OPTIMIZING THE ADAPTIVE ARRAY ANTENNA CONFIGURATION FOR INTERFERENCE REDUCTION CHARACTERISTICS IN W-CDMA

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Abstract

In order to improve frequency efficiency for cellular mobile radio systems, adaptive array antenna (AAA) in base station is an effective technology. In the case of introducing AAA, the relation between the configuration of AAA (the number and the radiation pattern of antenna elements) and frequency efficiency is the most important problem. In this paper, we clarify the optimum array antenna configuration taking frequency efficiency into consideration under multi-cell environments for W-CDMA.

1 Introduction

The third generation mobile cellular system such as W-CDMA and the fourth generation mobile cellular system are expected to transmit not only a low speed data such as voice but also a high speed data such as moving pictures. To realize such a high speed transmission within a limited frequency resource, the increase of frequency efficiency is required [1]. Cellular system can increase frequency efficiency by reducing the multiple access interference (MAI). Adaptive array antenna (AAA) in base station is one of effective techniques for the large reduction of MAI [2]. AAA controls the antenna beam pattern to increase the gain for a desired user and to decrease the gain for interfering users. The interference reduction effects of AAA depend on the antenna configuration, which is mainly the number and radiation pattern of antenna elements, so the relation between the antenna configuration and frequency efficiency is very significant. However, in previous works, such a study has been hardly conducted, especially for under multi-cell environments [3]. In this paper, we clarify the optimum antenna configuration of AAA under multi-cell environments for W-CDMA.

2 Simulation models

2.1 Cell model

As shown in Fig.1, the simulated area consists of 19 hexagon cells and each cell has 3 sectors. The radius of each cell is R [km]. In this paper, the effect of adaptive array antenna is estimated at the center cell indicated as the object cell in Fig. 1.

2.2 Mobile station model

The number of mobile stations is N_u (=20) [stations] in each cell. The position of stations is uniformly distributed in each cell. One of mobile stations in the center cell is defined as a desired user and other mobile stations in both the center cell and the other cells are defined as interferences.

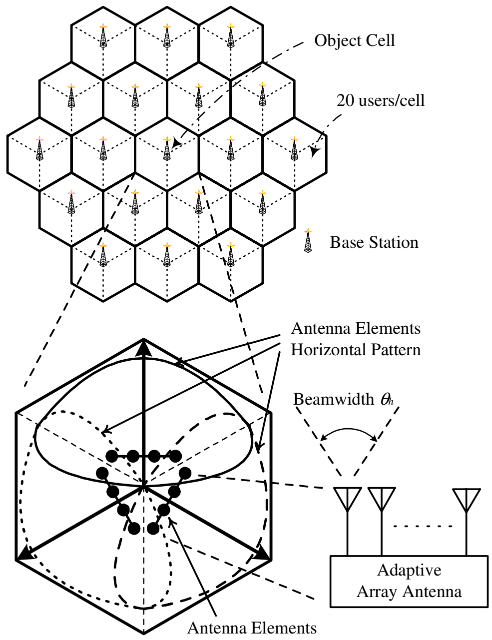


Fig. 1 Cell model

2.3 Propagation model

For simplicity, we focus on the distance attenuation and do not consider Rayleigh fading and log-normal shadowing. Therefore, received power E can be expressed as $E = Ar^{-\alpha}$ [W]. Here r is the distance between a mobile station and the base station, α is a distance attenuation constant and A is a constant determined as the transmit power of mobile station and so on.

2.4 Adaptive array antenna model

Fig. 2 illustrates the array antenna model for the numerical simulation. In this model, the number of antenna elements is N_a and the interval of each antenna element, d, is a half of the wavelength (=$\lambda/2$). The optimum antenna weights w_i (i =1,…, N_a) are directly calculated by SMI (Sample Matrix Inversion) algorithm [4]. Fig.3 shows examples of the radiation pattern of antenna elements. We assume a radiation pattern as follows [5]. Radiation pattern $G(\theta)$ of antenna elements with beamwidth θ_h [deg.] and side lobe level S_L (<0) [dB] is given by

$$G(\theta) = \begin{cases} \cos^m\left(\dfrac{\theta}{2}\right) & |\theta| \le \theta_e \\ 10^{S_L/10} & |\theta| > \theta_e \end{cases} \quad (1)$$

where m and θ_e are given by

$$m = \frac{-3}{10\log_{10}\left(\cos\dfrac{\theta_h}{4}\right)} \quad (2)$$

$$\theta_e = 2\cos^{-1}\left(10^{S_L/(10m)}\right) \quad (3)$$

2.5 Channel model

For simplicity, all users communicate at the same transmission rate. CDMA system can improve CIR (Carrier to Interference power Ratio) of users by using different pseudo-orthogonal spreading codes. Let processing gain be PG, then the average interference level of users decreases by 1/PG times.

