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FREQUENCY TRANSMIT DIVERSITY WITH OPEN-LOOP CHANNEL ESTIMATION

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1. Introduction

In WCDMA system the down-link capacity can be improved using antenna sectorization or transmit diversity. The first technique usually increases the system load and doubles the transceiver design complexity. The down-link transmit diversity gain performance is composed of the coherent combining gain and the multipath diversity gain. The coherent combining gain is possible with closed loop transmit diversity [1,2]. With 3GPP specifications down-link dedicated physical channel transmit diversity is introduced using the space time block coding technique (STTD) [1,2]. Other effective techniques are time-delay diversity and frequency diversity [1]. The diversity reduces the multipath fading effects and maintains constant received power level for power control accuracy. However, coherent combining is not perfect, because for all radio links only a single feedback command is provided and the feedback loop will have an adjustment delay especially with high speed mobile which further degrades the coherent combining. Hence, the actual gain obtained is low because of the code orthogonality loss, the multipath fading effect, and the feedback time synchronization problem. In contrast, the open loop transmit diversity suffers no speed sensitivity (Doppler spread). The technique proposed in this paper is open-loop frequency transmit diversity (FTD) with orthogonal channelization codes that reduce the intra-cell interference. The performance and analytical formulation, associated with the Maximum Ratio Combining (MRC) Rake receiver using the least-squares (LS) channel estimator, are investigated.

2. System Model

The frequency transmit diversity (FTD), presented in this paper, is shown in Fig.1. The proposed system is composed of the orthogonal variable spreading factor QPSK (OVSF-QPSK) modulator/demodulator, transmit frequency separation, and a MRC-Rake receiver [3] with open loop channel estimation. Down-link channelization codes (OVSF) are used within each basestation is used to separate the different terminals where $\{\overline{OVSF} \bullet OVSF\} = 0$. A typical ITU Vehicular (A) Test

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model [4] proposed in the UMTS TR 101 112 is implemented to realize the frequency-selective fading channel for the system simulations, in which paths A(a1) and A(a2) have an identical power delay profile with independent Rayleigh fading components on each tap for carriers f_{c1}=2130MHz and f_{c2}=2129.57MHz , respectively.

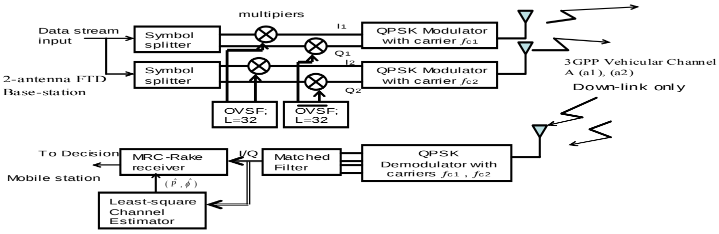

Fig.1 Two-branch FTD system model for WCDMA downlink measurements

For WCDMA systems the spreading factor is defined as *Spread_Factor = Chip_Rate/ Data_Rate*. The chip rate is equivalent to 3.84 Mchips/sec. Reducing the SF (Spreading_Factor) will enhance the transmitted data but will reduce the received signal to the interference power ratio (SIR). Therefore, the SIR and SF relationship can be described as

$$SIR_i(t) = SF_i(t) \times CIR_i(t) \qquad (1)$$

where SIR_i (t) and $CIR_i(t)$ represent the signal to interference power ratio and carrier to interference power ratio for the *i*th user at time instant *t,* respectively. The CIR is frequently adjusted to maintain the target SIR. The target SIR is determined by the outer loop power control which determines the allowable BER performance. We assume that there are *m* effective numbers of intracell users and an N spreading codes length. Using the Wiener-Hopf integral the orthogonal factor for the *j*th user, ξ_j , can be defined as

$$\xi_j = 1 - \frac{1}{m-1} \sum_{\substack{i=1 \\ i \neq j}}^{m-1} \left[P_i(u) R_{ij}(\tau - u) du / \overline{P_i} \right] \qquad (2)$$

$$= 1 - \sum_{i=1}^{m} \rho_{ij} \quad \text{where } 0 \le \tau \le (N-1)T_c \quad \text{and} \quad R_{ij}(\tau) = \frac{1}{NT_c} \int_0^{(N-1)T_c} C_i(t) C^H{}_j(t+\tau) d\tau .$$

