DOA Estimation in WCDMA

Using MUSIC Algorithm with Low Level Quantization

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저레벨 양자화와 MUSIC 알고리즘을 이용한

WCDMA 에서의 방향각 추정

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Abstract

이 논문은 WCDMA 와 안테나 배열 시스템에서 저레벨 양자화와 MUSIC 알고리즘을 사용하여 신호의 방향을 추정하는 방법을 제안한다. 추가의 Power-Up Function 이 필요 없는 방향각 방법으로 이동가입자의 위치를 알아내기 위해 안테나 배열을 이용하여, WCDMA 시스템에서 역확산 코드로 다수의 신호를 분리하고, 각 신호를 저레벨로 양자화 시켜 MUSIC 으로 신호의 방향각을 추정하였다. 이 방법을 이용하면 단말기의 안테나 출력파워가 낮더라도 기존 방법의 에러율과 비슷함을 시뮬레이션 결과로 알 수 있고, 양자화 비트를 처리하기 위해 필요한 메모리 또한 줄일 수 있어 하드웨어의 비용을 줄일수 있을것이다.

I. Introduction

In the early 21st century, mobile communication systems are expected to me by a continuous subscriber increase. SDMA can offer a broad range of ways to improve wireless system performance. In general, it can provide enhanced coverage through range extension, hole filling, and better building penetration. Given the same transmitter power output at the base station and subscriber unit, SDMA increases the range by increasing the gain of the base station antenna [1]. MUSIC is popular for its high resolution property in DOA estimation which exploits the eigen structure of the input data matrix [2]. However, it needs good SNR. Direction finding (DF) systems utilize antenna arrays and DOA estimation techniques to determine the direction of the signal of interest. The DOA measurement restricts the source location along a line in the estimated DOA, which is called a line-of-bearing (LOB). One of the key components of a receiver is the DOA quantization algorithm used to determine the DOA of the desired user's arrivals impinging on the antenna arrays and have investigated the problem of spectral estimation of clipped Gaussian noise. Other studies published over the past several decades have examined the effects of one bit clipping on the estimation of the autocorrelation function (ACF), and derived efficient algorithms for fast estimation of the ACF of the unquantized signal by using its one-bit quantized sample [3]. In this paper, we propose a WCDMA receiver for DOA estimation with the low level quantized DOA method, which is less demanding in complexity of hardware and memory. Sampling the data with an extreme clipping of a short bit results in severe information loss on the sampled data, as only the information about the sign

remains available after clipping. It is found that low level quantization gives a slightly worse performance; however, the advantage of using low level quantization sampling and correlation based estimators is that the noise influence can be reduced very largely and the correlation can be calculated very simply by clipping.

II. Signal Model

We consider a synchronous WCDMA systems with K users in a frequency selective fading channel which induces no multipath components per received signal [4]. Each signal is spread by a random binary sequence of length N. A base station is sectorized into three sectors, each with $120°$ coverage. An array of P uniformly spaced omni-directional antenna elements which are spaced in a uniform $1/2\ \lambda$ of transmission wavelength, are arranged in a liner array. To develop the equations for our systems, first we consider the signal received at one of the antenna elements, r_p,

$$r_p = SG_pAb + n_p \qquad (1)$$

where $S \underline{\Delta} [s_1 s_2 \cdots s_K]$ is the N-by-K data spreading code matrix and where s_k corresponds to the component of the kth user's signal. We assumed that the delay spread is small compared to the symbol period so that intersymbol interference can be ignored. The spreading codes are normalized by squared Euclidean norm of a vector. Matrix G_p is the block diagonal K-by-K response matrix defined by

$$G_p \underline{\Delta} diag[g_{1,p} g_{2,p} \cdots g_{K,p}] \qquad (2)$$

where $g_{k,p}$ is the complex steering coefficient from the kth user to the pth antenna,

