Beam reassignment method mitigates the blocking probability of Multi-Service CDMA

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***Abstract*— The CDMA service coverage is split into different cells. If the available resource in a cell is not sufficient to supply the user's requirement, that cell becomes a hot-spot. As a result, the call will be clogged. The hot-spot causes the high blocking probability. Therefore, various methods including channel borrowing, cell overlaying, adaptive cell sectorization and so on, have been mentioned in many papers. In this paper, we proposed a beam reassignment method (BR) to diminish the call-blocking probability of one hot-beam and multi-service CDMA. A simulation result shows the effectiveness of the BR method in a hot-spot in two and three service-classes.**

Keywords— blocking probability, hot-beam, hot-spot, multi-service, CDMA, beam reassignment.

I. INTRODUCTION

Recent growth in mobile telephone traffic in wireless cellular networks, along with the limitation of resource available, presents a challenge for the efficient use of system capability. The optimization problem will be highly complex if one or more cells in the network become "hot-spot" for some periods of time. For example, the bandwidth resources currently available in those cells are not sufficient to sustain the needs of current users in the cells.

Several schemes have proposed to handle the hot-spot situation: cell splitting, channel sharing, and antenna tilt [1-3]. However, those methods only apply to mobile communication systems using isotropic antennas.

We had considered the CDMA system using smart antennas with switched beamforming (SBF) technique and beam reassignment method. The SBF technique uses multiple beams to cover a whole cell. Hot-spot beam is called hot-beam [4].

This paper presents beam reassignment method to reduce the blocking probability in multi-service CDMA. The rest of this paper is organized as follows. Section 2 presents the related works. Section 3 introduces the formulae used for beam reassignment method in the case of two and three service classes. Section 4 shows the numerical results and some analyses. Finally, some conclusions are given in section 5.

II. RELATED WORKS

Many researchers have proposed various methods to relieve the blocking of hot-spot such as channel borrowing, cell overlaying [5], and adaptive cell sectorization [6]. In the paper of Christian Hartman [7], the author investigates the blocking probability of CDMA systems without the present of hot-beam. In addition, Hyunduk Kang in [4] proposed the beam reassignment method to reduce the blocking probability in case of one hot-beam and single service class. However, the main drawback is that all the papers did not show the method to handle the case of one hot-beam and multiple service classes. Therefore, in this paper, we propose the formulae as well as the simulation for beam reassignment method in the case of two and three service-classes to handle the drawback.

III. BEAM REASSIGNMENT METHOD IN CASE OF MULTIPLE SERVICE CLASSES

We examine the CDMA system with n different classes and model an antenna beam pattern by a brick wall antenna beam pattern as shown in figure 1.

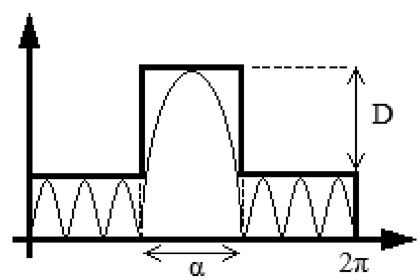

Fig. 1. Brickwall antenna pattern.

Where α is the main beamwidth and D is the sidelobe attenuation of the antenna.

In the CDMA system, to admit new users, we maintain the minimum E_b/N_0 (the energy per bit to noise power spectral density ratio) which denoted as γ_{min}.

By referring Equation (9) in [7], the admission condition for the system can be calculated by:

$$\sum_{j=1}^{n}\frac{N_j^{\alpha}}{s_j}+\frac{1}{D}\times\sum_{j=1}^{n}\frac{N_j^{\bar{\alpha}}}{s_j}\leq\frac{1}{\gamma_{\min}}-\frac{N_I}{P_0} \tag{1}$$

The probability that a call admission control CAC admits a new user in case of multiple service classes is:

$$P_a=P(\sum_{j=1}^{n}\frac{N_j^{\alpha}}{s_j}+\frac{1}{D}\times\sum_{j=1}^{n}\frac{N_j^{\bar{\alpha}}}{s_j}\leq C_0) \tag{2}$$

Where $C_0=\frac{1}{\gamma_{min}}-\frac{N_I}{P_0}$, N_I is the power of interference and P_0 is a normalizing power value of the CDMA system.

For a user of service class j (j=1,2,…,n), s_j is the spreading factor, N_j^{α} is the number of active users inside the main beam of the new user, and $N_j^{\bar{\alpha}}$ is those outside the main beam ($\alpha+\bar{\alpha}=2\pi$).