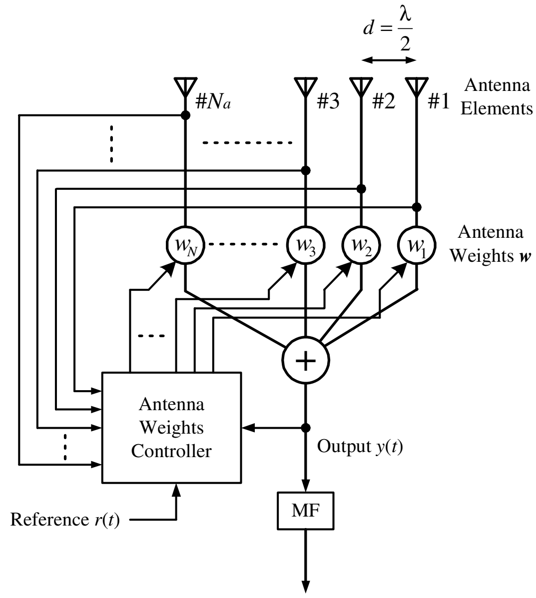


Fig. 2 Structure of adaptive array antenna

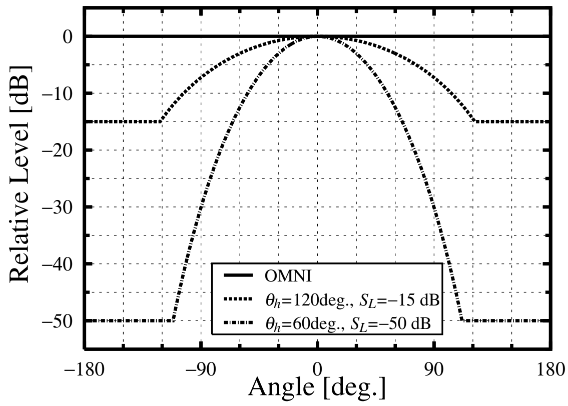


Fig.3 Radiation pattern of antenna elements

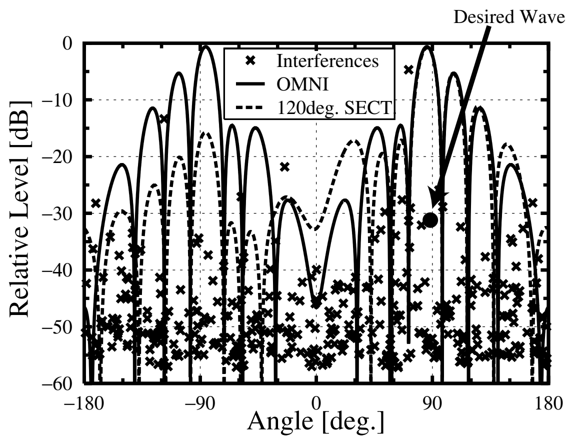


Fig.4 Example of antenna pattern with adaptive array antenna

3 Simulation method

In this paper, we estimate CIR normalized by PG, which is defined as CIR/PG instead of CIR. The simulation is as follows.

(i) The positions of mobile stations are randomly generated in the 19 cells.

(ii) We determine one of mobile stations in the center cell as a desired user and calculate its optimum antenna weights.

(iii) Based on the radiation pattern of the desired user, we calculate CIR/PG of the desired user.

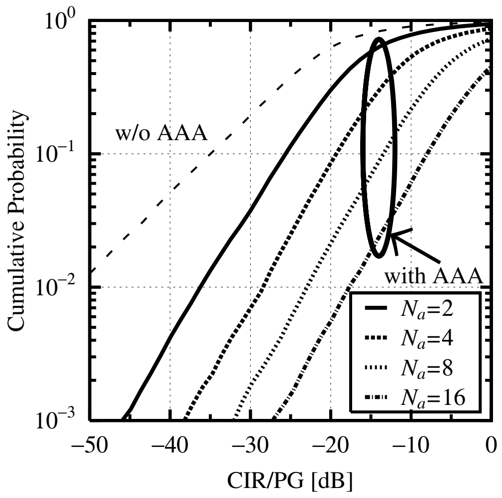
By repeating the above process from (i) to (iii), we calculate a cumulative probability of CIR/PG.

