Small-sized Shaped Beam Base-Station Antenna Designed to Reduce Inter-Sector Interference in High Speed Cellular Systems

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1. Introduction

Next generation high speed data wireless systems, such as LTE (Long Term Evolution) and Mobile WiMAX, will demand much higher link quality compared with current cellular systems whose main purpose is to manage voice traffic. For example, the maximum value of CINR (Carrier to Interference plus Noise Ratio) is 9.5 dB in a CDMA2000 1xEV-DO Rev. 0 cellular systems. On the other hand, the maximum value of CINR specified in a LTE cellular system will be approximately 30 dB.

In an actual cellular system, two types of interference exist in the cell. One is inter-cell interference between adjacent cells and the other is inter-sector interference caused in a single cell. In particular, high-speed cellular systems will be able to expand service coverage for the high data rate area by reducing inter-sector interference. This is because multi-level modulation schemes, such as 16QAM and 64QAM, will be applied under a high CINR condition around the center range of the cell.

In general, the conventional cell structure has been planned as a three-sector system with the directional antenna pattern in the horizontal plane. The optimum 3 dB beam width for the horizontal plane is in the range of 70 to 80 degrees for CDMA systems in order to reduce interference from and to other sectors [1]. However, non-negligible inter-sector interference remains due to the beam overlap around the edges of the horizontal pattern. This kind of interference can be reduced by adopting a narrower beam sector antenna in the base station. However, the narrower sector beam antenna increases low signal strength areas in the sector zone even if the interference from the other sectors is reduced.

This paper proposes a newly designed shaped beam antenna in order to reduce inter-sector interference by adopting the antenna beam shaping technique. The proposed shaping technique allows the antenna to maintain the 3 dB main beam width that is comparable with the conventional one. Furthermore, the antenna beam gain in the direction toward the edge region neighboring the other sectors of the horizontal antenna pattern can be reduced. In Section 2, the detailed structure of the proposed shaped beam antenna is presented. The results of the computer simulation and measured antenna pattern are indicated in Section 3. In conclusion, a summary of this paper is briefly described.

2. Antenna Structure

Figure 1 indicates the relationship between beam shaping and inter-sector interference. The figure on the left shows the horizontal antenna pattern of the conventional base station antenna and the figure on the right shows that of the proposed shaped beam antenna. The painted areas of these figures indicate the interference region between sector beams. The interference region for the proposed antenna is obviously smaller than that of the conventional one. From this figure, it is easy to understand that the proposed shaped beam antenna will improve the wireless link quality in the cell.

Figure 2 shows a cross-section of the proposed shaped beam antenna equipped with a radome in the simulation model. This proposed antenna has elements for both the vertical and horizontal polarization in order to achieve polarization diversity. Antenna elements are composed of a printed dipole. The elements for the vertical pol. are the horizontal array of two vertical dipoles, and the element for the horizontal pol. is the bent dipole. The inside diameter of the radome is 0.65 lambda (lambda is the wavelength of the center frequency in the band) and the thickness of the radome is 0.084 lambda. The main reflector mainly improves the value of the FB (front to back) ratio and the sub-reflector mainly adjusts the value of the 3 dB beam width. The proposed side sub-reflector, which is the most important component, reduces the gain of the main beam edge. Figure 3 shows the design model of this sub-array composed of four elements on the vertical line. The vertical dipoles and horizontal dipoles are alternately arranged in a vertical line.

3. Results of Simulated and Measured Radiation Pattern

Figure 4 shows the simulated antenna patterns in the horizontal plane of the vertical and horizontal polarization. The simulation software is by CST Microwave Studio [2]. The horizontal axis is the azimuth angle (degree), and the vertical axis is the magnitude (dB). In the figure on the left, the dotted line shows the radiation pattern without the side sub-reflector, and the solid line shows the radiation pattern with the side sub-reflector. In azimuth, the line from -60 to +60 degrees indicates the target sector region, and the lines from -180 to -120 degrees and from 60 to 180 degrees indicate the neighboring sector regions of the same base station. In this figure, the 3 dB beam width with sub-reflectors is 90 degrees and that without sub-reflectors is 76 degrees. On the other hand, the gain of the proposed shaped beam antenna equipped with the sub-reflector is significantly less than that of the conventional antenna in the neighboring sector regions.

In terms of the horizontal polarization antenna, the 3 dB beam width of the horizontal dipole in the horizontal plane is 76 degrees, and it originally has the shaped beam pattern. However, the back lobe of the horizontal dipole is very large in the horizontal plane. To suppress the back lobe, the antenna elements of the horizontal polarization adopt the bent dipole with the reflector as shown in Figure 2. In this figure, the bent angle of the dipole is 30 degrees. The right hand side of figure 4 shows the simulated antenna pattern in the horizontal plane of the bent dipole of the horizontal polarization and the non-bent dipole (so-called straight normal dipole). The solid line shows the radiation pattern of the bent dipole and the dotted line shows that of the straight dipole. As shown in this figure, the 3 dB beam width of both the bent dipole and the straight dipole is 86 degrees. On the other hand, the back lobe levels of the bent dipole are less than that of the straight dipole.