We can calculate the blocking probability of a CDMA system from equation (2). For example, we consider the CDMA system with one hot-beam and two service-classes, as shown in figure 2.

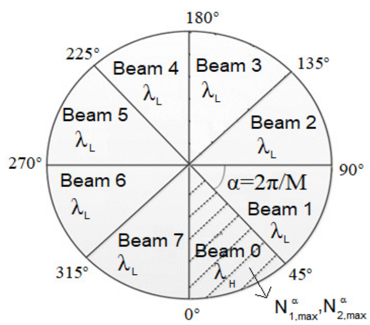

Fig. 2. Cell and traffic deployment before beam reassignment in case one hot-beam, two service-classes when M = 8.

λ_H and λ_L are the call arrival rate of the hot-beam and each lightly loaded beam, respectively.

We examine in the case that beam 0 is a hot-beam and the other beams are lightly loaded-beams. The BR method was applied by switching all beams in the counterclockwise direction to the new position with the ratio angle "r" to handle the hot-spots case. We should choose the value of r so that the blocking probability of the hot-beam as lower as possible.

The admissible probability of the hot-beam is given by:

$$P_a^H=\sum_{k_1=0}^{N_{1,\max}^{\alpha}}P(N_1^{\alpha}=k_1;\chi_H)\sum_{k_2=0}^{N_{2,\max}^{\alpha}}P(N_2^{\alpha}=k_2;\chi_H)$$
$$\times\sum_{l_1=0}^{l_{1,\max}^{\bar{\alpha}}}P(N_1^{\bar{\alpha}}=l_1;\chi_L)\sum_{l_2=0}^{l_{2,\max}^{\bar{\alpha}}}P(N_2^{\bar{\alpha}}=l_2;\chi_L) \tag{3}$$

Where $\chi_H=\frac{\lambda_H}{\mu}$ and $\chi_L=\frac{\lambda_L}{\mu}$ are the offered traffic loads of the hot-beam and each lightly loaded beam, respectively.

$P(N_1^{\alpha}=k_1;\chi_H)$ stand for the probability that the number of active users in hot-beam with an angular sector of width α is equal to k_1 (for the first service class). We apply probability for the Poisson distributions then we can calculate this value by using the following equation:

$$P(N_1^{\alpha}=k_1;\chi_H)=\frac{(\chi_H)^{k_1}}{k_1!}e^{-\chi_H} \tag{4}$$

We have a similar approach for $P(N_2^{\alpha}=k_2;\chi_H)$, $P(N_1^{\alpha}=k_1;\chi_L)$ and $P(N_2^{\alpha}=k_2;\chi_L)$.

We denote $N_{1,\max}^{\alpha}$ and $N_{2,\max}^{\alpha}$ as the maximum number of users within the sector α of the first and second service class. $N_1^{\bar{\alpha}}$ and $N_2^{\bar{\alpha}}$ are the maximum number of users outside sector α, and are a function of $N_{1,\max}^{\alpha}$ and $N_{2,\max}^{\alpha}$.

Those values can be determined using equation (1) with n=2:

$$\frac{N_1^{\alpha}}{s_1}+\frac{N_2^{\alpha}}{s_2}+\frac{1}{D}\times\frac{N_1^{\bar{\alpha}}}{s_1}+\frac{1}{D}\times\frac{N_2^{\bar{\alpha}}}{s_2}\leq C_0 \tag{5}$$

The blocking probability P_b is calculated by : $P_b=1-P_a$.
For each lightly-loaded beam, the admissible probability is:

$$P_a^L=\sum_{k_1=0}^{N_{1,\max}^{\alpha}}P(N_1^{\alpha}=k_1;\chi_L)\sum_{k_2=0}^{N_{2,\max}^{\alpha}}P(N_2^{\alpha}=k_2;\chi_L)$$
$$\times\sum_{l_1=0}^{N_{1,\max}^{\bar{\alpha}}}\sum_{i_1}^{l_1}P(N_1^{(M-2)\alpha}=i_1;\chi_L)P(N_1^{\alpha}=l_1-i_1;\chi_H)$$
$$\times\sum_{l_2=0}^{N_{2,\max}^{\bar{\alpha}}}\sum_{i_2}^{l_2}P(N_2^{(M-2)\alpha}=i_2;\chi_L)P(N_2^{\alpha}=l_2-i_2;\chi_H) \tag{6}$$

