

Performance of Iterative Equalizer for ISI channel

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Abstract

Iterative decision feedback equalizer (IDFE) is a recursive equalization technique that can help to achieve an additional performance gain for the system by combining iterative channel decoding and interference cancellation. In a single carrier-based system, the intersymbol interference (ISI) is a critical problem that must be resolved since it causes frequency selective fading. Based on the idea of sharing the estimated information in the process of iteration, IDFE is considered as an efficient solution to improve the robustness of the system performance on the ISI channel. In this paper, the IDFE is applied on single carrier FDMA (SC-FDMA) system to evaluate the performance under ISI channel. The simulation results illustrate that IDFE helps to improve the performance of the SC-FDMA system, especially with long delay spread channels.

Keywords: Equalization, Single carrier, ISI, Soft decision, Error propagation

1. Introduction

The intersymbol interference (ISI) is defined as the unwanted signal caused by neighbouring symbols in the time dispersive channel. This phenomenon has a negative impact on the performance of the various types of communication systems [1, 2]. An iterative equalizer is one of the solutions to deal with ISI at the receiver [3]. The iterative decision feedback equalizer (IDFE) combines iterative channel decoding with the decision feedback equalizer [4]. By utilizing IDFE, ISI can be cancelled out with the help of feedforward and feedback filters which can suppress the noise boosting in the equalization process. The estimated symbol as a form of soft information at the first iteration is a valuable reference for the interference cancellation process of the following iterations. By applying IDFE in the frequency domain, it can help to deal with a symbol by symbol equalization and avoid the long filter coefficient. Besides, by utilizing soft decisions, we can mitigate the error propagation which might be worse in the case of the hard decision. According to the previous research works [4, 5] where the iterative equalizer is applied in a single carrier system, the improvement of

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frequency domain IDFE is significant compared to the MMSE equalizer. In [5], performances of time domain based IDFE is also presented and compared with the frequency domain one. Results in [4] and [5] indicate that frequency domain IDFE is considered as a preferable solution with lower computation cost compared to time domain IDFE. Besides, the performance of the frequency domain IDFE is demonstrated in [6] with a single-input multiple-output (SIMO) system and multiple-user receiver. In this system, successive interference cancellation (SIC) and parallel interference cancellation (PIC) schemes are utilized. According to simulation results, the IDFE-based SIC and PIC scheme brings recognizable improvements compared to the conventional equalizer [6].

In this paper, the IDFE in the frequency domain is evaluated and compared with the conventional MMSE filter in the single carrier FDMA (SC-FDMA) system which is adopted in the uplink transmission in the LTE wireless communication system under the ISI channel [7]. In the following sections, the system model including the description of the major functional blocks and the filter design is discussed with the simulation results.

2. System Model

In this section, the system model of the SC-FDMA with IDFE is described. The transmitter of this system includes channel encoding, DFT spreading, IFFT transformation, and cyclic prefix (CP) addition. Upon arrival at the receiver side the time domain signal is transformed into the frequency domain signal after the CP is removed [7]. The interference cancellation process is performed in the frequency domain. The block diagram of IDFE in the frequency domain is shown in figure 1. The received signal Y is first equalized by the MMSE filter. The estimated symbol at i^{th} iteration $\hat{X}^{(i)}$ is fed to the channel decoder block after the inverse DFT and the symbol demapping process. The log-likelihood ratio (LLR) value for the data bit b at the output of the decoder is denoted by L_o . These LLR values are used to estimate the symbols and variance of each estimated symbol. This information plays an important role in designing the feedforward and feedback filter coefficient in the following iterations of interference cancellation. In our system, soft decision based on LLR information is utilized at the estimation block to detect the symbols and variance of symbols [4].

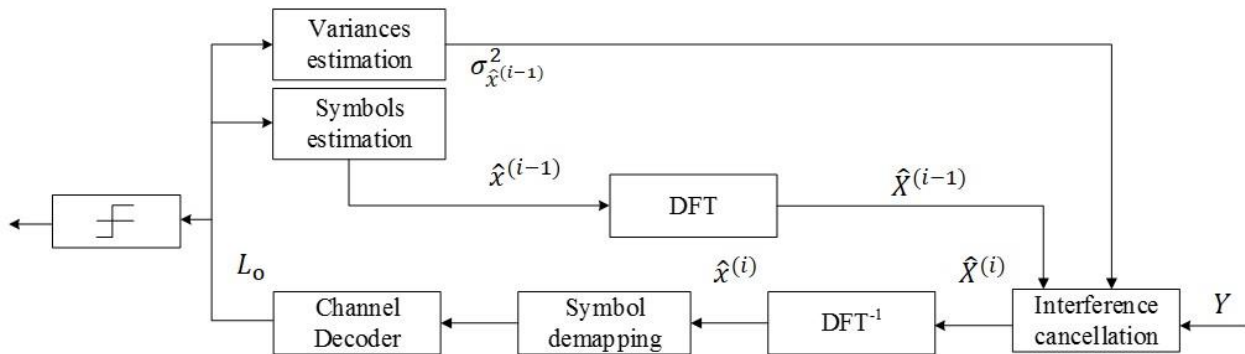


Figure 1. Block diagram of Iterative Decision Feedback Equalizer

The probability of each symbol is estimated with the LLR information from the decoder. In case the probability of each symbol is known, the symbol estimation at i^{th} iteration can be done as follows:

