Investigating the performance of spectrally efficient FDM system in time varying fading channel

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Abstract: Spectrally Efficient FDM system (SEFDM) empolys non-orthogonal overlapped multiple carriers to provide bandwidth savings. However, SEFDM suffers from the increased complexity and sensitivity to SNR degradations. In this paper we examine the performance of SEFDM signal in different fading channel conditions. SEFDM system has showed comparable performance as Orthogonal Frequency Division Multiplexing (OFDM) system for moderate spectrum compressions.

1 Introduction

Multicarrier modulation techniques, particulary Orthogonal Frequency Division Multiplexing (OFDM) system, have been proposed and implemented in many of systems recently. OFDM based systems are able to convey information at a much higher rates that can support the wide spectrum of bandwidth hungery applications. Furthermore, many publications appeared promoting a new system that supports higher spectal efficiency (SE). SE is increased by employing overlapped non-orthogonal carriers. The carriers are located at closer frequency spacings and/or transmission time of a symbol is shortened. Of these system Spectrally efficient FDM system (SEFDM) is based on relocating the carriers [1]. The SEFDM signal is efficiently generated using the Inverse Discrete Fourier Transfrom (IDFT) [2, 3], while the detection of the signal can follow different algorithms that eliminate the intercarrier interference [1, 4, 5, 6]. The SEFDM system provides competitive BER performance in AWGN channels [1, 4, 5, 6]. In addition, joint channel and signal detection in determinstic static channels is presented in [7] and the system showed promising perfomance in static fading channels. In this paper we examine the system performance under time varying channel conditions to provide a more realistic estimate of the system potential. Channel parameters based on the COST 207 Reference Models for rural and urban nonhilly areas are used.

2 SEFDM System Model

In the SEFDM system of [1] the incoming symbols are multiplexed onto the non-orthogonal sub-carriers to generate an SEFDM symbol. The sub-carriers are placed at closer spacing compared to OFDM system. The incoming symbols can be QAM modulated, therefore, are expressed as complex symbols s and will be referred to as symbols in the rest of this paper. For a system of N carriers, the SEFDM signal is expressed as

$$x(t) = \frac{1}{\sqrt{T}} \sum_{l=-\infty}^{\infty} \sum_{n=0}^{N-1} s_{l,n} exp\left(j2\pi n\alpha\left(t-lT\right)/T\right) \tag{1}$$

where $x(t)$ is the SEFDM signal in complex baseband representation, $\alpha = \Delta f T$, Δf is the frequency distance between the sub-carriers, T is the SEFDM symbol duration N is number of sub-carriers and $s_{l,n}$ denotes the symbol modulated on the n^{th} sub-carrier in the l^{th} SEFDM symbol. SEFDM carriers violate the orthogonality condition of OFDM systems where the spacing is equal to the inverse of the OFDM

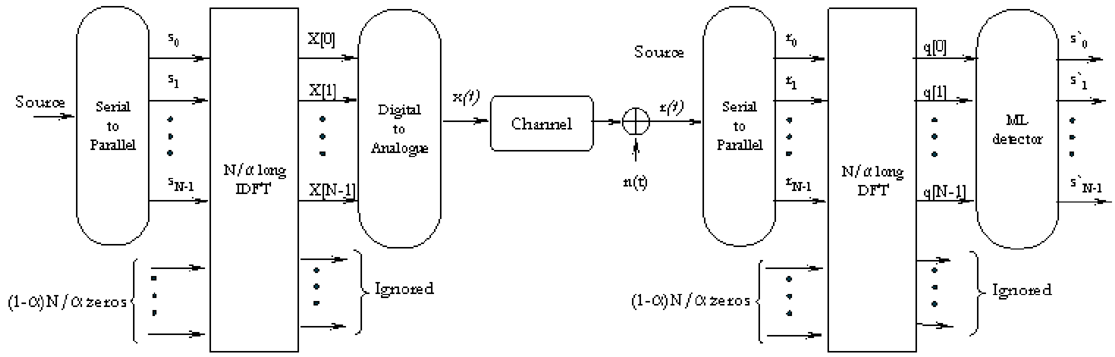

Figure 1: The SEFDM transceiver

symbol duration. The spectral efficiency improvement of the SEFDM signal over the OFDM approaches $1/\alpha$ with the increase in N.

Fig. 1 depicts a block diagram of an SEFDM transceiver. The transmitter is based on the IDFT and is explained in [2, 3]. The receiver obtains statisitcs of the signal by the DFT block and then applies maximum likelihood critiera to estimate the transmitted symbols. The signal is assumed to pass through a fading channel that is detailed in the next section.

3 Fading Channel Model

There are two common approaches for developing simulation models of communication channels; either transfer function models or tapped delay line (TDL) models for time invariant or time varying channels respectively. Transfer function models can be implemented in time or frequency domains using finite impulse filter (FIR) or infinite impulse filter (IIR). In particular multipath fading channel is modelled using TDL with tap gains and delays that are random processes. The multipath channel can categorized as diffused or discrete based on the number of multipath components. When there is a finite number of resolvabe multipath components the channel is considered discrete. When there is a continuum of multipath versions of the signal the channel is called diffused. For simulation purposes both discrete and diffused channels are modell as TDL but with difference in assigning tap gains and delays [8, 9, 10].