$$g_{k,p} = e^{j\pi(p-1)\sin\theta_k} \qquad (3)$$

matrix A is the real K-by-K diagonal matrix of amplitudes, b is the complex K-vector data symbols, and n_p is the zero-mean complex Gaussian noise vector with independent identically distributed (i.i.d) components whose real and imaginary components have variance σ^2. We define the stacked received signal $r \underline{\Delta} [r_1^H \cdots r_P^H]^H$,

$$r = \widetilde{S}GAb + n \qquad (4)$$

where $\widetilde{S}$ is the real NP-by-KP block toeplitz spreading code matrix with diagonal blocks S, $G \underline{\Delta} [G_1^H \cdots G_P^H]^H$ is the complex KP-by-K stacked response matrix, and $n \underline{\Delta} [n_1^H \cdots n_P^H]^H$ is the stacked received noise vector. The output of the code matched filters,

$$x \underline{\Delta} [x_1^H x_2^H \cdots x_P^H]^H = \widetilde{S}^T \widetilde{S}GAb + \widetilde{S}^T n \quad (5)$$

where $x_p = [u_{1p} u_{2p} \cdots u_{Kp}]^H$ is pth matched filter.

$$y \underline{\Delta} \widetilde{S}^T \widetilde{S}GAb + \widetilde{S}^T n \qquad (6)$$

The kth element of y is the matched output for user k, obtained by correlating each of the pth received signals with its codes, and summing over array indices p. This procedure is illustrated in Fig. 1.

III. Low Level Quantization

In this section we describe the low level quantization. The array covariance matrix for a unquantized symbol snapshot is given by

$$R_{yy}(\theta) = E[y(n)y(n)^H]$$ (7)

The signal is sampled using a coarse quantization that is characterized by the sign operation which is defined as

$$y^Q(n) = sign[y(n)]$$ (8)

The signal in each antenna element is narrowband and the quantization is done for each signal component separately. This is described using the complex sign operator,

$$y^Q(n) \equiv \frac{1}{\sqrt{2}}\big[sign(\mathrm{Re}\{y(n)\}) + jsign(\mathrm{Im}\{y(n)\})\big]$$ (9)

In general, covariance matrix is estimated directly from the data. The one bit quantization makes the ACFs functions of the unquantized data and the one bit clipped data to be bonded by a nonlinear invertible connection, known as the "arcsine law".

This connection, first discovered by Van-Vleck and later Jacovitti and Neri suggested a simple generalization of the real-valued arcsine law to complex variables. Using this, the covariance matrix estimated from the short quantized data can be recovered up to an unknown factor hat corresponds to the unknown values of the signal and noise power level. The reconstructed covariance matrix estimator $\hat{R}^q_{yy}$ is given by,

$$\widehat{R}^r_{yy} = \sin\left[\frac{\pi}{2}\mathrm{Re}\big(\hat{R}^Q_{yy}\big)\right] + j\sin\left[\frac{\pi}{2}\mathrm{Im}\big(\hat{R}^Q_{yy}\big)\right]$$ (10)

where $\widehat{R}^c_{yy}$ is an estimator for the covariance of the quantized signal $\{y(n)\}^N_{n=1}$ that is given by

$$\hat{R}^Q_{yy} = \frac{1}{N}\sum_{n=1}^{N} y^Q(n)y^{QH}(n)$$ (11)

