논문 2010-47TC-7-12

배열안테나 기반의 DSM 하이브리드 방식

(DSM Hybrid Technique Using Antenna Array)

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요 약

CDMA 시스템에서 다이버시티와 빔형성을 사용하는 새로운 하이브리드 방식인 DSM시스템을 제안한다. 손실확률분석을 통하여 제안하는 방식이 기존의 다이버시티나 빔형성 단독 시스템보다 우수한 성능을 가짐을 보였다.

Abstract

A novel hybrid antenna array system for the code division multiple access (CDMA) using the diversity and beamforming technique has been proposed which is called as a dynamic selection method (DSM). Through the derived outage probability analysis, we have shown that the proposed DSM technique can give benefit over the conventional diversity-only or beamforming-only system.

Keywords : Hybrid Adaptive Array Antenna, Beamforming,

I. Introduction

The capacity of code division multiple access (CDMA) system for mobile communication is mainly affected by two major factors. One is the multiple access interference (MAI) which can be overcome by beamforming technique. The other is fading phenomenon which can be overcome by diversity technique. In this thesis, we will utilize both of the diversity and beamforming technique to combat the fading and MAI simultaneously. This proposed hybrid technique is called as a dynamic selection method (DSM) hybrid antenna array since the diversity or beamforming branch is selected dynamically according to the channel variation in time domain. The performance will be analyzed based on the derived signal to interference plus noise (SINR) and outage probability equations.

II. Structure and Signal Model

Overall structure of the DSM hybrid system is shown in Fig.1 where the diversity and beamforming antenna arrays are constructed on the receiver side and one of them can be selected dynamically based on the measured SINR. The statistical characteristics of those received signals on the two branches are independent each other. The complex envelop representation of CDMA transmitted signal can be

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※ This research was supported by Kyungpook National University Research Fund, 2008.
접수일자: 2010년5월17일, 수정완료일: 2010년7월14일

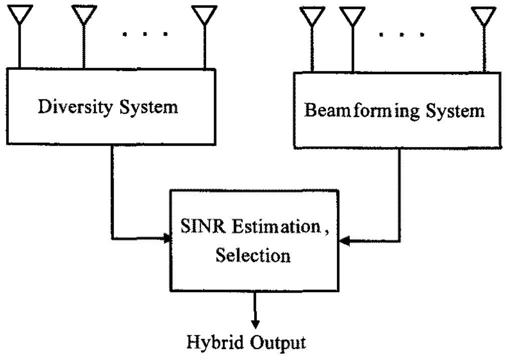

그림 1. DSM hybrid 시스템의 구조
Fig 1. Overall structure of DSM hybrid system.

Fig. written as

$$s_k(t)=\sqrt{E_b}\, b_k g_k(t) \tag{1}$$

where the E_b is bit energy, b_k is data symbol for the kth user, and $g_k(t)$ is symbol shaping function that is complex spreading waveform of direct-sequence spread spectrum signal. The complex envelop representation of received signal at the l th antenna is written as

$$r_l(t)=\sum_{k=1}^{K} r_{l,k}(t)+n(t), \qquad 1\le l\le L \tag{2}$$

where the L, K, $n(t)$ are number of antenna, user, and additive white Gaussian noise (AWGN) respectively. Let's consider the diversity branch first. The received signal at the l th antenna from the k th user can be represented as

$$r_{l,k}^{(D)}(t)=\alpha_{l,k}e^{j\phi_{l,k}}s_k(t-\tau_{l,k}) \tag{3}$$

where a is channel gain, ϕ is phase rotation due to fading, and τ is propagation delay. After despreading with the spreading waveform in the transmitted signal, the resultant output signal can be represented as

$$y_1^{(D)}=\sum_{l=1}^{L}\left[\sqrt{E_b}b_1\alpha_{l,1}e^{j\phi_{l,1}}+\sum_{k=2}^{K}\alpha_{l,k}e^{j\phi_{l,k}}\sqrt{E_b}b_k\rho_{1,(mai)}+\eta_1\right] \cdot \alpha_{l,1}e^{-j\phi_{l,1}}. \tag{4}$$