$P_i(u)$ and $\overline{p}_i$ are the instantaneous path gain and the average path gain for the *i*th user respectively. R_{ij} is the complex-valued cross-correlation function of $C_j(t)$ for the *jth* user spreading code and $C_i(t)$ for the *i*th user spreading code. ρ_{ij} represents the normalized cross-correlation coefficient for the *j*th user with *m*-1 interferers.

The down-link received power is multiplied by 1-ξ for the intracell interference, where ξ = 1 corresponds to perfect orthogonal intracell terminals. While ξ = 0 represents the intracell interference as completely asynchronous. The Carrier to Interference ratio (CIR) for the *j*th user at time instant is defined as $CIR_j(t) = \overline{P}_j(t) A_j(t) / \sum_{\substack{i=1 \\ i \neq j}}^{m-1} \overline{P}_i(t) A_i(t) + \zeta_i$ (3)

where m is the number of users in the same cell (intra-cell), Aj(t) represents the transmitted signal power of the *j*th user at time instant *t,* and ζ is average power of additive white noise.

3. Performance and Analytical Formulations

The total performance gain for down-link transmit diversity could be achieved using a MRC-Rake receiver, which is composed of the multipath diversity gain and coherent combining gain. The matched filter output, $\overline{S}_{QPSK}$, enters to each delay line of the Rake receiver. The sum of all finger outputs for L delay paths for K transmission antennas for user-*j* will be expressed as

$$\begin{aligned} r_j(t) = \mathrm{Re}\{&\sum_{k=1}^{K}\sum_{l=1}^{L}\frac{1}{NT_c}\int_{t=0}^{NT_c}\exp(-j\widetilde{\Phi}^{l}_{j,k})\exp[j(\gamma_k t+\varphi_k)]\{\sqrt{\widetilde{\mathrm{A}}_{j,k}(t)}\,\hat{p}^{l}_{j,k}\}\{S_{j,k}(t-\tau_l)C^{k}_{j}\}dt \\ &+\sum_{k=1}^{K}\frac{1}{NT_c}\int_{t_0}^{NT_c}\{\overline{I_0(t)}+n(t)\}\,p^{i}_{j}C^{i}_{j}dt\} \qquad (4) \\ =[\sum_{K=1}^{K}\widetilde{A}_{j,k}(t)\xi_{j,k}&\cos(\hat{\Phi}_{k-1})][\sum_{l=1}^{L}\vec{S}_{j,k}(t-\tau_l)\cos(\gamma_{k,l}t+\varphi_k)]+[\sum_{k=1}^{K}\overline{\xi}_{j,k}I_0(t)+\zeta_0] \end{aligned}$$

where γ_k is the Doppler frequency received at antenna-*k* with phase offset φ_k , $\widetilde{\Phi}_{j,k}$ is the relative phase difference in the signal paths transmitted by antenna-*k,* α_k is the *k*th path loss factor, and $S_j(t-\tau_k)$ is the spread signal for the *j*th user on excess delay τ_k . Note that $\{C^k_j \cdot C^u_j\} = 0$ for all $k \neq u$ and $\{C^k_j \cdot C^u_j\} = 1$ for all $k = u$, and $\xi_{j,k}$ represents the orthogonal factor at the *k*th path for the *j*th user at antenna-*k*, and $\overline{\xi}$ is its complement matrix (orthogonality loss; 1-ξ). $\widehat{\Phi}$ is the phase difference relevant to the reference path and ζ_0 is despreading white noise.