IV. Application of proposed structure

In this paper, we propose a new approaching WCDMA

structure of DOA estimation using the low level quantization. Fig. 1. The new technique has the advantages that the noise influence can be reduced and the data rate can be fast. The antenna signals digitized low level quantization bits before being sent to the digital signal processing (DSP) module for processing. We will illustrate our approach using MUSIC algorithm. Our method consists of two principal steps. First, the receiver will use low level bit quantization to reduce number of bits. The second step is the approximate DOA that is MUSIC algorithm with quantized value
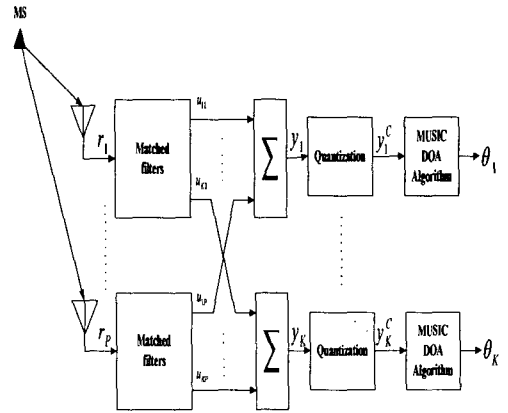

Fig. 1 Receiver structure of DOA detection.

V. Simulation and Results

In order to evaluate the performance of the quantized signal subspace DOA method in WCDMA systems, we made a computer simulation based on the following assumption. A base station with a ULA of 8 linear omnidirectional antennas with individual element spacing $1/2\lambda$ is considered. The additional noise contains spatially and temporally white Gaussian noise of zero mean and variance σ_n^2. We consider that the two mobile users are randomly distributed in azimuth around the base station with a uniform distribution over $[-60°, +60°]$.

The MEAN of the quantized DOA estimation is shown in Fig. 2, 3. We can find that the effect of DOA estimation is surprising when the number of quantization bits are small. 2bit quantizations were calculated according to Loyd-Max algorithm for scalar quantization [5]. We have examined the simulation under SNR[-30dB ~ +30dB]. The results of 1bit

quantized MUSIC(QMUSIC,) 2bit QMUSIC and no quantized MUSIC are plotted as the MEAN versus DOA angle compared with the desired user's angle.

As can be seen, the 2bit QMUSIC and unquantized MUSIC achieved similar performance in -5dB SNR and 2bit QMUSIC shows better performance than unquantizd MUSIC under lower -5dB SNR
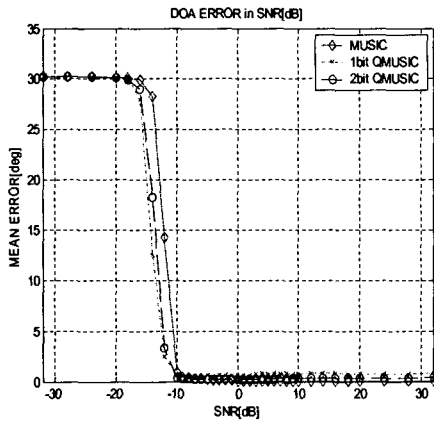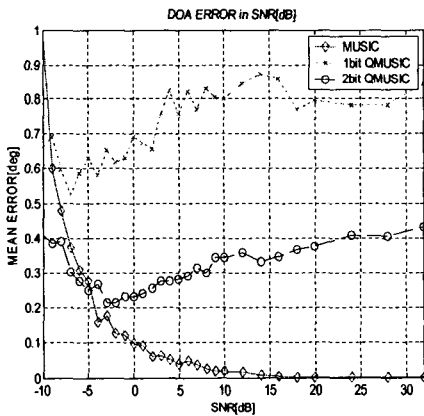

Fig. 2 Mean error of user's DOA in -30dB ~ 30dB.

Fig. 3 Mean error of user's DOA in -10dB ~ 30dB.

V. Conclusion

We simulated the multiple DOA estimation which doesn't need the power-up function used in TDOA with low level quantization. The results show that the low level quantization is robust under high white gaussian noise (WGN) and has better results in negative SNR by clipping. The presented method is applicable to WCDMA systems, where orthogonal codes used for signal spreading are masked by cell specific scrambling codes. It provides estimation of mean error under $\pm0.5°$ between -10dB ~ +30dB SNR. Our simulation did not include the effects of multipath. But the approach can be used to include a multipath model. In addition, the proposed system may reduce cost of the hardware because the system needs less memories and no gain controller.

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