4 Results of simulation

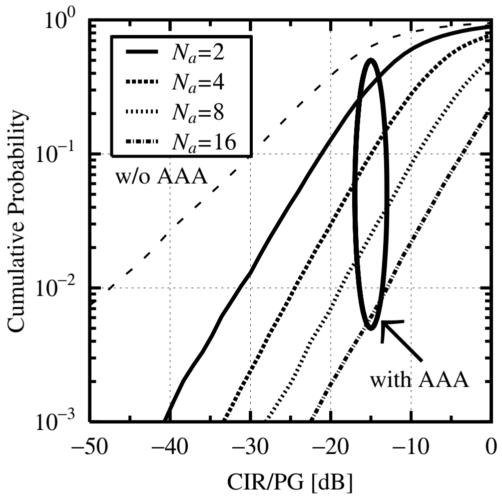
Fig.4 shows an example of radiation pattern when adaptation array antenna is applied. The adaptive array antenna has eight antenna elements. The solid lines show the case of antenna elements with omni radiation pattern. The dashed line shows the case of antenna elements with the beamwidth of 120 degrees and the side lobe level of –15 dB. As shown in the figure, the desired wave is tracked with the main lobe, while nulls of the antenna gain are set in the direction of large interferences.

Fig.5 (a) shows the cumulative probability of CIR/PG with a parameter of N_a in case of antenna elements with omni radiation pattern and Fig.5 (b) shows the case of directional radiation pattern with θ_h =120 deg., $S_L = -15$ dB. Comparing Fig.5 (a) with Fig.5 (b), we find that CIR/PG at 5% value of the cumulative probability in case of antenna elements with directional radiation pattern is better than that with omni radiation pattern.

Fig.6 shows CIR/PG at 5% value of the cumulative probability as a function of the number of antenna elements N_a. From Fig.6 we find that CIR/PG can be improved by about 6 dB when the element number of adaptive array antenna doubles.



(a) Omni radiation pattern



(b) Directional radiation pattern with θ_h =120 deg., $S_L = -15$ dB

Fig.5 Cumulative probability of CIR/PG

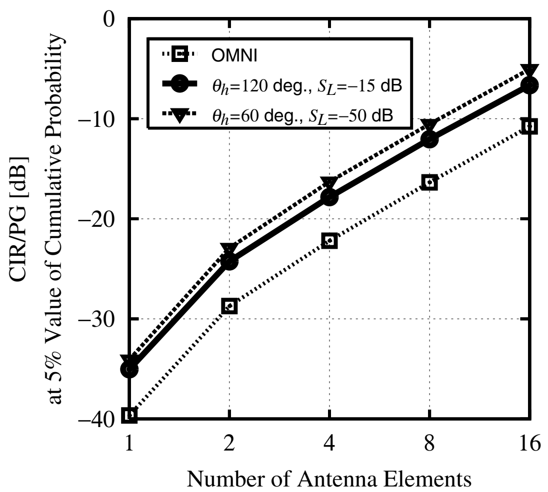


Fig.6 Relation between the number of antenna elements and necessary CIR/PG

Fig.7 shows CIR/PG at 5% value of the cumulative probability as a function of θ_h with parameter S_L . From Fig.7, we find that adaptive array antenna has an optimum beamwidth of antenna elements according to the side lobe level. In general, the optimum beamwidth of antenna elements is smaller than the sector beamwidth (120 degrees at 3 sectors cell).

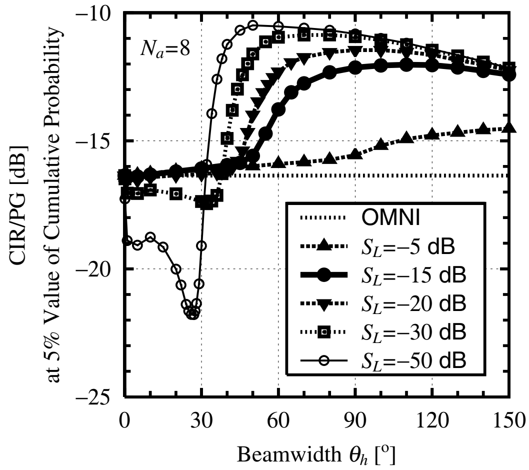


Fig.7 Relation between beamwidth and necessary CIR/PG

5 Conclusions

In this paper, we clarify the relation between the configuration of adaptive array antenna (the number and the radiation characteristics of antenna elements) and interference reduction effect for W-CDMA cellular system. Main results are as follows.

(1) When the number of antenna elements for adaptive array antenna doubles, CIR can be improved by about 6 dB.

(2) Adaptive array antenna has an optimum beamwidth of antenna elements according to the side lobe levels.

We expect that these results give the basic design concept to introduce adaptive array antenna for W-CDMA cellular system.

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