To confirm the validity of the simulation results, the horizontal beam pattern of the developed shaped beam antenna was measured in an anechoic chamber. Figure 5 shows the measured and simulated patterns of the vertical and horizontal polarization in the horizontal plane. On the left hand side of figure 5, the dotted line, solid line, and dashed line indicate the measured pattern of the conventional commercial antenna, the proposed antenna, and the simulated pattern of the proposed antenna, respectively. From this figure, the proposed antenna successfully reduced gain in the other sector region maintaining the main beam width. The measured pattern of the proposed antenna is almost identical to that of the simulated one. Some level difference in the back lobe region is observed by the existence of the metallic pole for the measurement. On the right hand side of figure 5, the measurement data of the horizontal polarization is almost identical to the results of the simulation.

From the above considerations, the effectiveness of the shaped beam pattern for both vertical and horizontal polarization is confirmed, and it can be concluded that the proposed shaped beam antenna will reduce the inter-sector interferences and expand the high quality service coverage.

4. Conclusion

This paper proposed a new type of small-sized shaped beam base station antenna that reduces inter-sector interference. The diameter of the radome is 0.65 lambda, which is extremely small. The proposed antenna can contribute to improving the quality of the high-speed data cellular system. Field tests under a variety of propagation environments will be conducted in the near future for further study.

Acknowledgments

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References

[1] K. Fujimoto, Mobile Antenna Systems Handbook, Third Edition, ARTECH HOUSE, pp.144-146
[2] CST MICROWAVE STUDIO http://www.cst.com/

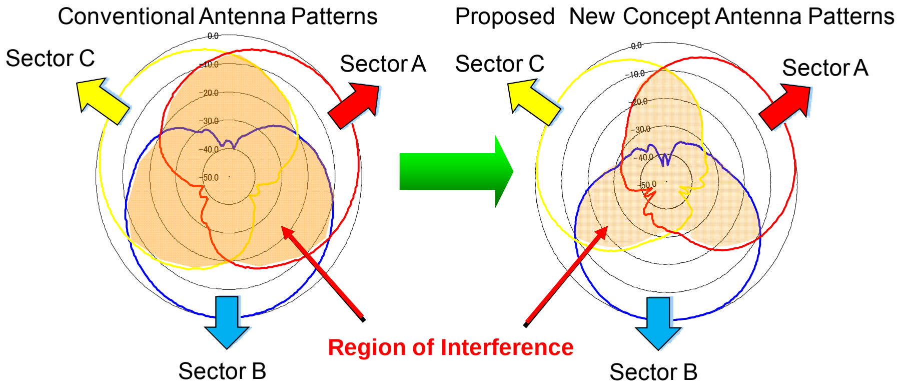
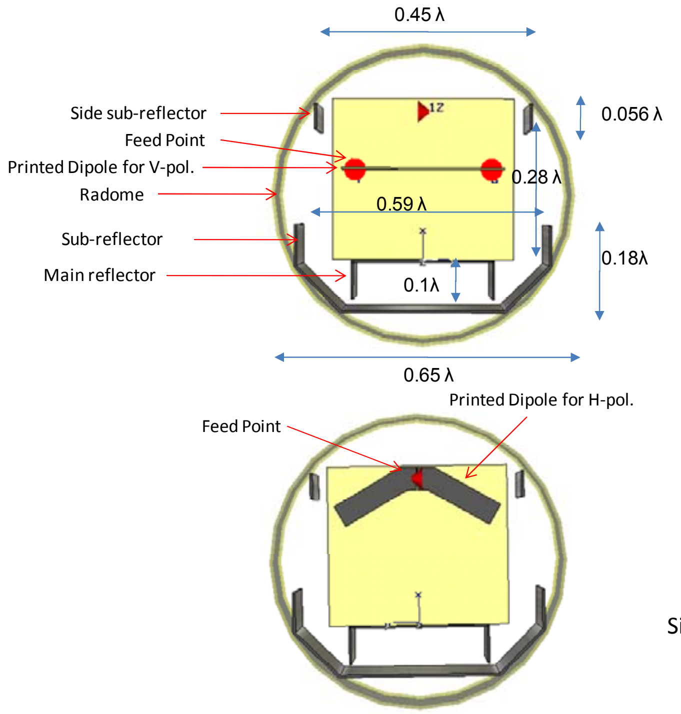


