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가중치를 이용한 CDMA 시스템 성능분석

이관형*, 김학윤**, 송우영***

On the Performance CDMA System Using Weighted Value

Kwan-Houng Lee *, Hack-Yoon Kim **, Woo-Young Song ***

요 약

이동통신시스템에서 사용자의 신호는 다른 방향에서 도래하는 신호로부터 간섭이 발생한다. 간섭을 제거하기위해서 다이버시티, 등화기 등 다양한 연구가 진행되었다. 본 논문에서는 배열안테나의 가중치을 구하여 신호대잡음비를 향상시키고자 한다. 가중치는 신호의 상관계수에 의해서 고유값과 고유벡터로부터 구한다. 구한 가중치를 CDMA시스템에 적용하여 시스템성능과 용량을 증가시켰다. 변조방식은 QPSK와 OQPSK를 시스템에 적용시켜 성능을 분석하였다.

Abstract

Interference occurs by signals received from directions that were different from the signals of the users in a mobile communication system. Various studies have been undertaken, including diversity, equalizer, etc., in order to reduce interference. In this study, the weighted value of the array antenna was obtained to improve signal-to-noise ratio. The weighted value was obtained as an eigen value and an eigen vector by using the correlation coefficient of the signal. The weighted value obtained was then applied to the CDMA system to increase system performance and capacity. Both QPSK and OQPSK modulation systems were applied to analyze performance.

▸ Keyword : CDMA, Diversity, weighted-valued, Modulation

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* 청주대학교 전자정보공학부 전임강사
** 청주대학교 전자정보공학부 부교수
*** 청주대학교 전자정보공학부 교수

Ⅰ. Introduction

With the recent increase in the demand for mobile communications, new technologies is anticipated to appear to provide high quality and high capacity services for all users, operators, and manufacturers. It is considered that OFDM/CDMA is the most appropriate wireless access system for the wireless transmission technology of mobile communication systems in the future. The beam forming technique of the array antenna is steadily proposed as one of the technologies to realize this future communication system. The antenna that applied the beam forming technique of the array antenna is known as smart antenna. Smart antenna is the intelligent antenna system that can react to the given signal environment and change its radial beam patterns automatically. It is based on the beam forming technique that combines signals received from antenna elements arrayed linear, circular, and planar antennas [1][2]. By beam forming, a complex antenna pattern is created through signal processing that combines and controls the sizes and phases of the signals received from the array antenna elements. Also, it is like a base station system that provides spatial filtering to increase or remove signals based on the direction of the arrival of the signals of each element [3]. In order to apply the array antenna in the CDMA system, spatial filtering must be performed to predict the direction of the signals of each path of the rake receiver and receive signals from a certain direction. The complex weighted vector should be predicted for the direction of the signal of the corresponding path, and multiplied by the signal received in order to perform spatial filtering for each direction of the path of the receiving signals [4][5]. A study on beam forming techniques by using the array antenna is being conducted in order to reduce such multiple access interference.

In this study, the performance of the CDMA system was analyzed by using the beam forming technique of the array antenna in the mobile communication channel. The interval of the array antenna was assumed as $\lambda/2$ to avoid grating lobes. Section Ⅱ describes the array antenna, while the weighted value of the array antenna for the signal model is obtained in Section Ⅲ. The weighted value obtained in Section Ⅲ was applied to the CDMA system in Section Ⅳ, and, finally, system performance was simulated and analyzed, as well as conclusions were discussed in Section Ⅴ.

Ⅱ. Array Antenna

The beam forming technique of the array antenna, which is applicable for the CDMA system under the influence of multi-path channels, is used in this study. Each signal component is affected by different delay, phase, incidence angle of the antenna, and amplitude variations before users receive it. At this time, the desired signal of the user also results into interference if it appears different in the receipt delay of more than one chip from the synchronized signal. In case of the CDMA system, the distribution of the delay of each signal component by multiple paths is much wider than chip distribution. The array antenna functions to array complex antenna elements and to control the excitation condition of each antenna element in order to obtain the desired directivity of the antenna [6]. In case of using array antenna as a base station for mobile communication, the array antenna forms a radio zone of the base station and depresses interferences between zones. Thus, it is used to increase gains by sharpening the directivity of the mobile station [7]. The structure that arranges multiple half-wave radiating elements linearly is generally used. They are usually arranged in equal intervals, as shown in Fig. 1 [8].