In (4), the first term represents wanted signal, the second term represents MAI, and the third term represents background noise in the output signal. The ρ is cross-correlation of two complex spreading signal due to MAI. If the spreading sequence has property of random code, the average cross-correlation energy of two spreading waveform is given by [1]

$$E\left[\left|\rho_{i,j}(\tau)\right|^2\right]\cong\frac{1}{G}. \tag{5}$$

The power of each component can be easily computed using (4). The desired signal power is given by

$$P_{1,(s)}^{(D)}=E_b\left|\sum_{l=1}^{L}\alpha_{l,1}^2\right|^2 \tag{6}$$

and the MAI power at the output signal is given by

$$P_{1,(mai)}^{(D)}=\frac{E_b}{G}\left|\sum_{l=1}^{L}\left(\sum_{k=2}^{K}\alpha_{l,k}e^{j\phi_{l,k}}\right)\alpha_{l,1}e^{-j\phi_{l,1}}\right|^2. \tag{7}$$

The background noise power is given by

$$P_{1,(n)}^{(D)}=\sigma_n^2\left|\sum_{l=1}^{L}\alpha_{l,1}e^{-j\phi_{l,1}}\right|^2. \tag{8}$$

Therefore the SINR of diversity branch can be written as

$$\gamma_D=\frac{P_{1,(s)}^{(D)}}{P_{1,(mai)}^{(D)}+P_{1,(n)}^{(D)}}. \tag{9}$$

Now let's consider the SINR of beamforming branch. The received signal at the l th antenna from k th user on the beamforming branch can be represented as

$$r_{l,k}^{(B)}(t)=\alpha_k e^{j\phi_k}e^{-j\omega\psi_{l,k}}s_k(t-\tau_{l,k}) \tag{10}$$

where the $\psi_{l,k}$ is time delay at l th antenna to the first antenna for k th user. Steering vector due to direction of arrival of users is represented as

$$\mathbf{v}_k=\left[e^{-j\omega\psi_{1,k}}\ e^{-j\omega\psi_{2,k}}\cdots e^{-j\omega\psi_{L,k}}\right]^T/\sqrt{L} \tag{11}$$

where T represents transpose of vector. The fading term can be represented as a fading factor

$$\beta_k = \alpha_k e^{j\phi_k}. \tag{12}$$

Using the steering vector and the fading factor in (11) and (12), we can define the channel vector as

$$\mathbf{a}_k = \beta_k \mathbf{v}_k. \tag{13}$$

The vector representation of the received signal at the beamforming array is

$$\mathbf{r}(t) = \sum_{k=1}^{K} \sqrt{E_b}\, b_k\, g_k(t-\tau_k)\mathbf{a}_k + \mathbf{n}(t). \tag{14}$$

The last term in (14) represents the noise vector. Despread signal for the 1st user is represented by

$$\mathbf{x}_1^{(B)} = \frac{1}{2}\int_{\tau_1}^{T+\tau_1} \mathbf{r}(t) g_1^*(t-\tau_1)\, dt. \tag{15}$$

We use sub-optimal beamforming technique where the weight vector is given by

$$\mathbf{w}_1 = \mathbf{a}_1 / L. \tag{16}$$

The output signal of beamforming system is

$$y_1^{(B)} = \mathbf{w}_1^H \mathbf{x}_1^{(B)}. \tag{17}$$

Utilizing the (15), (16), and (17), we can get the SINR of the beamforming system which is represented by

$$\gamma_B = \frac{E_b \alpha_1^2}{\frac{E_b}{L^2 G(K-1)}\left|\sum_{k=2}^{K}\beta_k\right|^2 \mathbf{v}_1^H\left[\sum_{k=2}^{K}\mathbf{v}_k\mathbf{v}_k^H\right]\mathbf{v}_1 + \frac{\sigma_n^2}{L}}. \tag{18}$$

Ⅲ. Performance Analysis

The outage probability (i.e., the percentage of time the instantaneous output SINR is below some prescribed level) of the beamforming branch will be computed according to the number of users. While the α_l^2 has a chi-squared probability density function (PDF) with two degree of freedom when the α_l is Rayleigh distributed[1], the PDF of γ_B can be represented as

$$f(\gamma_B) = (1/\Gamma_B) e^{-\gamma_B/\Gamma_B} \tag{19}$$

where the $\Gamma_B = E[\gamma_B]$ is average SINR over short-term fading SINR γ_B. In that case, the probability of γ_B is less than or equal to some specified value γ_s, i.e., the outage probability of beamforming branch can be computed as

$$\Pr(\gamma_B \le \gamma_s) = \int_0^{\gamma_s} f(\gamma_B)\, d\gamma_B = 1 - e^{-\gamma_s/\Gamma_B}. \tag{20}$$

