Fundamental Characteristics of Combined Tilting Base Station Antenna by Field Trials

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Abstract:
In the cellular mobile communication systems using sectored cell configurations, reducing the back-lobe interference of the base station (BTS) sector antenna that arrives at the other sectors in the same cell is very important to improve the Signal to Interference power Ratio (SIR) and thus cell throughput. Setting the beam tilt angle of the back-lobe deeper than that of main-lobe for the BTS sector antenna greatly reduces the back-lobe interference. We investigated the combined beam tilting method in order to realize the function by simulation in the previous work. In this paper, we clarify the improvements in SIR possible when applying the combined tilting technique to cellular systems by field trials in a rural cell near Tokyo.

Keywords: antenna tilting; base station antenna
Classification: Antennas and propagation

References

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1 Introduction
To realize high speed services cellular mobile communications systems need technologies that can suppress the co-channel interference from not only the neighboring cells but also the neighboring sectors of the same cell [1]-[3]. Antenna beam tilting is a promising candidate. BTS sector antennas usually employ the electrical tilting method, which has a constant tilt angle in the horizontal plane. Unfortunately, the antennas must be extremely large to strongly suppress the side-lobes and the back-lobes against the neighboring sectors in the same cell. On the other hand, the mechanical tilting method, which is utilized especially for deep tilting because of its simple configuration, has the special feature of different tilt angles in the horizontal plane. The combined beam tilting method which employed both the electrical tilt and the mechanical tilt was investigated in order to reduce the interference by simulation in the previous work [4]. In this paper, we clarify the improvements in SIR possible when applying the combined tilting technique to cellular systems by field trials in rural cell near Tokyo.

2 Principle of Combined Beam Tilting
The principle of the proposed method is illustrated in Fig. 1. Since a conventional antenna is perpendicularly installed in general as shown in Fig. 1(a), the directivity of the antenna is expressed by using a vertical directivity \( D_v(\theta) \) and a horizontal directivity \( D_h(\phi) \) as follows

\[
D(\theta, \phi) = D_v(\theta) D_h(\phi). \tag{1}
\]

\( D_v(\theta) \) and \( D_h(\phi) \) are independent of each other in this equation. Fig. 1(b) illustrates the proposed combined tilting antenna which has slightly upper mechanical tilt. Electrical tilt angle is set to deeper than the conventional by mechanical tilt angle \( |\theta_m| \) in order not to change the service coverage. Because the horizontal directivity depends on the vertical directivity and the mechanical tilting angle, the directivity of combined tilting antenna is given by

\[
D_m = D_m(\theta, \phi, \theta_m). \tag{2}
\]

The main beam direction of vertical plane regarding azimuth angle is shown in Fig.1(d) when front tilt angle is 95 degrees and mechanical tilt angle is 0 degree (Fig. 1(a)) or -3 degrees (Fig. 1(b)). Although the main beam direction of the conventional is constant regarding azimuth angle, that of the combined tilting changes according to azimuth angle. The tilt angle in the front region does not remarkably vary. However, the tilt angle in the side and back region greatly change lower. This effect causes larger propagation loss at the side or back region as shown in Fig. 1(c). As a result, this combined tilting method realize both minimum side effect in own sector and suppression of the interference from neighboring sectors.
3 Experiment Specifications and RSRP

Field trials were executed at a rural cell near Tokyo, as described in Fig. 2(a). Only one BTS with 3-sector was operated in the field trials. All the antennas were set to the same mechanical tilting angle even if the mechanical tilting angle was changed. LTE signals were transmitted from the antennas installed at 40 m height tower and the signal at the car top antenna was received by a measuring receiver (Anritsu ML8780A). We measured the signals of both the conventional tilting and the combined tilting through the same course.

