EFFECT OF VARIABLE DIRECTIVITY BASE STATION ANTENNA FOR MOBILE RADIO

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1. Introduction

The number of mobile and portable telephone users has increased so rapidly that there soon will be a shortage of radio channels in urban and metropolitan areas. This is an important problem that limits total system capacity.

One solution is to install many new base stations and decrease the cell size. Its cost is excessive, however, it is difficult to find enough places that offer the desired antenna height. From the viewpoint of cost performance, we want to improve the capacity without new base stations. Many techniques of co-channel interference reduction have been proposed. They include cell sectorization(1)(2), beam tilting (3), reuse partitioning(4), micro cell, interleave channel assignment, dynamic channel assignment, transmission power control, and adaptive cancellation(5).

The technique of dynamic antenna pattern control achieves higher spatial reuse efficiency; the base station antennas have narrow beams and track each mobile station which boosts desired waves while suppressing undesired waves. There are two types of antenna system: adaptive arrays and switched multibeam. The former forms a beam by digital processing; the latter tracks a mobile station by selecting one of many beams.

The adaptive array antenna system is well known to have high performance against co-channel interference in ideal environments(6)(7)(8). However, as the coming wave has the distribution of angles in a real propagation environment(9), null beams that reduce co-channel interferences cannot be formed perfectly. The adaptive array antenna system without null beams has never been examined, and has not been compared to the switched multibeam antenna system. The relation between beam width(number of beams) and reduction in interference has not been clarified for either system.

In this paper, we discuss the relation between beam width and co-channel interference reduction of the adaptive array system without null beams in a comparison against both the present sector system and the switched multibeam system.

2. Antenna system

Figure 1 shows the antenna systems considered. The subsector system has many narrow beams corresponding to each subsector transceiver as Figure 1(a); channel assignment to beams is fixed. When a mobile station crosses from one beam to another, hand-off is performed by network circuit control equipment.

Figure 1(b) shows the switched multibeam system. A switching matrix behind of the multibeam forming circuit monitors signal strength from mobile stations. When a mobile station crosses between two beams, the beam with higher signal level will be selected without frequency hand-off. Beam direction in these two systems is fixed, however mobile stations can be tracked by switching beams.

Figure 1(c) shows the adaptive array system. In this system one beam is formed continuously to track a mobile station.

3. Simulation model

Long term constant is 3.5, standard deviation is 6.5dB. In the assumed environment, the interference noise is higher than thermal noise; this typical of metropolitan areas.

Figure 2 shows a co-channel cell layout that has 19 hexagonal cells. Each cell has

3 sector zones. Cell distance is given by,

$$D1 = \sqrt{3N}\ R, \quad D2 = 3\sqrt{N}\ R, \quad D3 = 2\sqrt{3N}\ R \quad (1)$$

where R, N note cell radius and cluster size, respectively. One mobile station exists on each channel beam. The signal to interference ratio(SIR) of the center cell is calculated using total signals from co-channel cells to obtain outage probability as follows,

$$SIR^{up} = PO^{up} / \Sigma Pi^{up}, \quad SIR^{dw} = PO^{dw} / \Sigma Pi^{dw} \quad (2)$$

Transmitter power is 1W and power control is not used.

Figure 4 shows the antenna pattern in the horizontal plane. Figure 5 shows it in the vertical plane. In these two figures, peak level is normalized to 0dB. As we assume that the antenna height is 75m, cell radius is 1500m, beam width is about 4deg., and tilt angle is about 5deg.. Both the side lobe level toward the nearest co-channel cell and the side lobe level toward self cell are -10dB. Figure 6 shows the propagation loss obtained by using the vertical pattern in figure 5. Distance is normalized by cell radius R. The loss, except in the cell edge area, is higher than that of the omni vertical pattern.

Figure 7 shows the beam model of each system where θ bw notes beam width. Subsector, switched multibeam system in figure 7(a) selects the beam having maximum signal level. In this simulation, both systems are treated using the same model. As this system has fixed directional beams, the beam peak is not necessarily directed to the mobile station. In particular, the gain at the boundary decreases to -3dB. On the other hand, figure 7(b) shows the adaptive array system. As the main beam always tracks the mobile station, the beam peak is always directed to the mobile station. No adaptive algorithm is needed because null beams are not necessary.