Coherent combining gain (Gcm)

As indicated in (4), the coherent combining gain can be obtained using closed loop transmit diversity where the relative phase difference is adjusted in the basestation,i.e., $\hat{\Phi}_{k-1} = 0^{\circ}$. This ideally provides gain with $10 \times \log(k)$ in dB when K transmit antennas are employed. From our proposed FTD the input to the MRC-Rake receiver is theI/Q complex output of the matched filter. Therefore coherent demodulation with known path parameters is assumed in this system [5, 6, 7]. The coherent combining gain can be achieved by calculating the Chernoff bound on error probability [5, 6] from the second part of the first term and the second term of (4).

Multipath diversity gain (Gmd)

The diversity gain is equivalent to the reduction in power rising with fast power control. This means to minimize the transmitted power, to achieve at least the minimum CIR, which therefore obtains the minimum data rate. Trying to achieve the maximum CIR for all users will result in high outage probability due to interference limit performance and only a few of the users will benefit. FTD adopted with coherence bandwidth for carrier separation is effective in improving the outage probability and down-link capacity. By rewriting (3), the CIR measurement can be obtained from the first part of the first term and third term of (4) where coherent combining is assumed.

$$CIR_j(t) = \sum_{k=1}^{K}\widetilde{A}_{j,k}(t)\xi_{j,k}\cos(\hat{\Phi}) / \sum_{k=1}^{K}\overline{\xi}_{j,k}I_0(t)+\zeta_0 \qquad (5)$$

In power control algorithm [2], the optimum power vector is the minimum power vector that can achieve the target QoS (i.e. BER=10^{-3}) and the minimum CIR.

4. BER simulations and conclusions

The average BER performances of OVSF-QPSK are evaluated base on the Monte Carlo simulation for FTD system, as shown in Fig.1, using channel parameters as indicated in Table 1. The frequency separation, Δ*f*, is selected to reduce the sensitivity to multipath fading and enhance the diversity gain, which is equivalent to the coherence bandwidth (B_c=430KHz). In Fig.2, the total transmit diversity gain versus E_b/N_o at BER=10^{-3} is achieved at about 4.5dB and 4~5dB without and with intra-cell interferences, respectively. This is very close to the value expected from the performance achieved using the closed-loop channel estimator [2]. The individual gains based on (4) and (5) under Table 1 conditions, associated with intra-cell interferences, were calculated to G_{cm}≅2.1 dB assuming the perfect power control (received constant power) and G_{md}≅ 2.25 dB assuming the coherent combining (i.e. 3dB for K=2), respectively. The intra-cell interference effect can be substantially reduced using an open-loop FTD with the MRC Rake receiver.

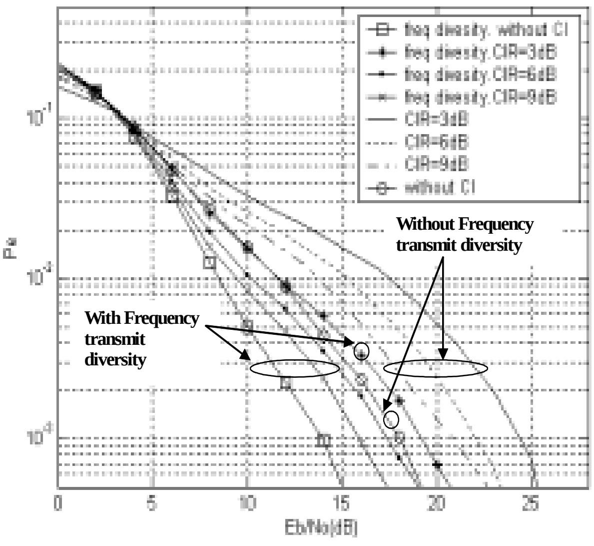

Fig.2 BER performance of open-loop with Δ*f*=430KHz and N=32

Table 1

Δ*f*	Measured ρ_{ij}	Measured ξ	Channel Type
430KHz	0.2987+j0.3034	0.5743	Vehicular (A) speed 15Km/h

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