Now we will derive the outage probability of diversity branch. The maximal ratio combining (MRC) method has been used for the diversity branch and the outage probability for MRC diversity system is already well known[2]. When the γ_D is sum of L exponentially distributed random variables for Rayleigh fading channel, the PDF of such a sum is known as chi-squared distribution with $2L$ degree of freedom. The PDF can be represented as

$$f(\gamma_D) = \frac{\gamma_D^{L-1}}{\Gamma_D^L (L-1)!} e^{-\gamma_D/\Gamma_D} \tag{21}$$

where the $\Gamma_D = E[\gamma_D]$ is the average SINR over short-term fading SINR γ_D[2]. The probability of γ_D is less than or equal to some specified value γ_s, i.e., outage probability of diversity branch can be computed as

$$\Pr(\gamma_D \le \gamma_s) = \int_0^{\gamma_s} f(\gamma_D)\, d\gamma_D = 1 - e^{-\frac{\gamma_s}{\Gamma_D}} \sum_{k=1}^{L} \frac{(\gamma_s/\Gamma_D)^{k-1}}{(k-1)!}. \tag{22}$$

From the above result, we can easily derive the outage probability of proposed DSM hybrid system since the error probabilities of diversity and beamforming branches are independent. Thus the probability that both of diversity and beamforming branches are simultaneously less than or equal to γ_s is represented as

$$\Pr(\gamma_B, \gamma_D \le \gamma_s) = \left[1 - e^{-\frac{\gamma_s}{\Gamma_D}}\right]\left[1 - e^{-\frac{\gamma_s}{\Gamma_D}} \sum_{k=1}^{L} \frac{(\gamma_s/\Gamma_D)^{k-1}}{(k-1)!}\right]. \tag{23}$$

To analyze the performance of DSM hybrid, the outage probabilities of the three different system have been compared in Fig.2 using the (20), (22), and (23). In Fig.2, the number of antennas for both of the diversity-only and beamforming-only system is 12 whilethe number of antennas for both of the diversity and beamforming branch in DSM hybrid system is 6 for each. Therefore the entire complexities of the three systems are same. The E_b/N_o for background noise setting is fixed to be 10dB and the spreading factor is 16. As we can see in Fig.2, when the number of users is small, the performance of DSM technique is better than that of the beamforming-only but slightly worse than that of the diversity-only since the fading is more dominant than MAI. However when the number of users becomes large, i.e., MAI becomes more dominant than fading, the performance of DSM hybrid technique is better than that of the diversity-only but slightly worse than that of beamforming-only system.

Now let's discuss about the benefits of DSM hybrid system. When the high speed data communication service is required under environment of small number of users, the operator tends to use the diversity technique to combat the fading. However the operators cannot only focus on the small number of users. They should also prepare situation that many users share same system resources, i.e., case of MAI level is increasing, therefore the beamforming technique would be more desirable in that case. Actually, one of most important issue of the CDMA network design is that how many users can be supported in a cell, which is called as system capacity. Therefore the most desirable performance is to follow the trajectory of diversity curve when the number of users is smaller than around 40 in the Fig. 4 and it also follows the trajectory of beamforming when the number of users is greater than around 40. However this is impractical since the diversity and beamforming array cannot be swapped during of operation. To solve the above dilemma, we prefer the system which has better performance than that of beamforming and close to that of diversity system at the same time under the small number of users. Additionally, we also want that this system has better performance than that of the diversity and close to that of the beamforming simultaneously under the large number of users. Therefore the DSM system can meet those requirements in some extent and guarantee relatively constant quality of service regardless of the number of users under the CDMA network.

Ⅳ. Conclusion

In this thesis, a novel hybrid antenna array system which is called as a DSM has been proposed to cope with the fading and MAI simultaneously. To analyze the performance of DSM hybrid, the SINR and outage probability have been derived. As a result of analysis based on the derived equations, we have shown that the DSM hybrid can provide better performance than that of the beamforming and constant quality of service than that of the diversity.

References

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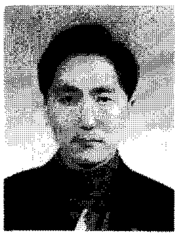
저 자 소 개



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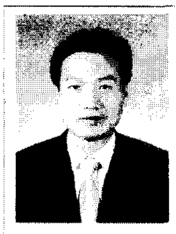

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