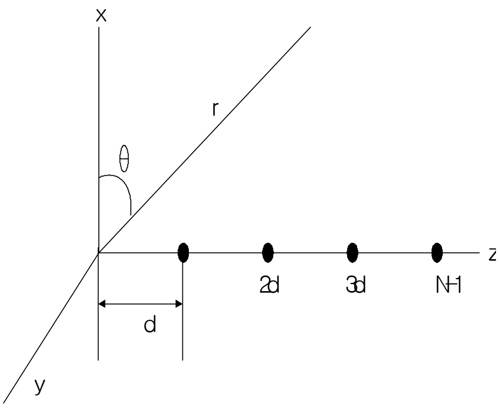

Fig. 1 Array antenna
그림 1. 배열 안테나

There is no general advantage when the intervals of the array antenna are not equal. In this case, the arranged antenna is known as the element antenna or element, and the interval d is called the element interval. Since the array antenna is arranged symmetrically to the z-axis, the total of all the elements can be expressed as the following [8]:

$$AF(\theta) = A(\theta)\sum_{n=0}^{N-1} I_n \exp(j\phi_n + jnkd\cos\theta) \cdots\cdots (1)$$

Where, $A(\theta)$ is the directivity of one element, I_n is amplitude, and φ_n is phase. $AF(\theta)$ is an array factor. Assuming that $I_n = 1$ and $\varphi = 0$, the array factor is as follows.

$$AF(\theta) = A(\theta) \sum_{n=0}^{N-1} \exp(jnkd\cos\theta) \cdots\cdots (2)$$

$$= \frac{1-e^{(jN\varphi)}}{1-e^{(j\varphi)}} \cdots\cdots (3)$$

$$= \left| \frac{\sin(N\varphi/2)}{N\sin(\varphi/2)} \right| e^{(j\psi)} \cdots\cdots (4)$$

where $\phi = kd\cos\theta$ is $\psi = (N-1)\phi/2$. When expressing the radiation characteristics of the antenna, the normalized maximum is used as the aggregate maximum. Since the aggregate maximum of $AF(\theta)$ is N, eq. (4) is normalized, and as shown below.

$$AF(\theta) = \left| \frac{\sin(N\varphi/2)}{N\sin(\varphi/2)} \right| \cdots\cdots (5)$$