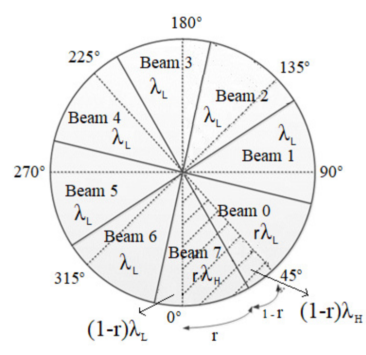

Fig. 3. Cell and traffic deployment after beam reassignment in case one hot-beam, two service-classes when M = 8.

We will cover the BR method as shown in figure 3 with the value of r = 0.5. We have two new hot-beams with the same admissible probability after the BR method. These beams share the load between the original hot-beam and lightly-loaded beam. It's mean that the offered traffic load of the new hot-beam for each service class is:

$$\chi_{H^{'}+L^{'}} = \chi_{H^{'}} + \chi_{L^{'}} = \frac{\chi_H}{2} + \frac{\chi_L}{2} \tag{7}$$

Then the new hot-beam have the admissible probability:

$$\begin{aligned} P_a^{L^{'}+H^{'}} &= \sum_{k_1=0}^{N_{1,\max}^{\alpha}} \sum_{p_1=0}^{k_1} P(N_1^{\frac{\alpha}{2}} = p_1; \chi_{L^{'}}) P(N_1^{\frac{\alpha}{2}} = k_1 - p_1; \chi_{H^{'}}) \\ &\times \sum_{k_2=0}^{N_{2,\max}^{\alpha}} \sum_{p_2=0}^{k_2} P(N_2^{\frac{\alpha}{2}} = p_2; \chi_{L^{'}}) P(N_2^{\frac{\alpha}{2}} = k_2 - p_2; \chi_{H^{'}}) \\ &\times \sum_{l_1=0}^{N_{1,\max}^{\bar{\alpha}}} \sum_{r_1=0}^{l_1} P(N_1^{(M-3/2)\alpha} = r_1; \chi_L) P(N_1^{\frac{\alpha}{2}} = l_1 - r_1; \chi_{H^{'}}) \\ &\times \sum_{l_2=0}^{N_{2,\max}^{\bar{\alpha}}} \sum_{r_2=0}^{l_2} P(N_2^{(M-3/2)\alpha} = r_2; \chi_L) P(N_2^{\frac{\alpha}{2}} = l_2 - r_2; \chi_{H^{'}}) \end{aligned} \tag{8}$$

So far, we have already proposed the formulae for calculating the blocking probability of two service-classes.

The admissible probability of the hot-beam in the case of three service-classes [8] is given by:

$$\begin{aligned} P_a^H &= \sum_{k_1=0}^{N_{1,\max}^{\alpha}} P(N_1^{\alpha} = k_1; \chi_H) \sum_{k_2=0}^{N_{2,\max}^{\alpha}} P(N_2^{\alpha} = k_2; \chi_H) \sum_{k_3=0}^{N_{3,\max}^{\alpha}} P(N_3^{\alpha} = k_3; \chi_H) \\ &\times \sum_{l_1=0}^{l_{1,\max}^{\bar{\alpha}}} P(N_1^{\bar{\alpha}} = l_1; \chi_L) \sum_{l_2=0}^{l_{2,\max}^{\bar{\alpha}}} P(N_2^{\bar{\alpha}} = l_2; \chi_L) \sum_{l_3=0}^{l_{3,\max}^{\bar{\alpha}}} P(N_3^{\bar{\alpha}} = l_3; \chi_L) \end{aligned} \tag{9}$$

For each lightly-loaded beam, the admissible probability is:

$$\begin{aligned} P_a^L &= \sum_{k_1=0}^{N_{1,\max}^{\alpha}} P(N_1^{\alpha} = k_1; \chi_L) \sum_{k_2=0}^{N_{2,\max}^{\alpha}} P(N_2^{\alpha} = k_2; \chi_L) \sum_{k_3=0}^{N_{3,\max}^{\alpha}} P(N_3^{\alpha} = k_3; \chi_L) \\ &\times \sum_{l_1=0}^{N_{1,\max}^{\bar{\alpha}}} \sum_{i_1}^{l_1} P(N_1^{(M-2)\alpha} = i_1; \chi_L) P(N_1^{\alpha} = l_1 - i_1; \chi_H) \\ &\times \sum_{l_2=0}^{N_{2,\max}^{\bar{\alpha}}} \sum_{i_2}^{l_2} P(N_2^{(M-2)\alpha} = i_2; \chi_L) P(N_2^{\alpha} = l_2 - i_2; \chi_H) \\ &\times \sum_{l_3=0}^{N_{3,\max}^{\bar{\alpha}}} \sum_{i_3}^{l_3} P(N_3^{(M-2)\alpha} = i_3; \chi_L) P(N_3^{\alpha} = l_3 - i_3; \chi_H) \end{aligned} \tag{10}$$

We also have two new hot-beams with the offered traffic load $\chi_{H^{'}} + \chi_{L^{'}}$ after the BR method. The admissible probability of these beams is calculated by:

$$\begin{aligned} P_a^{L^{'}+H^{'}} &= \sum_{k_1=0}^{N_{1,\max}^{\alpha}} \sum_{p_1=0}^{k_1} P(N_1^{\frac{\alpha}{2}} = p_1; \chi_{L^{'}}) P(N_1^{\frac{\alpha}{2}} = k_1 - p_1; \chi_{H^{'}}) \\ &\times \sum_{k_2=0}^{N_{2,\max}^{\alpha}} \sum_{p_2=0}^{k_2} P(N_2^{\frac{\alpha}{2}} = p_2; \chi_{L^{'}}) P(N_2^{\frac{\alpha}{2}} = k_2 - p_2; \chi_{H^{'}}) \\ &\times \sum_{k_3=0}^{N_{3,\max}^{\alpha}} \sum_{p_3=0}^{k_3} P(N_3^{\frac{\alpha}{2}} = p_3; \chi_{L^{'}}) P(N_3^{\frac{\alpha}{2}} = k_3 - p_3; \chi_{H^{'}}) \\ &\times \sum_{l_1=0}^{N_{1,\max}^{\bar{\alpha}}} \sum_{r_1=0}^{l_1} P(N_1^{(M-3/2)\alpha} = r_1; \chi_L) P(N_1^{\frac{\alpha}{2}} = l_1 - r_1; \chi_{H^{'}}) \\ &\times \sum_{l_2=0}^{N_{2,\max}^{\bar{\alpha}}} \sum_{r_2=0}^{l_2} P(N_2^{(M-3/2)\alpha} = r_2; \chi_L) P(N_2^{\frac{\alpha}{2}} = l_2 - r_2; \chi_{H^{'}}) \\ &\times \sum_{l_3=0}^{N_{3,\max}^{\bar{\alpha}}} \sum_{r_3=0}^{l_3} P(N_3^{(M-3/2)\alpha} = r_3; \chi_L) P(N_3^{\frac{\alpha}{2}} = l_3 - r_3; \chi_{H^{'}}) \end{aligned} \tag{11}$$

$N_{1,\max}^{\alpha}$, $N_{2,\max}^{\alpha}$ and $N_{3,\max}^{\alpha}$ are the maximum number of users within the sector α of the first, second and third service class. $N_1^{\bar{\alpha}}$, $N_2^{\bar{\alpha}}$ and $N_3^{\bar{\alpha}}$ are the maximum number of users outside sector α, and are a function of $N_{1,\max}^{\alpha}$, $N_{2,\max}^{\alpha}$ and $N_{3,\max}^{\alpha}$. We use equation (1) to calculate those values.

$$\frac{N_1^{\alpha}}{s_1} + \frac{N_2^{\alpha}}{s_2} + \frac{N_3^{\alpha}}{s_3} + \frac{1}{D} \times \frac{N_1^{\bar{\alpha}}}{s_1} + \frac{1}{D} \times \frac{N_2^{\bar{\alpha}}}{s_2} + \frac{1}{D} \times \frac{N_3^{\bar{\alpha}}}{s_3} \le C_0 \tag{12}$$

First, we need the flowchart to determine the admissible probability P_a, then the blocking probability $P_b = 1 - P_a$ before implementing Matlab code. We have suggested the flowchart to calculate the admissible probability of hot-beam in case of two service-classes in figure 4.

In the same way, we will have a flowchart to find out the admissible probability for each lightly loaded-beam, and new hot-beam in two service-classes and three service-classes, respectively.