4. Results

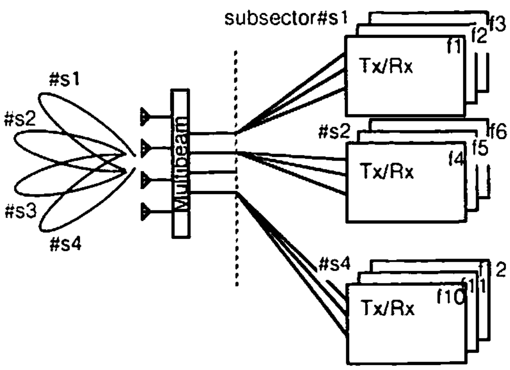
Figure 8 shows outage probability when the number of sectors is 3 with a 120 degree beam. The parameter is cluster size which ranges from 1 to 7. When the cluster size decreases, the outage probability increases. We use the value of 3 sectors, cluster size 7(fixed 120deg. beam) in this figure as a reference for later results. As an example, when cluster size decreases from 7 to 4, outage probability increases from 12% to 25% with SIR 20dB. Figure 9 shows the outage probability of the subsector, switched multibeam system with cluster size 4. The parameter is beam width(number of sectors) which varies from 120deg.(3 sectors) to 5deg. (72 sectors). From this figure, about 40deg. satisfies the reference value. Figure 10, which shows the outage probability of the adaptive array system with cluster size 4, indicates that this system requires less than 60deg. beam antenna. Comparing both systems, it is found that the adaptive array without null beams can be realized but the subsector, switched multibeam can not if using the same 60deg. beam antenna. This is because the gain of the subsector, switched multibeam decreases in the boundary regions while the adaptive array suffers no such loss.

Figure 11 shows the relation between the beam width and the distance of co-channel cells. The distance is normalized by the radius of cluster size 7. Cluster size 7, 4, 3 and 1 mean normalized distances of 1, 0.76, 0.66 and 0.38, respectively. When the beam width is less than 60deg., the beam width of the adaptive array can be 15deg. wider than that of the subsector, switched multibeam at the same distance. It is found that either system fails to realize cluster size 1 if the beam is narrower. To realize cluster size 1, the side lobe level must be less than -15dB or beam nulls are required.

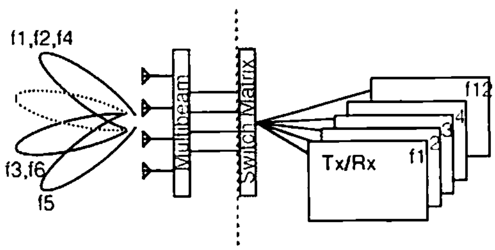
5. Conclusion

This paper has shown the relation between the beam width and the distance of co-channel cells with the adaptive array system without null beam. A comparison was made to the subsector, switched multibeam system. The beam width of the adaptive array can be 15deg. wider than that of the subsector, switched multibeam at the same distance.

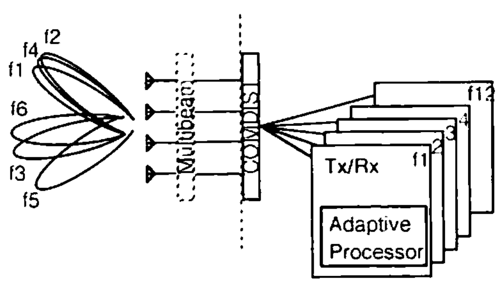
References
(1)N.Nakajima, K.Nakano:" Spectrum Efficiency of Sector Cell Layout ", ICICE Tech. Rep. RCS89-18 (1989-10)
(2)T.Kanai : " A Study on Channel Assignment for Sector Cell Layout ", Trans. ICICE, J73-B-II, No.11, pp.595-601, (1990-11)
(3)M.Sinji ed.:" Idotsushin ", pp.197, Maruzen, 1989
(4)S.W.Halpern : " Reuse partitioning in cellular systems ", Tech.Conf., VTC-83, pp.322-327, (1983)
(5)H.Suzuki : "Adaptive signal processing for optimal Transmission in mobile radio communications ", ICICE Trans. E77-B, No.5, pp.535-544, May 1994.
(6)S.C.Swales, M.A.Beach, D.J.Edward, J.P.MacGeehan : "The performance enhancement of multi-beam adaptive base-station antennas for cellular land mobile radio systems", IEEE Trans. VT-39, No.1, pp.56-67, Feb. 1990.
(7)" Special Issue ", Trans. ICICE, J75-B-II, No.11, (1992-11)
(8)T.Ohgane :" Spectral efficiency improvement by base station pattern control for land mobile cellular systems", IEICE Trans. E77-B, No.5, pp.598-605, May 1994.
(9)S.Kozono, S.Sakagami:" Correlation Coefficient on Base Station Diversity for Land Mobile Communication Systems ", Trans. ICICE,, J70-B, No.4, pp.476-482, (1987-4)



(a) Subsector system.



(b) Switched multibeam sysyem.



(c) Adaptive array system.

Fig. 1. Antenna system.

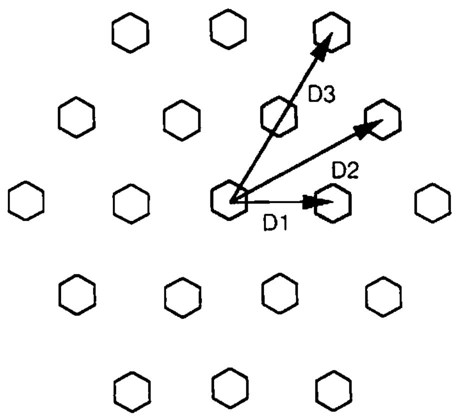


Fig. 2. Co-channel cell layout.

