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Adaptive Array Antenna for Joint Optimizing Spatial and Temporal Equalization in Both Transmitter and Receiver for DS/CDMA systems

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1 Introduction

Demands of high speed and reliability in mobile radio communication increases rapidly. The most serious problem in the DS/CDMA (Direct Sequence Code Division Multiple Access) transmission of digital signals is not only ISI (Intersymbol Interference) due to multipath distortion in a mobile radio channel but also CCI (Co-Channel Interference) due to the correlation between the spreading codes. If the channel characteristic is known in advance, it will be possible to change the impulse response by using transmission filtering. We have already proposed the joint transmitter and receiver system for the TDMA system and evaluated the performance [1]. In this paper, we will propose a extended system for the DS/CDMA.

This paper describes the channel model for DS/CDMA in time and space domains and proposes a joint equalization system in transmitter and receiver for DS/CDMA in both time and space domains.

2 System Model and Channel Model

This paper uses the complex baseband model, which is independent of the modulation scheme. At first, we describe the notation of transmitter side. The j^{th} $(j = 0, 1, \cdots, J-1)$ user's spreading or pseudo-noise (PN) sequence signal $c_j(t)$ and data are represented by $c_j(t)$ and $b(t)$, respectively. Then the transmitted signal for the j^{th} user $x_j(t)$ is given by

$$x_j(t) = c_j(t) b_j(t). \tag{1}$$

It is assumed that a transmission array antenna can transmit the signals by using several antenna weight sets for different directions and for each user at the same time. The transmission array antenna consists of several precoders, which are the digital filters, and several antenna weight sets. The number of precoders is the same as the number of directions for transmission. The precoders for j^{th} user are represented by this vector

$$W_{t,j}(t) = \left[\begin{array}{cccc} W_{t,0}^{j}(t) & W_{t,1}^{j}(t) & \cdots & W_{t,K-1}^{j}(t) \end{array} \right]^T. \tag{2}$$

The antenna weight sets for j^{th} user are represented by the matrix $Q_{t,j}$.

$$Q_{t,j} = \begin{bmatrix} q_t(\phi_{j,0}) & 0 & \cdots & 0 \\ 0 & q_t(\phi_{j,1}) & \cdots & 0 \\ \vdots & \vdots & \cdots & \vdots \\ 0 & 0 & \cdots & q_t(\phi_{j,K-1}) \end{bmatrix} \tag{3}$$

Each component of this matrix is M-dimensional vector and this matrix means that the transmitter can transmit the signals for K directions at the same time. $q_t(\phi)$ is defined by

$$q_t(\phi) = \frac{1}{\sqrt{M}} \left[\begin{array}{cccc} 1 & e^{-j\pi \sin\phi} & \ldots & e^{-j(M-1)\pi \sin\phi} \end{array} \right], \tag{4}$$

where the number of antenna elements is M, and the output total power is normalized one.

Next, the notations of the spatial and temporal channel and the receiver of the j^{th} user are described. It is assumed that the channel characteristic for arrival angles θ_{l_j} at the receiver of the j^{th} user is represented by a vector

$$h_{j,l}(t) = \left[\begin{array}{cccc} h^j_{l,0}(t) & h^j_{l,1}(t) & \cdots & h^j_{l,K-1}(t) \end{array} \right] \tag{5}$$

where l=0, 1, $\cdots$, L_j-1 and L_j denotes the total number of paths of j^{th} user. We defined the path as its past history due to bearing. Therefore, the spatial and temporal channel changes the signals from K inputs to L_j outputs for j^{th} user.

The signals through L_j paths are received with a phase shift according to the arrival angles $\theta_{j,l}$. Let the reception steering vector for bearing θ be $q_r(\theta)$ ($N-$dimensional) given by

$$q_r(\theta) = \frac{1}{\sqrt{N}} \left[\begin{array}{cccc} 1 & e^{-j\pi \sin\theta} & \ldots & e^{-j(N-1)\pi \sin\theta} \end{array} \right]^T, \tag{6}$$

where N denotes the number of antenna elements of the receiver. Let the reception array antenna weights be $W_{r,j}$ ($N-$dimensional). Then the received signal vector $\mathrm{z}_j(t)$ for j^{th} user actually is composed of signal vectors through each path of all users and a white Gaussian noise vector $\mathrm{n}_0(t)$ of zero mean and variance σ_n^2. The data can be obtained by multiplying the sequence of j^{th} user. The channel model is represented by Fig. 1 $Q_{r,j}$ and $W_{r,j}$ are defined like

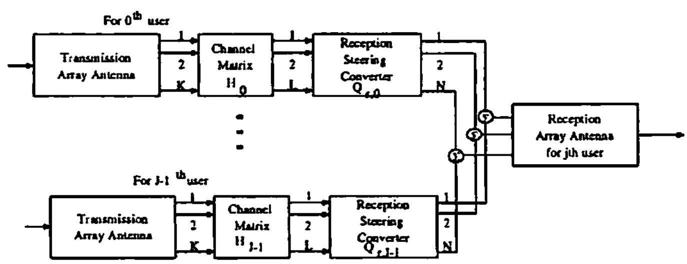

Fig. 1: Extended Channel including Transmitter and Receiver

as one of the transmitter. H_j is represented as

$$H_j = \begin{bmatrix} h^j_{0,1}(t) & h^j_{0,2}(t) & \cdots & h^j_{0,K-1}(t) \\ h^j_{1,1}(t) & h^j_{1,2}(t) & \cdots & h^j_{1,K-1}(t) \\ \vdots & \vdots & \vdots & \vdots \\ h^j_{L_j-1,1}(t) & h^j_{L_j-1,2}(t) & \cdots & h^j_{L_j-1,K-1}(t) \end{bmatrix}, \tag{7}$$