IV. NUMERICAL RESULTS

We execute the Matlab code for two cases: one hot-beam with two service-classes and three service-classes. Moreover, we develop the graphical user interface in figure 5 so that users can visualize the blocking probability. The GUI allows the users to change all the system values such as main beam width, SNIR and so on.

In this paper, we evaluate the performance of beam reassignment method by calculating the blocking probability of the hot-beam and the lightly loaded beam before and after beam rotation. Table 1 (using first value) and Table 2 provide the values for the system parameters, figure 6 and figure 7 show the result.

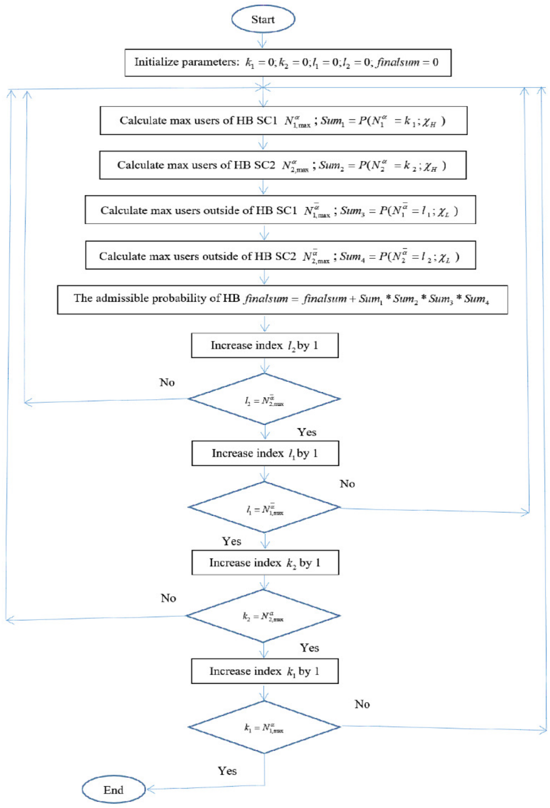

Fig. 4. Flowchart to calculate the admissible probability of hot-beam in case one hot-beam, two service class.

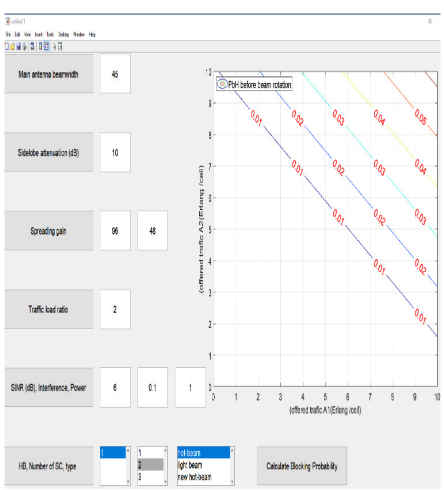

Fig. 5. The graphical user interface to visualize the blocking probability.

Furthermore, we simulated the proposed formulae on the following system: Intel Core i7 8700 - CPU 3.2 GHz; RAM - 16 Gigabytes; Microsoft Windows 10 64 bits.

Some experiments will take from few days to few weeks when we increase the values of the system parameters. We choose the small values of spreading gain in the case of three service-classes due to limited time.

TABLE I. SYSTEM PARAMETERS FOR NUMERICAL RESULTS IN CASE OF 1 HB, 2SC

Parameters	First Value	Second Value	Description
R_{cell}	1 km	1 km	Cell radius
γ_{req}	6 dB	5 dB	Required SINR
α	45	30	Main antenna beamwidth
D	10 dB	10 dB	Sidelobe attenuation
P	1 W	1.2 W	Normalizing power value
N_I	0.1 W	0.08 W	Interference and noise power
s_1	96	48	Spreading gain of SC 1
s_2	48	24	Spreading gain of SC 2
ξ	2	1.2	Traffic load ratio of HB

TABLE II. SYSTEM PARAMETERS FOR NUMERICAL RESULTS IN CASE OF 1 HB, 3 SC

Parameters	Value	Description
R_{cell}	1 km	Cell radius
γ_{req}	6 dB	Required SINR
α	15	Main antenna beamwidth
D	10 dB	Sidelobe attenuation
P	1.1 W	Normalizing power value
N_I	0.09 W	Interference and noise power
s_1	32	Spreading gain of SC 1
s_2	24	Spreading gain of SC 2
s_3	16	Spreading gain of SC 3
ξ	1.2	Traffic load ratio of HB

Figure 6 represents blocking probabilities before and after the BR method in case of one hot-beam and two service-classes ($\alpha = 45^0; s_1 = 96; s_2 = 48; \xi = 2$).

