Tri-mode Index Modulated Spectral Efficient Frequency Division Multiplexing for Multi-Input Multi-Output Channels

Md. Shahriar Kamal, Muhammad Sajid Sarwar, *Soo Young Shin
Department of IT Convergence Engineering,
Kumoh National Institute of Technology (KIT), Gumi, South Korea
Email: {msrkamal, sajid.sarwar, *wdragon}@kumoh.ac.kr

Abstract

This work proposes tri-mode (TM) spectral efficient frequency division multiplexing (SEFDM) aided by index modulation (IM) for multi-input multi-output (MIMO) channel networks. The traditional SEFDM-IM activates a subset of subcarriers to transmit classical constellation symbols. It reduces intercarrier interference (ICI) associated with non-orthogonal subcarriers of conventional SEFDM while compromising efficient utilization of frequency resources. TM-SEFDM is designed to transmit two differentiable constellation alphabets based on an index activation pattern. Contrary to dual-mode SEFDM, it works with partial activation, which can offer a balanced trade-off between bit error rate (BER) and SE. TM-SEFDM can increase the index information of conventional subcarrier-based IM techniques without requiring extra energy for transmission, and lower modulation sizes can be used to achieve SE like its c-ounterparts, which helps to improve BER performance.

Ⅰ. Introduction

To accommodate rapidly increasing demand for data rates and massive connectivity, future wireless generation asks for high spectral efficiency (SE). Multi-input multi-output is a promising technique for the ever-increasing user demands in the upcoming wireless generation. Spectral efficient frequency division multiplexing (SEFDM) is another technique that compromises the orthogonality of OFDM to gain high SE at the expense of intercarrier interference (ICI) [1]. Deployment of index modulation (IM) on SEFDM addresses the ICI issue. Contrary to conventional SEFDM, SEFDM-IM does not activate all the available subcarriers; rather, it activates subcarriers partially based on an activation pattern to transmit supplemental information implicitly [2]. However, the partial inactivation inherited from conventional IM leads to inefficient usage of frequency resources [2-3]. To utilize frequency resources efficiently dual mode (DM) SEFDM takes the help of distinguishable constellation alphabets [4]. Although this can achieve high SE, it could increase ICI due to the utilization of all non-orthogonal subcarriers of SEFDM.

Against this background, tri-mode (TM) SEFDM for MIMO channels is proposed to achieve SE gain and transmission diversity. This increases index information while using two differentiable constellation alphabets of conventional modulation along with it. The partial activation assisted by TM-SEFDM can mitigate ICI and enables a balanced trade-off between bit error rate (BER) and SE.

Ⅱ. Proposed Methodology

The transmitter block diagram of MIMO-TM-SEFDM is illustrated in Figure 1. There are A_t transmit antennas at the base station (BS) and A_r receive antennas at the receiver. The incoming D bits are divided into G groups such that each group contains d bits ($D = Gd$). The process in each group is identical; therefore, for brevity, only the transmission process of g^{th} group will be explained. In a group, d bits are divided into d_1 and d_2 bits, which will be used to select active indices and modulate constellation symbols, respectively. The system contains N_s total subcarriers, which are divided into G blocks such that each block contains $n = N_s/G$ subcarriers. Out of n, k subcarriers will be activated. In each subblock, $k = k_1 + k_2$ subcarriers, where k_1 and k_2 will carry symbols from M_1 and M_2 constellations, respectively. The constellations M_1 and M_2 are distinguishable and do not have any common point i.e., $M_1 \cap M_2 = \phi$. The remaining $n - k$ subcarriers are set to zero which will help to reduce ICI among non-orthogonal subcarriers of the SEFDM system. An SE, achieved by g^{th} group can be calculated as follows:

