Type I
·········· : Type II
- - - - - - : Type III

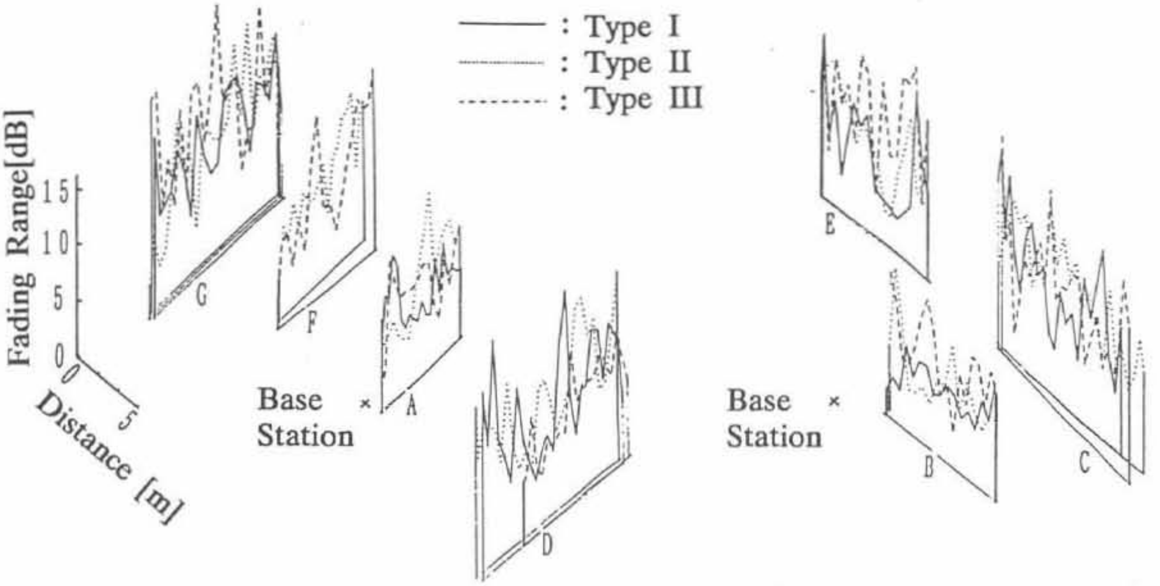
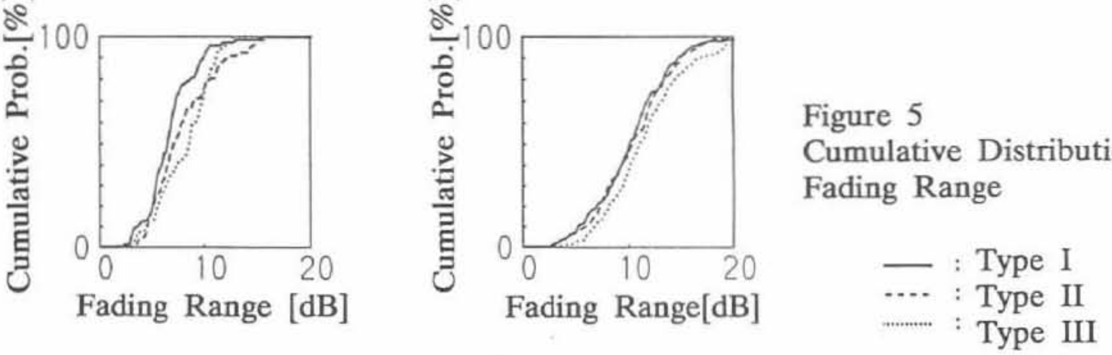


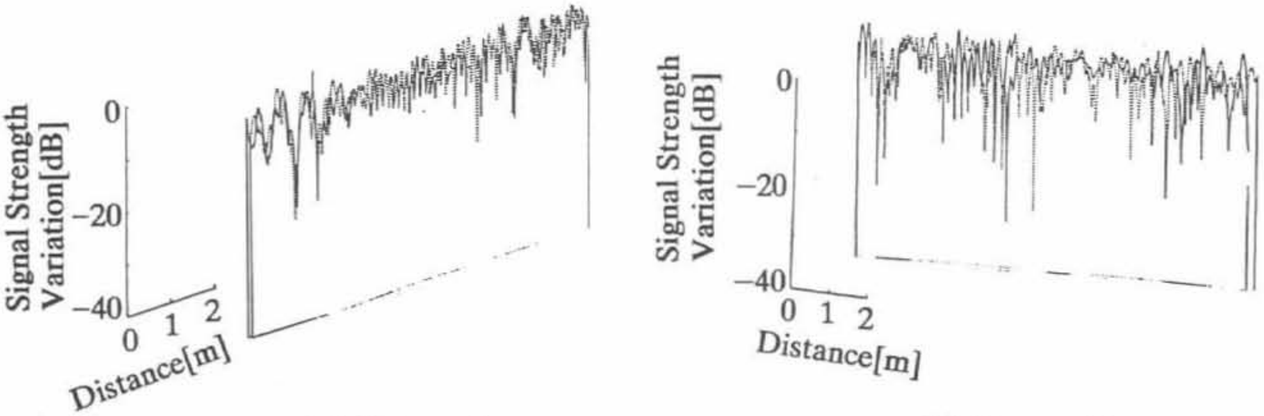
Figure 4 Fading Range Comparison



(a) Courses A & B

(b) Courses C,D,E & G

Figure 5
Cumulative Distribution of Fading Range



(a) Course A

(b) Course E

Figure 6 Difference in Signal Strength Variation on Both Ways
(Antenna: Type I)