3 Joint Optimal Transmitter – Receiver System in Space and Time Domains

3.1 Precoding on Transmitter Side

In this section we will describe the equalization scheme on the transmitter side of user j^{th}. At first, we assume that $h^j_{l,k} = 0$ for $l \neq k$. This means that each signal for j^{th}, which is transmitted for different directions, is independent. However co-channel interferences of other users exist in the received signal. Then, if the transmitted signal is designed to the time inverse of the channel for each direction by using the channel information, the received signals from each direction for j^{th} user must be matched for each channel of the direction. So, in this paper, the precoder coefficients for each direction is represented by

$$W^j_{l,k}(t) = {h^j_{k,k}}^*(\tau_k - t), \tag{8}$$

where τ_k represents the maximum delay in the impulse response $h^j_{k,k}(t)$ and $*$ represents complex conjugate. In this paper, since we assume the duplex scheme is two-way interactive communication such as TDD/FDD, the channel information can be obtained. The transmitted signals equalized by the channel since each precoder is matched for channel impulse response of each direction. Therefore, the received signals through each path are the same as the output of matched filter.

3.2 Equalization on Receiver Side

When the transmitted signals are precoded by using precoders for each transmission direction, the each received signal through each path is the matched filter output. Therefore, if the channel information estimation is perfect and no noise exists, the equalizer on the receiver side isn't need. However, the channel information estimation is not perfect and the noise exists. Moreover, when the received signals can be processed by using the array antenna or digital filter, the diversity gain is obtained.

It will be assumed in the paper that the fading rate of the channel is slow enough for spatial variation of each channel tap vector to be perfectly tracked. When the multibeam array antenna is used, the path diversity on the receiver side can be achieved. Then, the number of the antenna weight sets needs the same as the number of arrival angles at the receiver. The each antenna pattern of antenna weight sets is made corresponding to the arrival angles. The antenna weight for the arrival angle $\theta_{j,l}$ is obtained by

$$W_{r,j}(\theta_{j,l}) = \frac{1}{\sqrt{N}} \begin{bmatrix} 1 & e^{j\pi \sin\theta_{j,l}} & \dots & e^{j(N-1)\pi \sin\theta_{j,l}} \end{bmatrix}^T. \tag{9}$$

The received signal is combined by using the multibeam array antenna, and the receiver can equalize based on Viterbi Algorithm by using channel information.

4 Computer Simulations

4.1 Simulation Model

The proposed joint transmitter – receiver system in the spatial and temporal domains is evaluated based on the number of users. At first, the simulation specifications for the evaluation is shown table 1. In this simulation, the sequence estimation is performed under the assumption that a channel is estimated perfectly.

Table 1: Computer Simulation Model

element distance	half wavelength	spreading code	gold sequence
the number of transmission path	2	transmission angle ϕ_0	10 [deg]
the number of reception path	2	transmission angle ϕ_1	50 [deg]
features of array antenna	line	reception angle θ_0	30 [deg]
modulation for information	BPSK	reception angle θ_1	60 [deg]

4.2 Numerical Results

Fig. 2 shows that the bit error probability depends on the number of users. In the digital cellular system, the increasing of channel capacity is needed and by using the proposed system the high capacity is expected. Moreover, Fig. 3 shows that the achievable transmission rate of the proposed system can be close to the channel capacity when the number of users is small.

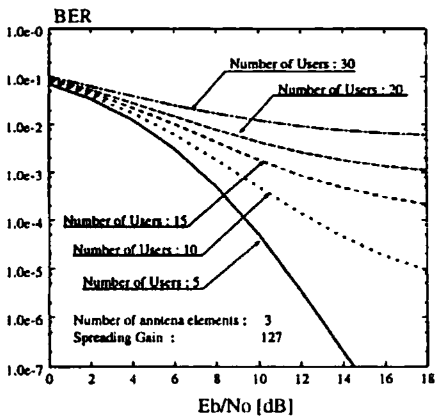

Fig.2: BER according to the Number of Users

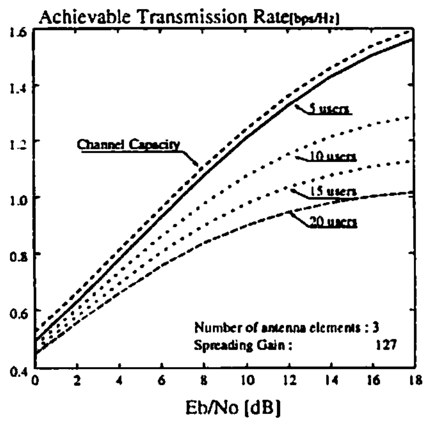

Fig.3: Achievable Transmission Rate according to the Number of Users

5 Conclusion

In this paper, we have proposed the spatially and temporally joint equalization system in both a transmitter and a receiver from the view point of optimization for both transmitter and receiver side. Hereafter, we will consider to evaluate the performance of the proposed system in some cases.

References

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