3.1 SEFDM in Discrete Multipath Fading Channel

The discrete multipath fading channel composes of a number of discrete independent multipath components. The input-output relationship of this channel is described as

$$y(t) = \sum_{1}^{N} \rho_n(t)\, x(t - \tau_n), \tag{2}$$

where $\rho_n(t)$ and τ_n represent the attenuation and propagation delay associated with the n^{th} multipath component. The complex path gain $\rho_n(t)$ is a time varying random process with a PDF defined by the doppler spectrum and whose power is a function of the respective delay and is obtained from the multipath intensity profile.

In this work we assumed a Rayleigh fading channel with the multipath intesity profile defined from the COST 207 reference models of rural and urban nonhilly areas for different maximum doppler frequencies. For comparison purposes preliminary test on a quasi static channel were performed. The quasi static channel assumed random multipath components for each symbol transmission. The delays of these components were assumed to be fixed within a symbol transmission.

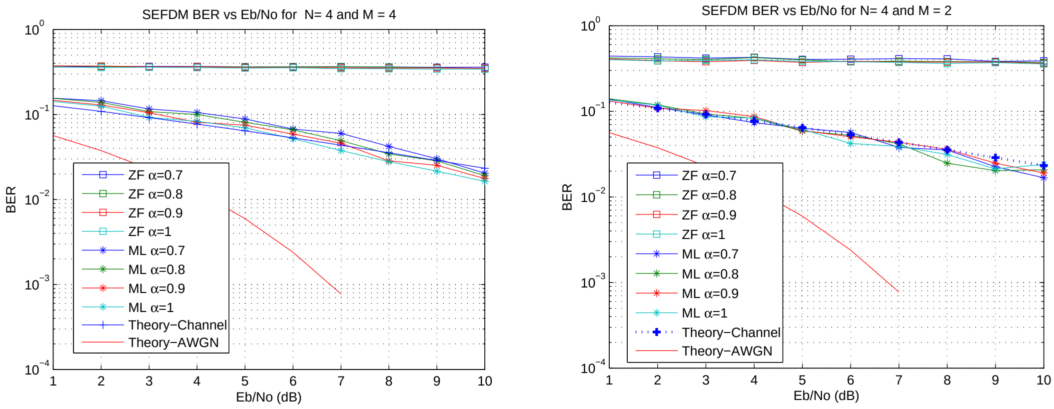

Figure 2: BER performance of SEFDM system in quasi static channel for different values of α and 4QAM (left) and BPSK (right).

4 Numerical Results

The SEFDM signal was first tested through a quasi static channel defined as:

1. Within the SEFDM transmission time the channel has a fixed number of multipath components.
2. Rayleigh fading is assumed and effects on amplitude and phase are considered.
3. The complex attenuation of each path is assumed to be constant over a symbol interval and has independent values over adjacent symbols, therefore , no doppler spectral shaping is needed.
4. The simulation assumed uniform delays between the different taps.

Fig. 4 depicts the performance of an SEFDM system in the described channel. Results show that performance is almost the same as OFDM for ML detection while for ZF detection both SEFDM and OFDM suffered massive BER degradation. This suggests that the degradation in performance is due to the ill conditioning of the ZF equalization matrix.

The SEFDM signal is then tested in time varying channel with different maximum doppler frequencies. Fig. 4 depicts the BER performance for $\alpha = 0.8$ and 0.6. From the figure it is clear that the time varying channel results in some performance degradations that is proportional to how fast the channel characteristics are changing which is also the case for OFDM system. No substantial degradations with respect to the level of bandwidth compression , denoted by α, are evident.

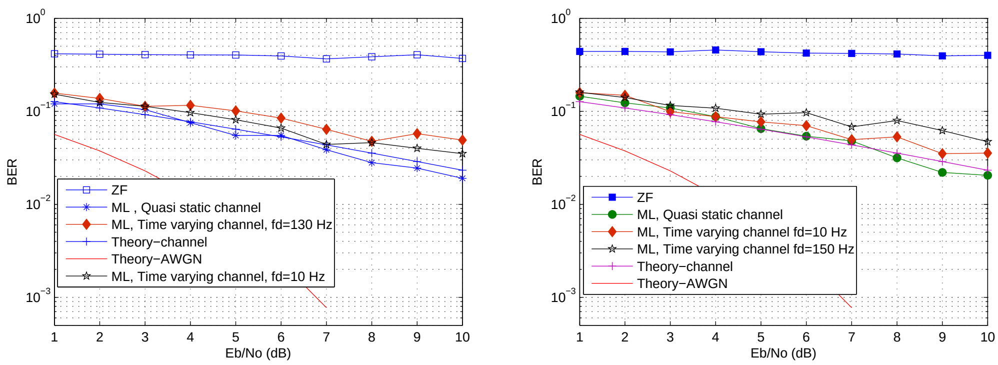

Figure 3: BER performance of SEFDM system in time varying channels for $\alpha = 0.8$ (right) and $\alpha = 0.6$ (left) .

5 Conclusions

In this paper we examined the performance of spectrally efficient FDM system under time varying fading channel conditons. The TDL model for simulating fading channels is adopted. Numerical results showed that in quasi static channels the SEFDM system showed performance close of OFDM system. Investigations under time varying channels conditions, the SEFDM signal showed BER degradations in time varying channels in a similar level as OFDM. Further investigations are necessary for a complete assessment of the system performance with more carriers and bandwidth savings.

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