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# Closed-loop pre-equalization for wireless MC-CDMA systems under QoS requirements

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**Abstract**

This paper addresses the dynamic pre-equalization problem in the downlink and uplink of MC-CDMA systems by following a distributed feedback perspective, and including explicit quality-of-service (QoS) restrictions. The proposals for the downlink and uplink are synthesized taking into account implementation considerations. The QoS requirements for each active user are translated into a prescribed signal to interference-noise ratio (SINR) after detection at the receiver. In the downlink, an independent pre-equalization factor per subcarrier is suggested which induces diversity in the problem formulation, where a simple matched-filter at the mobile units is assumed for signal detection at the mobile units (MU). In this formulation, the pre-equalization factors that minimize the transmission power and achieve the objective SINR can be accomplished. Meanwhile, in the uplink, a uniform pre-equalization scaling for all subcarriers is proposed, where now multiuser detectors are considered at the base station (BS) in order to achieve the objective SINR's. Moreover, a general closed-loop control structure is addressed which could simultaneously consider our proposals in the downlink and uplink. This framework allows to use distributed control algorithm previously proposed for power control in CDMA systems. Also, stability conditions are analytically deduced to guarantee convergence of the iterative algorithms. An extensive simulation evaluation is

*Abbreviation:* BER, bit-error rate; BS, base station; CDMA, code division multiple-access; CP, cyclic-prefix; CSI, channel state information; IFFT, inverse fast Fourier transform; IPT, independent pre-equalized transmission; FFT, fast Fourier transform; FSR, frame success rate; QoS, quality of service; MAI, multiple-access interference; MC-CDMA, multi-carrier code division multiple-access; MC-DS-CDMA, multi-carrier direct-sequence code division multiple-access; MISO, multiple-input single-output; MF, matched filter; MMSE, minimum mean square error; MU, mobile unit; P/S, parallel-to-serial; SINR, signal to interference-noise ratio; UPT, uniform pre-equalized transmission; ZF, zero forcing.

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presented which shows that the QoS requirements are always satisfied for different load conditions in the MC-CDMA system.


## 1. Introduction

Mobile wireless communications have evolved dramatically in the last twenty years. The new technologies in this field look to accomplish high data rates despite time-varying displacement profiles of the mobile units. Recent advances in wireless interfaces have suggested multicarrier code division multiple access (MC-CDMA) for high data rate transmissions. MC-CDMA combines two technologies: orthogonal frequency-division multiplexing (OFDM) and CDMA, in order to improve the communication efficiency [1–3]. In MC-CDMA, the transmitter spreads the information over a set of subcarriers using a predefined spreading sequence in the frequency domain. Hence, part of the transmitted symbol corresponding to a chip of the spreading sequence is broadcasted through each subcarrier [2]. This concept can be applied for downlink and uplink transmissions in wireless interfaces. One advantage of this technology is that it can lower the symbol rate in each subcarrier, so it is easier to quasi-synchronize the transmissions.

In MC-CDMA, there have been efforts to improve the quality of the transmission-reception process by pre-equalization [4–6] and multiuser detection [7,8]. In the pre-equalization techniques, the transmission amplitude and phase are adjusted in order to optimize a cost function related to the detected symbols. The cost functions are usually related to the signal-to-interference and noise ratio (SINR), which is linked to the bit-error-rate (BER) and frame-success-rate (FSR) [9]. The BER and FSR are two metrics used to evaluate the quality of service (QoS) in a transmission. Hence if the SINR has to be adjusted to a specific value, as described in [10], there are two available choices: IPT (a complex pre-equalization factor by subcarrier), or UPT (a common amplitude scaling for all subcarriers). One advantage of IPT is that by the induced diversity the minimum transmission power that satisfy the SINR restrictions could be accomplished.

Another approach to improve the QoS in wireless interfaces is dynamic power allocation of the transmitted symbols [11]. In fact, this strategy has been investigated in great detail for CDMA systems [12], where different distributed power assignment techniques have been suggested in the uplink transmissions, as game theory strategies [13], passivity control [14], $H_\infty$ control [15,16], Smith predictors [17], proportional-integral algorithms [18] and LQ control [19]. The most important challenges in power control for CDMA systems are the multiple-access interference (near-far effect), time-varying profiles in the channel gains, measurement and processing delays in the closed-loop system, measurement uncertainty and noise [11,20]. In fact, pre-equalization is a more general problem than power allocation, since in the first one, the scaling factors of the transmitted symbols are complex values and in the latter one, just the amplitudes are modified. Moreover, it is of practical interest to achieve pre-equalization inside an iterative closed-loop scheme, since there is robustness inherited by the feedback structure to measurement uncertainty and noise [21].

Despite the advantages of power control, this scheme has been scarcely explored in MC-CDMA. The only related references are [22,23]. However, the focus of [22] is on multicarrier direct-sequence CDMA (MC-DS-CDMA) [1,3], which has a different transmission–reception structure. Meanwhile, in [23], closed-loop power control in