$$\hat{x}^{(i)} = \sum_{a_x \in \mathbb{S}} a_x \Pr(a_x) \quad (1)$$

where \mathbb{S} is a set of the complex constellation symbols and a_x is a complex symbol on the constellation. Based on the estimated information, the feedforward F_f and feedback F_b filter coefficients are calculated as follows [4]:

$$F_f = \frac{H^* \sigma_{\hat{x}^{(i-1)}}^2}{(|H|^2 \sigma_{\hat{x}^{(i-1)}}^2 + \sigma_n^2)}, \quad (2)$$

$$F_b = -(F_f H - 1), \quad (3)$$

where $\sigma_{\hat{x}^{(i-1)}}^2$ is the variance of the estimated symbol, σ_n^2 is noise variance and H is the channel response in the frequency domain. The estimated symbol at the i^{th} iteration is calculated as:

$$\hat{X}^{(i)} = F_f Y - F_b \hat{X}^{(i-1)}. \quad (4)$$

3. Simulation Results

In this section, the IDFE performances under various delay spread channels are investigated. The exponential decaying channel model is assumed with RMS delay spreads of 0.03, 3, and 30 μ s. 16QAM modulation and the turbo encoder with a coding rate of 1/2 are used at the transmitter. The size of DFT is 36 sub-carriers and the number of OFDM symbols is 14 for each user. Two OFDM symbols are used as reference signals. In the single carrier FDMA system in LTE, maximum of 16 users can access the uplink channel at the same time. In our simulation, we ignore the effect of the interference between subcarriers. It can be noticed in figure 2 that the longer delay spread can lead to more degradation in the BER performance. However, by applying the IDFE, system performance is improved in all cases.

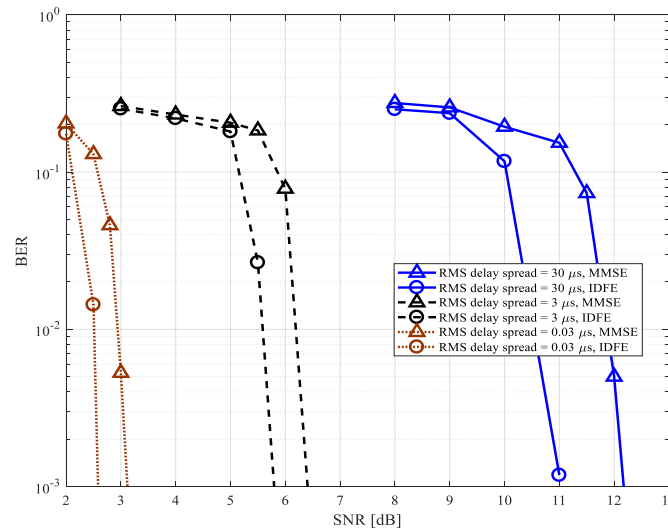


Figure 2. Performance of IDFE at exponential decaying channel with different RMS delay spreads

In this simulation, the performances of the IDFE are obtained after the second iteration. It is worth noticing that the performance gaps between the IDFE and MMSE are getting bigger as the delay spread increases. In detail, at RMS delay spread of $0.03 \mu\text{s}$, the improvement from MMSE to IDFE is about 0.7 dB. This number increases to 0.9 dB when the RMS delay spread is equal to $3 \mu\text{s}$. At the delay spread of $30 \mu\text{s}$, the improvement increases to 1.2 dB. From the simulation results, it is shown that the performance improvement can be achieved by iteration of the equalization process. This improvement comes from the feedback part which plays an important role to exclude the residual interference after each iteration. Also, the level of confidence of the feedback information is increased when the estimated symbols get closer to the original value. This feature of the iterative equalizer in IDFE can help to improve the performance of the system even in the channel with high levels of ISI.

4. Conclusion

In this paper, the performance of IDFE in the single carrier based system is investigated. According to the simulation results, IDFE improves the performance of the SC-FDMA system compared to the MMSE equalizer and the performance gap increases as the delay spread of the transmission channel gets bigger. By performing in the frequency domain, IDFE can benefit from interference cancelation for each symbol separately which helps to reduce the complexity of the filter coefficient design process. Also, soft symbol estimation can help to provide more information to the following iterations and get rid of error propagation which is a critical problem in the iterative equalizer with the hard decision.

Acknowledgement

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