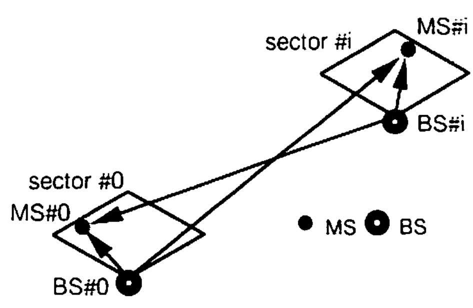


Fig. 3. Interference between cells.

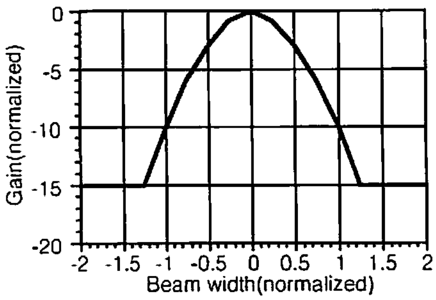


Fig. 4. Antenna pattern in horizontal plane.

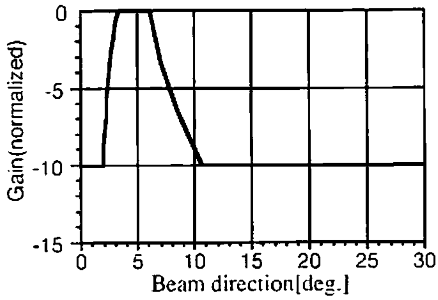


Fig. 5. Antenna pattern in vertical plane.

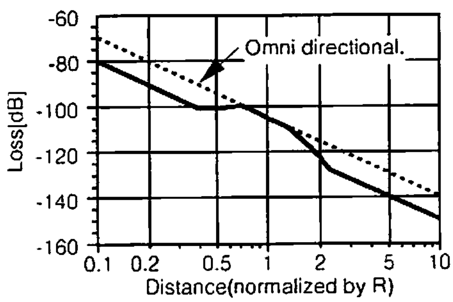
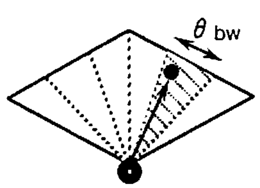
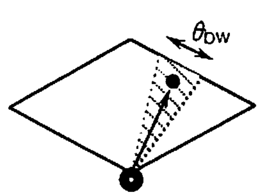


Fig. 6. Propagation loss.



(a).Subsector, switched multibeam model.



(b).Adaptive array model.

Fig. 7. Beam model.

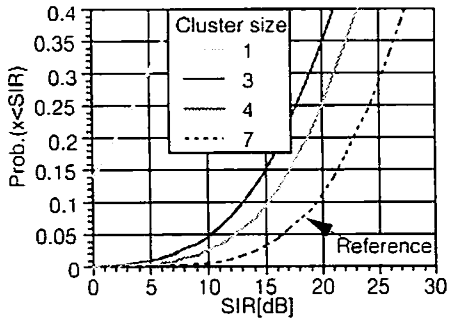


Fig. 8. Outage probability (3 Sectors 120deg. beam)

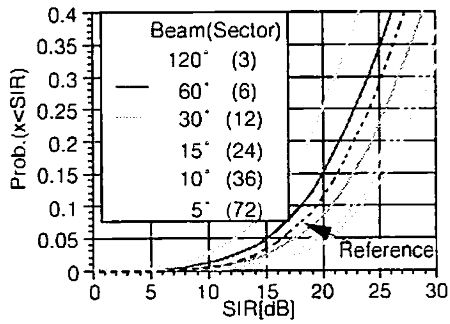


Fig. 9. Subsector, switched multibeam system.(Cluster size 4)

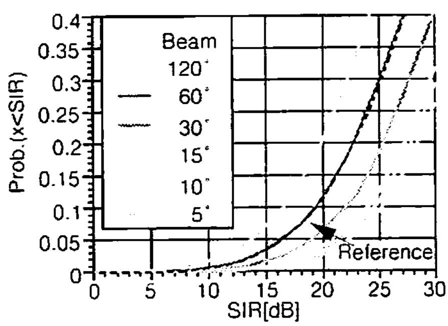


Fig. 10. Adaptive array system. (Cluster size 4)

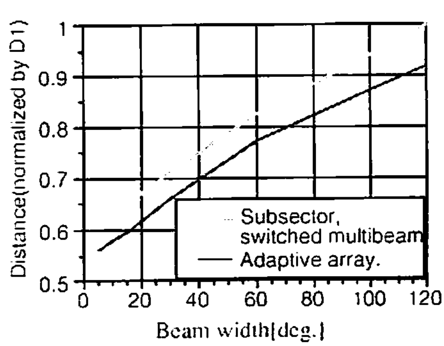


Fig. 11. Relation between beam width and distance.