RSRP (Reference Signal Received Power) data of 3 sectors at the each point were measured and plotted in the area map every one second, as described Fig. 2(b-d). A north sector, a west sector and an east sector face toward $\varphi = 0$ deg. (the due north), -120 deg. and 120 deg., respectively. Upper row of Fig. 2(b-d) indicates the RSRP map of the conventional tilting. Lower row is the maps of combined tilting angle of -3 degrees. From the figure, it was clarified that the level of power received from all the sectors were reduced at the neighboring sectors when the combined tilting method was employed.
(a) Experiment specifications.

| Specification                  | Value                                           |
|-------------------------------|-------------------------------------------------|
| Frequency                     | 2.1 GHz                                         |
| Beam width in the horizontal plane | 90 deg. (F/B =25 dB)                        |
| Beam width in the vertical plane   | 5.5 deg.                                      |
| Beam tilting angle @ front      | 5 deg.                                         |
| Height of BTS antenna          | 40 m                                           |
| Mechanical tilt angle \( \theta_m \) | 0, - 3 deg.                                   |
| Number of sectors              | 3                                              |
| Height of received antenna (car top) | 2.3 m                                     |
| Received antenna               | Sleeve dipole antenna                          |

4 SIR Improvement in Radial and Round Course

The purpose of the method is to suppress the interference from not the other cells but the neighboring sectors of the same cell. Therefore, the SIR between the own sector and the neighboring sectors in the same cell (Eq.(3)) is evaluated in order to obtain the above fundamental characteristics of the method. The radial course and round course as shown in Fig. 1(c) were selected to get the distance characteristics and the angle characteristics of SIR, respectively.

\[
SIR = \frac{RSRP_{own}}{RSRP_{neighboring}^+ + RSRP_{neighboring}^-} \quad (3)
\]

4.1 Radial Course (Distance Characteristics)

First, Fig. 3 indicates the SIR distribution on the radial course whose angle is \(-50 \pm 5\) deg. The measured range is from 150 to 1,600 m in the figure. Green and red lines indicate the north and west sectors, respectively. Fig. 3(a-1) shows the conventional tilting method. In the figure, because both sectors have the same vertical directivity, the SIR is constant regarding distance. The value of SIR is almost corresponding to the difference between both directivities. In this course, the SIR characteristics of west sector are reverse against that of north sector.
because the influence of east sector is negligible. The results of combined tilting are shown in Fig. 3(a-2). It is found that the SIR changes according the distance, comparing with the conventional method. Because own sector directs null beam of vertical pattern toward around 250 m point, the SIR at that point decreases. Although the above null beam of own sector exists in the conventional tilting too, the neighboring sectors also have the same null beam. In other words, the null beams of both sectors face completely toward the same vertical angle. Therefore, such a problem does not occur regarding the conventional tilting. Although there is little improvement in the short range between 250 and 350 m, remarkable improvement in the range of more than 350 m can be observed. In this paper, because we evaluate the SIR as an isolated cell environment, the SIR increases when the distance becomes large. (Please note that the SIR at the cell edge region decreases as neighboring cells exist around own cell in actual environments. Therefore, it is necessary to design carefully cell layout, front tilting and so on.)

4.2 Round Course (Angle Characteristics)

Next, the angle characteristics of SIR when the distance between BTS and measuring point is constant were evaluated. The data of distance of between 750 and 850 m were picked up from all the measured data and were plotted to Fig. 3(b). In the figure, x-axis indicates the azimuth angle of the measured point. Fig. 3(a-1) and 3(b-2) show the conventional tilting, the combined tilting of -3 degrees, respectively. In each figure, green line, red line and blue line indicate the north, the west and the east sectors, respectively. From the figure, it is very easy to recognize the service coverage of each sector. Even if the mechanical tilting angle changes, the sector edge angles that the SIR is equal to 0 dB do not vary. And the angles are -175, -70 and 80 degrees, respectively. From these data, it was clarified that the sector edges of the own cell were independent of mechanical tilting.

On the other hand, the SIR within the coverage of own sector can be improved significantly. From the figure, it was found that the SIR data with mechanical tilting were significantly sharper and higher than that without mechanical tilting. From the other viewpoint, the SIR at the point outside the service coverage seriously decreases when employing the method. Moreover, the SIR at central direction of own sector is higher than that at sector edge in each sector. In these figures, there are some lacks of data at the central direction of service coverage. It is the reason that the RSRP level of the interference was too weak to receive in these points. From these results, antenna radiation pattern which affects the SIR improvement directly is found to be one of most important feature.

From the viewpoints of both distance and angle characteristics, it was clarified that the proposed combined tilting method had significant suppression effects of the neighboring sectors by evaluating the fundamental characteristics.
5 Conclusion

A beam tilt method for base station sector antenna that creates different beam tilt angles for back-lobe and main-lobe by combining both electrical and mechanical beam tilting, was examined and evaluated by field trials. It was clarified that the proposed method strongly suppressed the co-channel interference from the back-lobe and significantly improved the SIR.