Figure 1 Relationship between Beam Shaping and Inter-Sector Interference



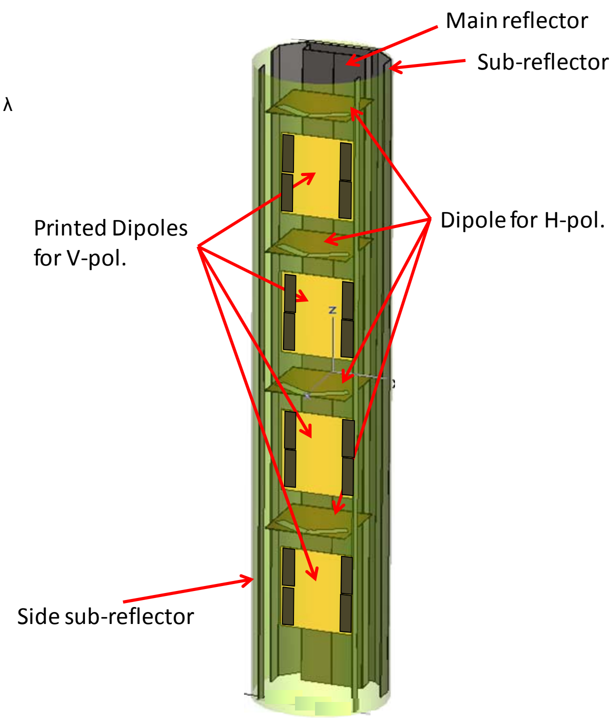


Figure 2 Cross-section inside Radome in Horizontal Plane at Proposed Antenna (Above: V-pol. Dipole, Below: H-pol. Dipole.)

Figure 3 Perspective for Four element Sub-array inside Circular Radome

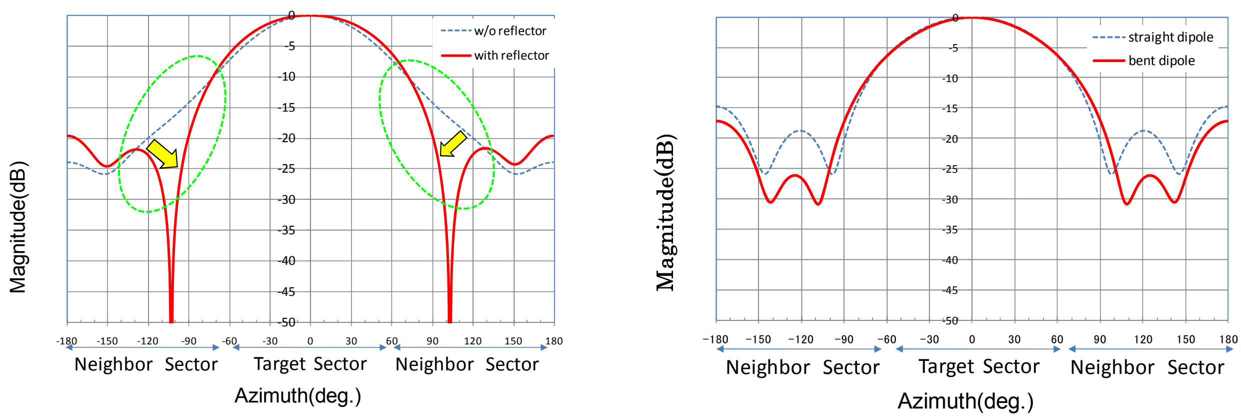


Figure 4 Simulated Horizontal Pattern (Left: V-Pol. Right: H-Pol.)

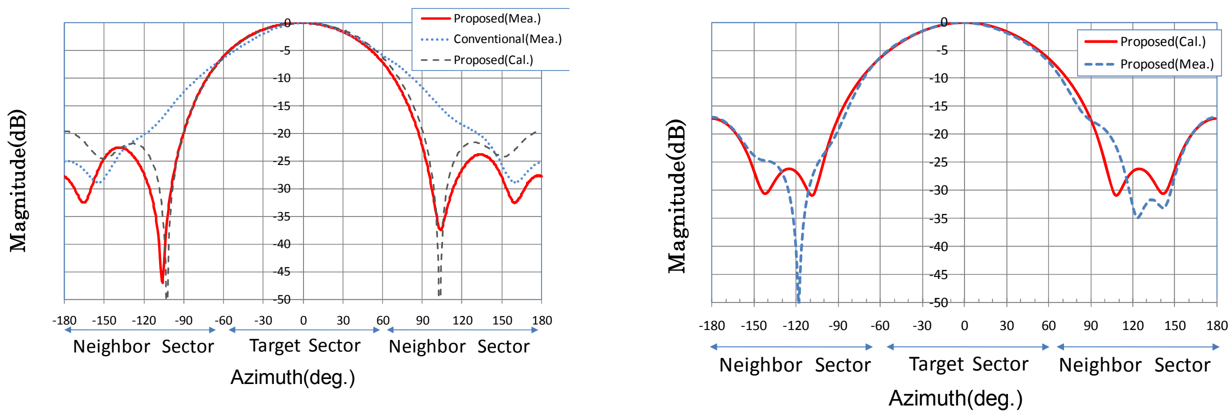


Figure 5 Measured and Simulated Horizontal Pattern (Left: V-Pol. Right: H-Pol.)