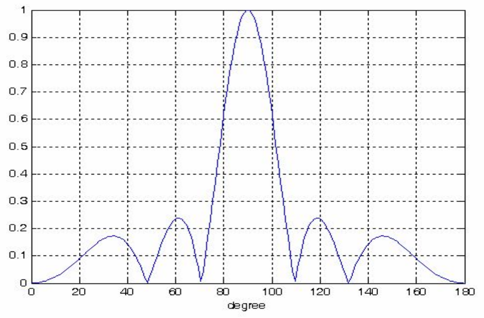

Fig. 2 Beam pattern when N=6
그림 2. N=6일때 빔 패턴

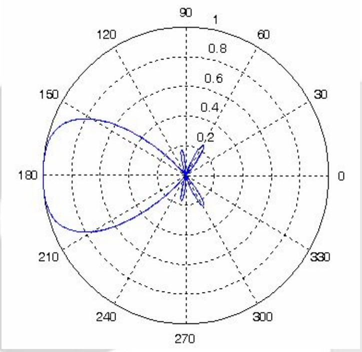

Fig 3. Radial pattern when N=6
그림 3. N=6일때 방사 패턴

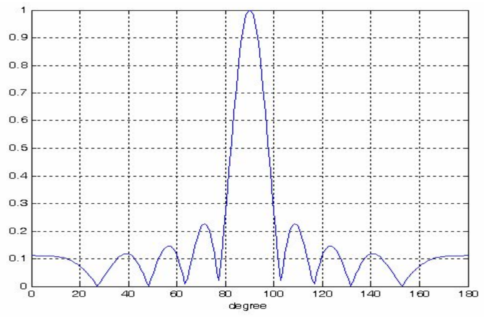

Fig. 4 Beam pattern when N=9
그림 4. N=9일때 빔 패턴

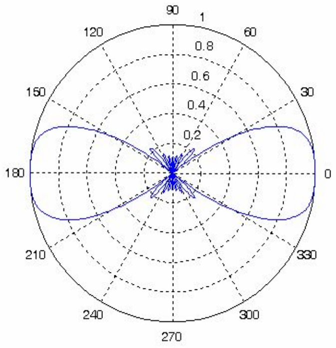

Fig 5. Radial pattern when N=9
그림 2. N=9일때 방사 패턴

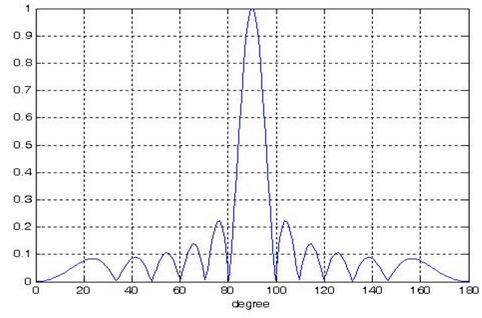

Fig. 6 Beam pattern when N=12
그림6. N=12일때 빔 패턴

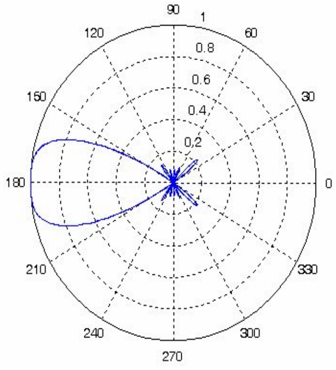

Fig 7. Beam pattern when N=12
그림 7. N=12일때 방사 패턴

III. SIGNAL MODEL

It is appropriate to use linear array antenna for the base station to search users in a single cell environment. Assuming that N users are distributed randomly, bandwidth can be spread through different pseudo codes in the CDMA system. It was assumed that the number of linear array antennas in the base station is M

In this study, a simple plane wave model was used and the over-all structure was analyzed in two-directional systems. Assuming that the power control is ideal, and the receiving power of the array element is at the same level for each user, the output of the array antenna is as follows [9]:

$$y(t)=\sum_{i=0}^{N}\sqrt{P}b_i(t)h_j(t)a_i + N(t) \quad \cdots\cdots\cdots\cdots (8)$$

where, P is the receiving power of the users, and $b_i(t)$ is the data symbol. $h_j(t)$ is the spreading code of the user, and its value, 1. a_i , is the $M\times L$ array response of the receiving signal of the ith user, and $N(t)$ is Gaussian noise. Here, the process gain of the code is as follows.

$$GG=\frac{T_b}{T_c} \quad \cdots\cdots\cdots\cdots (9)$$

T_b is the beat cycle, and T_c is the chip cycle. The array response vector of the ith user is as follows[10][11].

$$a_i=\begin{bmatrix} 1 \\ e^{(j2\pi d_1 \sin\theta_i)} \\ e^{(j2\pi d_2 \sin\theta_i)} \\ \vdots \\ e^{(j2\pi d_{N-1} \sin\theta_i)} \end{bmatrix} \quad \cdots\cdots\cdots\cdots (10)$$

The interval of the array antenna element is $\lambda/2$, and θ_i is the phase involving the receiving signal and array element. The antenna array output from the ith user is combined with the weighted vector (w_i). Here, the beam formation output is as follows.

$$Z_i(t) = w_i^H y(t) \quad \text{(11)}$$

Where, $(\bullet)^H$ is the complex conjugate transpose matrix. In order to combine the receiving signal of the array antenna, the ith signal and the weighted vector W_i are combined, and for this, W_i shall be obtained. The maximum signal-to-noise ratio is used for the optimum limitation of the ith user. The weighted signal is the correlation function of the ith user in the signal of the ith user and the spreading code, and can be expressed as follows.

$$G_i(L) = \int_{T_b}^{LT} h_i(t)[w_i^H(t)\sum_{i=0}^{N}\sqrt{P}b_i(t)h_i(t)a_i + N(t)]dt \quad \text{(12)}$$

where, wave delay is ignored. Assuming that the data bit b_i는 is independent of each other, the mean is zero. $N(t)$ is the function of the complex Gaussian random vector and the covariance of the zero mean, and is expressed as follows.

$$En(t)n^H(t) = \sigma^2 I \quad \text{(13)}$$

Where, $I = M \times M$, and $\sigma^2$is noise variance. In terms of data bit and noise, the interference-plus-noise of the desired signal is expressed as follows.

$$IS = \mathrm{Pr}\ ^2_{i,j} w_j^H R_{aa} W_j \quad \text{(14)}$$

$$IL = w_i^H R_{kk} W_i \quad \text{(15)}$$

$$R_{aa} = a_i a_i^H \quad \text{(16)}$$

$$R_{kk} = P\sum r^2_{i,j} R_{aa} + \sigma^2 r_{i,j} I \quad \text{(17)}$$

Where, $r_{i,j}$ is the cross-correlation between the ith and jth spreading codes $(i \neq j)$, and is expressed as follows.

$$r_{i,j} = \int_{T_b}^{LT_b} h_i(t)h_j(t)dt \quad \text{(18)}$$

here, the eigen value is expressed as follows.

$$EV = R_{kk}^{-1/2} R_{aa} R_{kk}^{(1/2)^*} \quad \text{(19)}$$

Assuming that the array response vector is estimated perfectly, the weighted value of the beam formation is expressed as follows.

$$w_i = \alpha R_{kk}^{-1} R_{aa} \quad \text{(20)}$$

Where α is an arbitrary constant. Therefore, the signal-to-noise ratio is expressed as follows.

$$SINR = \frac{IS}{IL} = \mathrm{Pr}\ ^2_{i,j} \frac{w_i^h R_{aa} W_i}{w_i^h R_{kk} W_i} \quad \text{(21)}$$

$$= \mathrm{Pr}\ ^2_{i,j} R_{aa} R_{kk}^{-1} \quad \text{(22)}$$

In this case, error probability is expressed as follows.

$$P_2(\gamma) = \int_0^{\infty} \mathrm{Pr}\ ^2_{i,j} R_{aa} R_{kk}^{-1} d\gamma \quad \text{(23)}$$

Therefore, mean error probability is expressed as follows[12].

$$P_2 = \int_0^{\infty} P_e(\gamma) P_2(\gamma) d\gamma \quad \text{(24)}$$

where $P_e(\gamma)$ is probability density function of QPSK and OQPSK modulation.

