Time-Domain Equalizer for OFDM Systems Based on SINR Maximization
Hossein Zamiri-Jafarian, Hossein Khoshbin, and Subbarayan Pasupathy

Abstract—A new method is proposed in this paper to design the time-domain equalizer for orthogonal frequency division multiplexing systems based on maximizing signal-to-interference-plus-noise ratio (SINR) at the output of the equalizer. The method called Maximum SINR Time-domain Equalization (MSINR-TEQ) is derived based on a new formulation of SINR. Computer simulation and analytical results show the performance of the MSINR-TEQ method and its superiority in comparison with the performance of the much-used method of channel impulse response shortening.

Index Terms—Channel shortening, discrete multitone, minimum intersymbol interference equalizer, orthogonal frequency-division multiplexing (OFDM) systems, time-domain equalization.

I. INTRODUCTION

ORTHOGONAL frequency-division multiplexing (OFDM) is a multicarrier modulation scheme that partitions a broadband channel into a number of parallel and independent narrowband subchannels. A cyclic prefix (CP) is inserted between the OFDM symbols in order to mitigate intersymbol interference (ISI) and interchannel interference (ICI) effects for signal transmission over multipath channels. To avoid ISI and also ICI (and thus make the subchannels orthogonal), the CP interval should not be shorter than the channel-impulse response (CIR) interval. However, appending CP to each OFDM symbol decreases the bandwidth efficiency of the OFDM system; thus the CP interval should be a small fraction of the OFDM symbol interval.

To maintain the bandwidth efficiency, a time-domain equalizer (TEQ) is used in the OFDM systems to eliminate the ISI and ICI effects when the CIR interval is longer than the CP interval. Two major approaches for TEQ design have been proposed. The first is the approach proposed by, called impulse response shortening (IRS),1 is to shorten the effective length of the overall impulse response (DIR) (convolution of the CIR and equalizer impulse response) based on different criteria [1]–[5] such as maximizing or minimizing the energy of a window of the OIR [1]–[3] or minimizing the power delay spread of the OIR [4]. Other criteria consider the noise power in addition to the energy of a window of the OIR subject to maximizing bit rate or minimizing ISI based on the signal-to-interference plus noise (SINR) of each subcarrier [5]. In the second approach a desired impulse response (DIR) with the length of the CP interval is defined based on a criterion and then a TEQ is designed by minimizing the mean squared error between the OIR and the DIR [6]–[9].2 Also, the schemes proposed in [1] and [5] have been derived in [12] under a generalized MMSE framework.

In this paper, we propose a new method to design the TEQ for the OFDM systems based on maximizing SINR. The criterion is formulated by identifying the signal, ISI, ICI and noise powers at the output of the equalizer. We show that the contribution of each tap coefficient of the OIR to the SINR depends on its time index in addition to its power and also N + ν tap coefficients of the OIR contribute to the signal power when N and ν are the OFDM symbol and the CP intervals, respectively. Based on the signal, ISI, ICI and noise powers, we define SINR, this being different than those used in earlier literature such as [5] and [11]. Note that the time index of the tap coefficient has been considered in the ISI plus ICI power in [11], however, in addition to not considering the noise power, only the power of ν + 1 tap coefficients have been used as the signal power in the criterion of [11]. Meanwhile, the ISI and ICI powers are derived separately in our approach that is more general than the proposed method in [14] for deriving interblock interference (ISI plus ICI) power that has been used in [11].

The other sections of the paper are organized as follows. System model and TEQ design criteria based on the IRS and the MMSE methods are presented in Section II. Shortcoming of the IRS and the MMSE methods is highlighted in this section as well. The maximum SINR time-domain equalization (MSINR-TEQ) method is proposed in Section III. Section IV provides some computer simulations and comparisons. Discussions and some conclusions are drawn in Section V.

II. SYSTEM MODEL AND TIME-DOMAIN EQUALIZER DESIGN CRITERIA

The discrete model of an OFDM system with a TEQ is shown in Fig. 1. q(k) = \[q_0(k), \ldots, q_{N−1}(k)\]^T is an OFDM symbol in the frequency domain such that each q(k) is selected from a q-ary constellation and \((\cdot)^T\) represents the transpose operation. \(x(k) = [x_0(k), \ldots, x_{N−1}(k)]^T\) is an N-point inverse fast Fourier transform (N-IFFT) of q(k). s(k) = \([x_N−q(k), \ldots, x_{N−1}(k), x_0(k), \ldots, x_{N−1}(k)]^T\) is the transmitted signal after appending a CP with length \(\nu\) to the x(k); h(l), \(l = 0, \ldots, L−1\) is the CIR with length \(L\); \(f(l), l = 0, \ldots, M−1\) is the impulse response of equalizer with length \(M\). \(n(l)\) is a zero mean additive Gaussian noise with autocorrelation function \(R_n(l)\).

The OIR is defined as \(g(l) = h(l)*f(l)\), where ‘*’ stands for convolution operation. Duration of the OIR is \(L_g = L + M−1\). Although the OIR interval becomes even longer than \(L\), the CIR

1It is also called maximum shortening SNR (MSSNR) and zero-forcing TEQ (ZF-TEQ) [5], [12].

2Based on considering the impact of a simple frequency-domain equalizer in which MMSE or ZF criterion is used, another approach of TEQ design has been proposed in [10] to maximize the bit rate.