Reduced Complexity Interleaved Multi-Carrier CDMA for Passive Optical Networks

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Abstract: A reduced complexity interleaved multi-carrier CDMA technique is proposed for passive optical networks (PONs). The proposed technique provides performance improvement compared to traditional O-OFDMA with less complexity than MC-CDMA.

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1. Introduction

Passive optical networks (PONs) are known as a promising solution for futuristic data networks. In recent years, multiple access techniques for the next-generation PONs is considered one of the hottest research areas [1]. Optical orthogonal frequency-division multiple-access (O-OFDMA) technique is one of the best candidates for future PONs as it provides high spectral efficiency, and simple transmitter and receiver design [2]. Multi-carrier code-division multiple-access (MC-CDMA) technique combines the benefits of OFDMA with the simplistic scheduling capability of CDMA. However, this comes at the cost of increasing the number of operations and hardware complexity [3].

In this paper, we propose a technique that is referred to as reduced-complexity interleaved multi-carrier CDMA (RC I-MC-CDMA). The proposed technique considers variable spreading code length and interleaved sub-bands instead of continuous spreading codes with length equal to the available codes used in conventional MC-CDMA. This allows for a variable complexity design. System level simulation shows that the overall computational complexity could be reduced by about 90% with an increased power of only 0.5 dBm.

2. RC I-MC-CDMA System Description

RC I-MC-CDMA assumes variable length Walsh orthogonal spreading codes and interleaved sub-band based on the required system performance and complexity. Frequency resources distribution is shown in Fig. 1. Sub-carriers are distributed into N interleaved sub-bands based on the used spreading code length. Each user is allocated a certain spreading code on a specific sub-band. Each group of the interleaved sub-carriers, for sub-band users, share each sub-band using spreading codes. The allocated sub-band for each user is rotated per frame to simplify channel allocation procedure by reducing the needed channel information.

The overall signal processing of proposed system is shown in Fig. 2. Data bits from each user are mapped to the corresponding QPSK symbols. Modulated QPSK Symbols for each sub-band are collected and spread using Walsh orthogonal codes. The resultant coded symbols are then mapped on interleaved sub-carriers. The sub-carriers are mapped to the O-OFDM transmitter which modulates the laser diode. Asymmetrically clipped optical OFDM (ACO-OFDMA) is selected for its simplicity and power efficiency. At the receiver, the reverse signal processing techniques are applied to retrieve the transmitted data bits.

The number of additionally required multiplications, N_M, and additions, N_A, for the RC I-MC-CDMA compared to that of traditional O-OFDMA for a given K sub-carriers, N sub-bands, $M = \frac{K}{N}$ code length, and K users can be computed as:

$$N_M = \left(\frac{K^2}{N}\right) \qquad \text{and} \qquad N_A = \left(\frac{K}{N} - 1\right) \times N \tag{1}$$

3. Performance Simulation Results

System level simulation was performed in order to validate the performance and complexity gain of RC I-MC-CDMA with QPSK modulation, and 512 FFT sub-carriers size. The LD is operating at a wavelength of 1550 nm.

Simulation results are shown in Fig. 3. The MC-CMDA outperforms ACO-OFDMA by around 4 dB but requires an additional 16384 multiplications. It is clear that the proposed RC I-MC-CDMA offers a variety of options at a different extra computational cost allowing for tunable system design. It is shown that for a code length of 64, the complexity

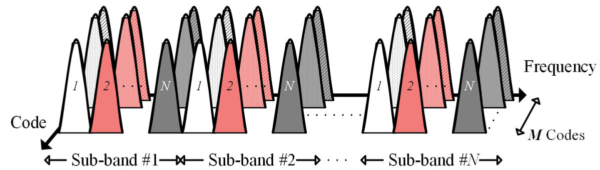


Fig. 1. RC I-MC-CDMA frequency resources distribution methodology.

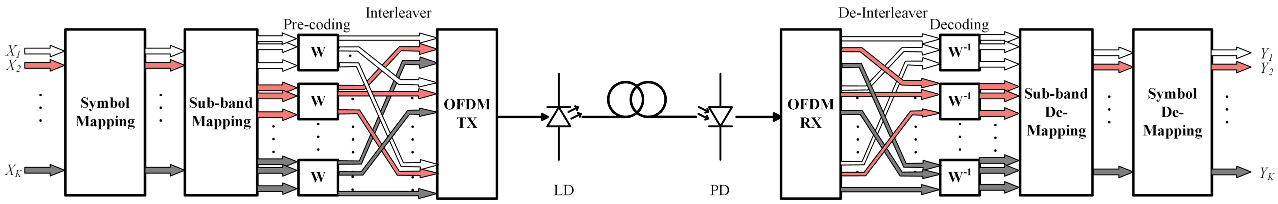
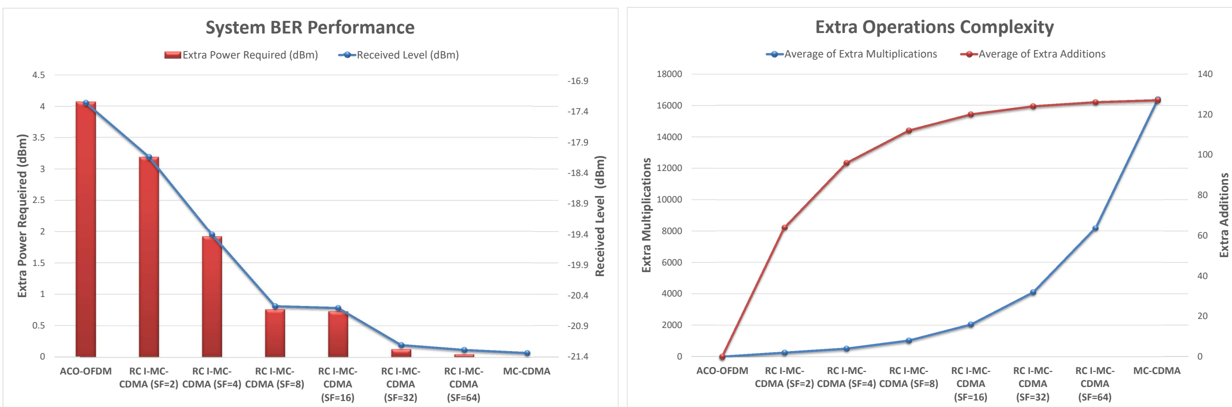


Fig. 2. User data processing flow diagram.

is reduced by 50% with power less than 0.1 dBm. Also, a code length of 16 provides around 90% reduced complexity at an additional power penalty of 0.5 dBm.



(a) Performance analysis of required power for RC I-MC-CDMA technique.

(b) Complexity analysis of the extra required multiplication and additions for RC I-MC-CDMA technique.

Fig. 3. System simulation results for RC I-MC-CDMA technique (with variable code lengths and spreading factors (SF)) in comparison to traditional O-OFDMA and MC-CDMA techniques.

4. Conclusion

The possibility of extending the RC I-MC-CDMA technique to PONs has been proposed. This allows for adjusting the overall system complexity and performance compared to traditional O-OFDMA and MC-CDMA techniques. Simulation results have shown that by using RC I-MC-CDMA technique with a code length of 16, the computational complexity can be reduced by 90% while increasing the launch power by just 0.5 dBm.

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