IV. SIMULATION

For a mobile, wireless channel environment, the Nagakami fading distribution was applied in the multi-path fading environment. Simulation was conducted by obtaining the weighted value of the array antenna to compare and analyze the bit error probability for both QPSK and OQPSK modulation systems in a multi-path fading environment. Fig. 8 shows the bit error probability (BER) that used N=6,9,and 12 array antennas in a reverse direction channel. According to the comparison of bit error probability for QPSK and OQPSK modulation systems at 15 dB, QPSK was 10^{-4} and OQPSK was 10^{-5}. In this study, it was proven that the OQPSK modulation system was better than the QPSK modulation system by about 10 dB. Bit error probability will be enhanced if more than 12 elements are arrayed.

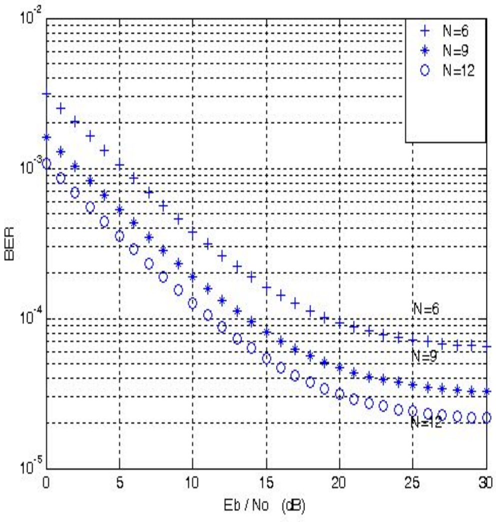

Fig 8. BER of QPSK
그림 8. QPSK의 비트에러률

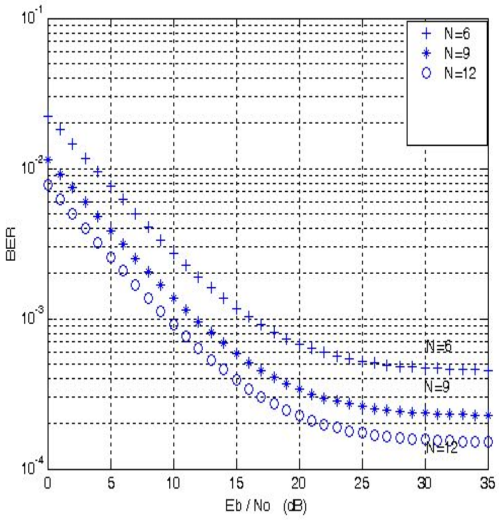

Fig 9. BER of OQPSK
그림 9. OQPSK의 비트에러률

IV. CONCLUSIONS

In this study, bit error probability was compared and analyzed by obtaining weighted value, which is an important factor in the beam forming technique of the array antenna, in order to reduce interferences in the fading environment of the CDMA system. Both QPSK and OQPSK modulation systems were applied for comparison. According to the study result that applied the weighted value calculated in this study to the CDMA system, it is considered more appropriate for the OQPSK system than the QPSK system. Also, spatial diversity could be obtained, and interferences of MAI were reduced through the array antenna system. The beam forming technique of the array antenna system performs spatial filtering that received desired signals for the user by tracking phase differences between array antenna elements by the direction of the path of the signal, resulting in significant reduction of the complexity of the system. Therefore, the beam forming technique of this array antenna system is considered to contribute significantly to the development of mobile communications in the future.

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저자소개

이 관 형

2004년 8월 : 청주대학교 전자공학과(공학박사)

2005년 3월 ~ 현재 :청주대학교 전자정보공학부 전임강사

<관심분야>무선이동통신, 알고리즘

김 학 윤

1996년 3월 : 일본 동북대학교 시스템정보과학(공학박사)

1997년 3월 ~ 현재 :청주대학교 전자정보공학부 부교수

<관심분야>디지털신호처리

송 우 영

1988년 2월 : 연세대학교 전자공학과(공학박사)

1982년 3월 ~ 현재 :청주대학교 전자정보공학부 교수

<관심분야>안테나, 초고주파공학