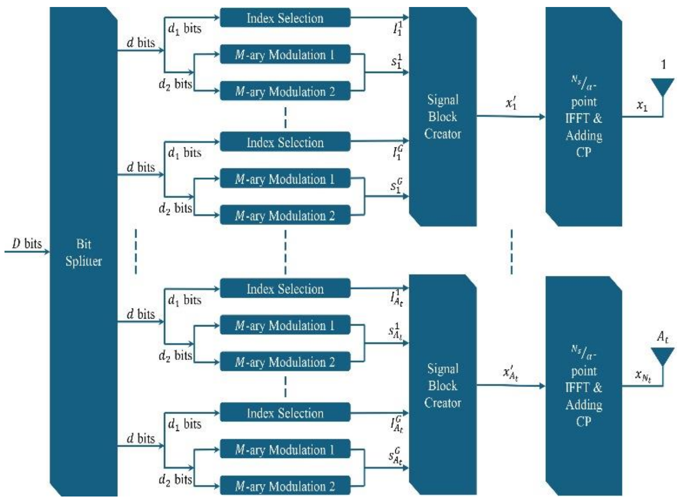

Figure 1. Block diagram for MIMO-TM-SEFDM

$$R = \frac{1}{\alpha N_s}\left[\left\lfloor log_2\left(\binom{n}{k}\times\binom{k}{k_1}\right)\right\rfloor + k_1 \times log_2(M_1) + k_2 \times log_2(M_2)\right] \quad (1)$$

The active indices of MIMO-TM-SEFDM can be expressed as

$$\boldsymbol{I}_a^g = \left[i_a^g(1), i_a^g(2), \dots i_a^g(k)\right]^T \quad (2)$$

where $g = 1, 2, \dots, G$ and $a = 1, 2, \dots, A_t$. Then, the symbol vector mapped on I_g^t is given below,

$$\boldsymbol{S}_a^g = \left[s_a^g(1), s_a^g(2), \dots s_a^g(k)\right]^T \quad (3)$$

where $s_a^g \in M_1$ and $s_g^a \in M_2$ for k_1 and k_2 subcarriers, respectively. Once the symbols are mapped over a predefined activation pattern, the subblocks are concatenated to form a block of MIMO-TM-SEFDM. Then non-orthogonal subcarriers are generated by passing this block through $\frac{N_s}{\alpha}$ -point inverse fast Fourier transform (IFFT). Here, α represents the subcarrier compression factor, which is equal to 1 for conventional OFDM and it is $0 < \alpha < 1$ for SEFDM. It is expressed as $\alpha = \Delta f T$, where Δf and T denote the subcarrier spacing and symbol period, respectively. The transmitted signal is written as follows:

$$\boldsymbol{x}_a = \frac{1}{\sqrt{T}} \sum_{n=0}^{N_s-1} \boldsymbol{S}_g^a \times exp(j2\pi n\alpha t/T). \quad (4)$$

After IFFT, a cyclic prefix CP , greater than the channel tap length is inserted to control inter-symbol interference (ISI). These transmission blocks are transmitted from A_t antennas simultaneously through a Rayleigh fading MIMO channel $\boldsymbol{H}_{b,a}$ ($b = 1, 2, \dots, A_r$). The signal received at the b^{th} antenna as $\boldsymbol{y}_b$,

$$y_b = \sum_{a=1}^{A_t} \boldsymbol{H}_{b,a}\text{diag}(\boldsymbol{x}_a) + \boldsymbol{w}_b \quad (5)$$

where $\boldsymbol{w}_b$ represents additive white Gaussian noise (AWGN) with zero mean and variance σ^2 . At the receiver, CP is removed and then FFT is applied. After that the block is separated into subblocks containing N subcarriers in each, and then joint maximum likelihood decoder is applied to detect active indices and corresponding constellation symbols with the aid of a pre-defined activation pattern known both at the transmitter and the receiver.

IV. Conclusion

This article has suggested MIMO-TM-SEFDM exploiting two differentiable constellation alphabets. This design can help to enhance SE by transmitting more bits via index information while enabling massive connectivity. It can also aid in improving BER performance because partial activation of non-orthogonal subcarriers reduces ICI and ISI.

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