Figure 7 shows blocking probability of hot-beam with the case of one hot- beam and three service-classes ($\alpha = 15^0; s_1 = 32; s_2 = 24; s_3 = 16; \xi = 1.2$).

We can observe that the blocking probability of the new hot-beam is less than the original one and higher than the blocking probability of the lightly loaded beam. For example, in figure 6, given the offered traffic loads of service class 1 (A1=10) and service class 2 (A2=10), the value of blocking probability of the hot-beam, lightly loaded beam and new hot-beam are 0.0631; 0027; 0.0186 respectively.

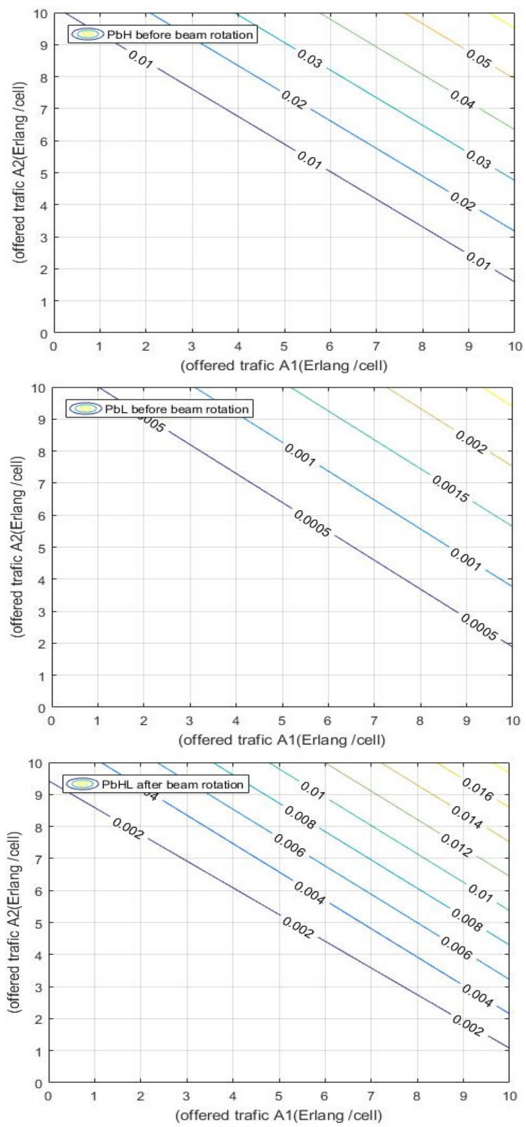

Fig. 6. The blocking probability before and after the BR method in case of one hot-beam and two service-classes.

The BR method works for all the cases. After the beam rotation, the blocking probability of the hot-beam is reduced.

To evaluate the BR method in more detail, we change each of the system parameters in table 1 (using second value) and get the result in table 3.

In table 3, column 1 denotes the value change of system parameters. Column 2 to 4 show the blocking probability of hot-beam, light beam, and new hot-beam respectively. Column 5 describes the percentage of new hot-beam, compared with the original one. Column 6 indicates the decrease by percentage of blocking probability of the original hot-beam using the BR method. In the last column, the higher value of percentage decrease means better performance.

We can see clearly that the percentage decrease varies across the system parameters. There is a significant change when we increase the value of SNIR from 5dB to 6dB. The percentage decrease between the new hot-beam and the original hot-beam is 28.89 percent with the first value of SNIR, while the percentage decrease is 19.02 percent with the second value of SNIR. It means that the performance of the BR method decreases when we increase the value of SNIR.

