Spectral Efficient Frequency Division Multiplexing with Index Modulation for Next Generation MIMO Networks

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Abstract

In this work, we propose an index modulated spectral efficient frequency division multiplexing (SEFDM-IM) technique for the future multiple-input-multiple-output (MIMO) cellular networks. SEFDM has the capability to enhance spectrum efficiency by utilizing less bandwidth with same benefits as conventional OFDM offers. The inherent nature of IM technique induces the sub-carriers to be switched off in a manner to reduce the inter-carrier-interference (ICI), and this concept can easily be extended for SEFDM to yield the reduced bandwidth consumption with low bit-error-rate (BER). Later, the integration of SEFDM-IM to the multi-input-multi-output (MIMO) system is sought as a new signaling technique to meet high capacity demands for beyond 5G (B5G) and 6G wireless communication system, where the simulation results confirm the performance of the proposed system as well.

Ⅰ. Introduction

Limited spectrum is a fundamental issue for future wireless communication systems. To meet the current requirements for B5G & 6G authors present the SEFDM-IM for the MIMO wireless networks. The concept of SEFDM is originated from faster than Nyquist (FTN) signaling [1], it achieves a spectral efficiency gain for the multi-carrier system by compressing the subcarriers and violating the orthogonality of the conventional OFDM. Significant spectral efficiency gains and the considerable error performance of SEFDM has been discussed in the literature [2]. Subcarrier index modulation is another spectral efficient and robust scheme in dealing with inter- carrier-interference (ICI) of OFDM [3]. The index modulation, initially studied for OFDM i.e., OFDM-IM which transmit extra bits over the sub-carrier indices along with the $\mathcal{M}$-ary modulation [4]. Integration of IM for compressed subcarriers of SEFDM can be useful for capacity enhancement [5]. Inspiring from different research related to SEFDM-IM and MIMO-OFDM-IM, we present a model for MIMO-SEFDM-IM. It performs almost 25% better in terms of capacity as compared to the conventional OFDM based systems.

Ⅱ. Proposed Methodology

The transmitter block diagram of MIMO-SEFDM-IM is shown in Figure 1. A MIMOSEFDM system with N_t transmit antenna, N_R receive antenna and N_F subcarriers are considered. The incoming bit stream B is divided into G groups such that each sub-group contains b bits which are utilized for SEFDM sub-block transmission having length $N = \frac{N_F}{G}$. For SEFDM, subcarriers are compressed with factor $\alpha < 1$. Index modulation of SEFDM subcarriers is employed to send information over some of the subcarrier indices as well as $\mathcal{M}$-ary modulated symbols are transmitted over these selected indices. The transmission rate using SEFDM-IM scheme can be given as,

$$R_g = \left(1/\alpha\right)\left(\left\lfloor log_2 \binom{N}{K} \right\rfloor + K log_2 \mathcal{M}\right)/N$$

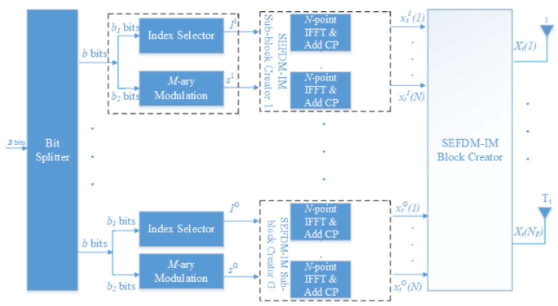

Figure 1. System block diagram for MIMO-SEFDM-IM

K is the selected subcarriers out of N in each sub-block of SEFDM and others are set to zero. Signal representation for any sub-block of SEFDM-IM scheme can be written as follows,

$$x^g = \frac{1}{\sqrt{T}} \sum_{n=0}^{N-1} s_n^g exp(j2\pi n\alpha t/T)$$

At the transmitter, the SEFDM-IM sub-blocks are concatenated to form the main SEFDM-IM block. The time domain SEFDM symbols obtained from IFFT process are normalized to have the unit energy. We assume that wireless communication channel remains unchanged during the transmission of MIMO-

SEFDM-IM frame, and CP length is greater than the channel taps. The received signal is expressed as,

$$y_r = \sum_{t=1}^{N_t} diag(x_t) H_{r,t} + v_r$$

y_r is the received signal vector for the r_{th} antenna and $H_{r,t}$ is the wireless channel between transmit antenna t and receive antenna r and follows Gaussian distribution. v_r is the AWGN noise considered with zero mean and variance σ^2. Prior to detection, the received signal is separated for each group. The following signal can be achieved for each sub-block g.

III. Result Analysis

This section describes the capacity analysis SEFDM provides higher capacity for a given bandwidth because the subcarriers are suppressed using factor α whose value can be varied between 0 and 1. Smaller the α higher will be the capacity. According to literature SEFDM provides 25% capacity improvement without effecting BER. The ergodic capacity of the MIMO-SEFDM-IM system is obtained as,

$$C = \frac{1}{\alpha} \frac{\sum_{g=1}^{G} b_{1g} + \sum_{g=1}^{G} b_{2g}}{N_F + N_{CP}} E\left\{\log\left[\det\left(\mathrm{I}_{N_r} + \frac{\rho}{N_t} \boldsymbol{H}_{r,t}\left(e^{j2\pi n\alpha/N_F}\right) \boldsymbol{H}_{r,t}^{\mathrm{H}}\left(e^{j2\pi n\alpha/N_F}\right)\right)\right]\right\}$$

For different values of bandwidth compression factor α capacity of the proposed system can be seen in Figure 2.

IV. Conclusion and Future Work

The presented research shows that multi antenna SEFDM-IM outperforms conventional OFDM-IM in terms of bandwidth efficiency and capacity. Through the proposed scheme, subcarrier compression up till 25% is achievable with appropriate detection. IM adds benefits of extra bits transmission over subcarrier indices and helps to reduce ICI. To utilize all subcarriers effectively, dual mode index modulation could be possible solution for future work.

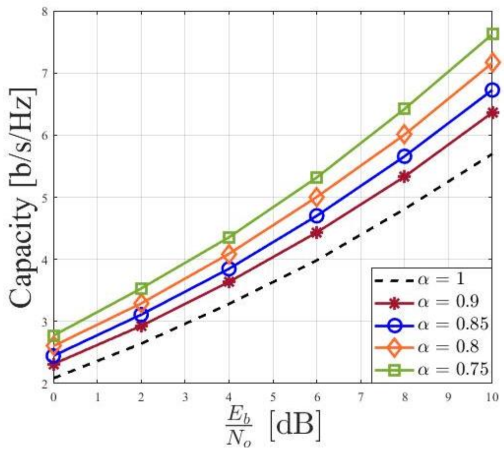

Figure 2. Capacity analysis for 2 by 2 MIMO-SEFDM-IM

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Reference

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