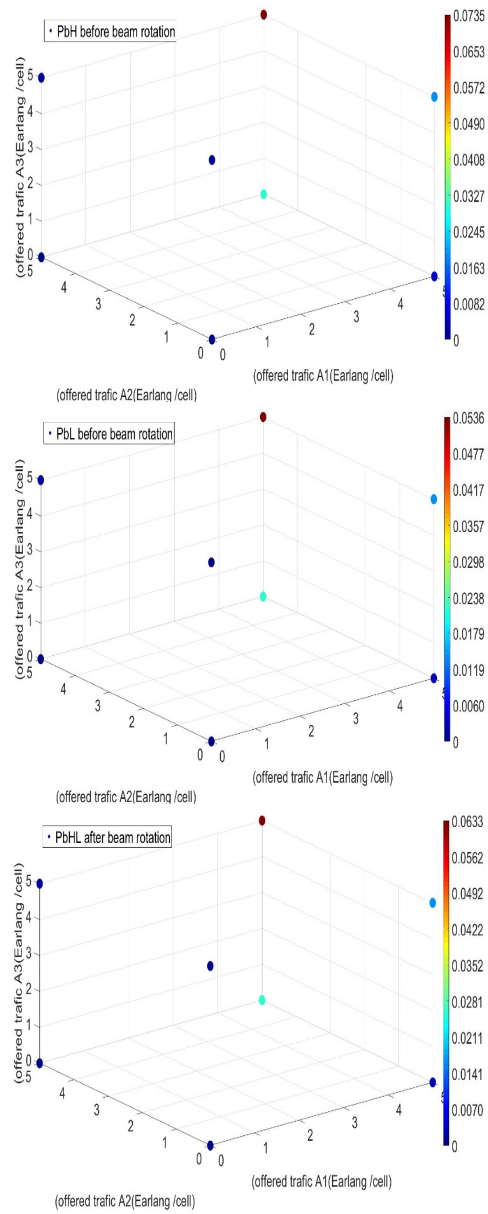

Fig. 7. The blocking probability before and after the BR method in case of one hot-beam and three service-classes.

TABLE III. THE EFFECTIVENESS OF THE BR METHOD WHEN CHANGING THE VALUES OF THE SYSTEM PARAMETERS

	hot-beam	light beam	new hot-beam	Percent of new/HB	percentage decrease
without change	0.012	0.006	0.008	71.110	28.890
beam width: 45	0.051	0.027	0.038	74.510	25.490
SNIR: 6	0.096	0.061	0.078	80.974	19.026
Noise: 0.1	0.021	0.011	0.016	73.588	26.412
Power: 1.0	0.018	0.009	0.013	72.960	27.040
Side lobe: 9	0.021	0.011	0.015	74.262	25.738

V. CONCLUSIONS

This paper has already proposed the formulae to evaluate the BR method in case of multiple service classes. We reduce the blocking of the original hot- beam and use the BR method to solve the hot-spot problem.

We will consider the value of ratio angle in the near future. We will suggest the formula to calculate the blocking probability with an arbitrary value of ratio angle using the BR method.

We increase the sidelobe attenuation and the normalizing power value to increase the performance of the BR method. Reducing the interference, the main beamwidth, and SNIR will make the same effect.

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REFERENCES

[1] J. Wu, J. Chung, and C. Wen. "Hot-Spot Traffic Relief with a Tilted Antenna in CDMA Cellular Networks", IEEE Trans. on Veh. Tech., Vol. 47, No. 1, February 1998.

[2] A. Ahmad, "A CDMA Network Architecture Using Optimized Sectoring", IEEE Trans. on Veh. Tech., Vol. 51, No. 3, pp. 404-410, May 2002.

[3] C.U. Saraydar and A. Yener, "Adaptive Cell Sectorization for CDMA Systems", IEEE JSAC, Vol. 19, No. 6, pp. 1041-1051, June 2001.

[4] Hyunduk Kang, Seokjin Sung, Insoo Koo, and Kiseon Kim, "On Blocking Probability of Multi-Beam CDMA Systems Using SBF Array antennas", Wireless Personal Communications: An International Journal, Vol. 35 Issue 1-2, Oct. 2005.

[5] T. -S.P. Yum W. -S. Wong, "Hot-spot traffic relief in cellular systems", IEEE Journal on Selected Areas in Communications, Volume 11 Issue 6, September 2006.

[6] A.S. Anpalagan and E.S. Sousa, " Adaptive cell sectoring using fixed overlapping sectors in CDMA networks", IEEE International Conference on Communications, 14 June 2001.

[7] C.Hartmann, " On capacity and blocking of multi service CDMA systems with smart antennas", IEEE Proceedings IEEE 56th Vehicular Technology Conference, 10 December 2002.

[8] R.Mathar and M-A.Remiche, “The impact of different service on the outage probability in UMTS”, IEEE 54th Vehicular Technology Conference, Vol. 2, October 2001.