

Orthogonal Frequency Division Multiplexing (OFDM) in Optical Communications with Direct Detection for Metro Networks

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ABSTRACT

The paper addresses OFDM transmission over optical links with low and moderate cost optics which is mandatory in access and in metro applications. Here we address especially direct detection receivers using photo detectors without the need for local lasers at the transmitter side. Thus the transmission becomes nonlinear due to the magnitude squared envelope detection which requires attention when used in dispersive fibre links. We consider several solutions to overcome this problem and we optimize the transceiver design.

Keywords: optical communications, modulation, OFDM, direct detection

1. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is well known in classical digital communications. Optical communications, however, is currently accelerating its effort to implement sophisticated transmitter and receiver structures to increase data throughput. Consequently, investigation into optical OFDM nowadays is a very hot topic [1-4]. There are two strategies for transmitting the quasi-analogue OFDM signal. One solution is given by optical I-Q-modulation in conjunction with coherent detection (CO-OFDM) [2, 3]. A second method restricts to a real OFDM signal transmitted with intensity modulation and direct detection and is called optical DD-OFDM. While CO-OFDM shows higher performance in terms of bandwidth efficiency and receiver sensitivity, DD-OFDM provides the advantages of OFDM, like robustness towards fibre dispersion, with low effort. Hence, here we focus on the latter approach as we consider mainly shorter reach and cost efficient metropolitan area networks.

2. OFDM BASED ON DIRECT DETECTION

Fig. 1 depicts the system setup. The binary data stream (here at 43Gb/s) is parallelized and mapped into complex symbols. By means of the choice of symbol mapping (e.g. QPSK, QAM), bandwidth efficiency and sensitivity can be balanced. In this contribution we use QPSK mapping onto 512 subchannels.

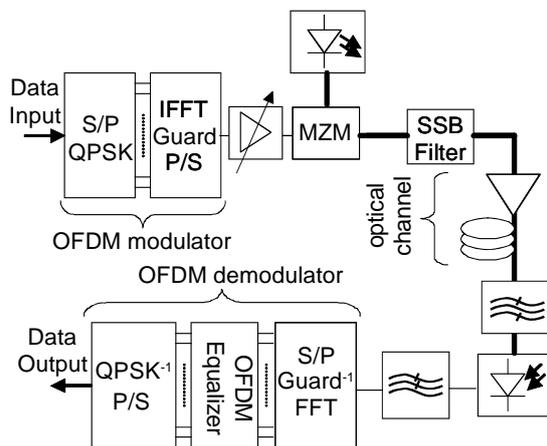


Fig. 1 OFDM set-up with direct detection

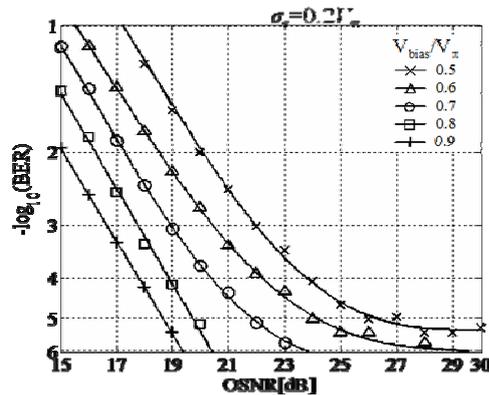


Fig.3. Experimental results BER over OSNR

The complex symbols are fed into an IFFT together with supplementary complex conjugate symbols in order to generate a real output signal. Moreover, half of the input of the IFFT around the DC value is filled with zeros to create an OFDM spectrum that avoids interference with second-order nonlinearity after squaring in the photo diode [1]. Alternatively, this signal can be constructed by means of a complex IFFT followed by electrical I-Q up-conversion. After serialization, the guard interval may be added resulting in the electrical quasi-analog signal to be transmitted over the optical channel. The signal is clipped appropriately and fed into an optical Mach-Zehnder modulator (MZM). After transmission, a photodiode (PD) converts the optical signal into the electrical

domain, where OFDM demodulation and frequency-domain equalization are performed. For back-to-back transmission, the channel is equal to the identical system. In this case, guard interval and equalizer are not required.

3. RESULTS

We investigate several design parameters for optimum receiver and transmitter design. At the receiver side we investigate the interplay between the strength of the DC component, which is required for direct detection, and the amplitude of the OFDM signal, which should be balanced between sufficient OSNR-performance and small nonlinear impact due to the modulator nonlinearity. Some results are shown in fig. 2, where the required OSNR over the required bandwidth is shown for b2b as well as for a 8x80km SSMF transmission. We conclude that bandwidth occupancy can be exchanged for OSNR tolerance – a very well known general principle in communications.

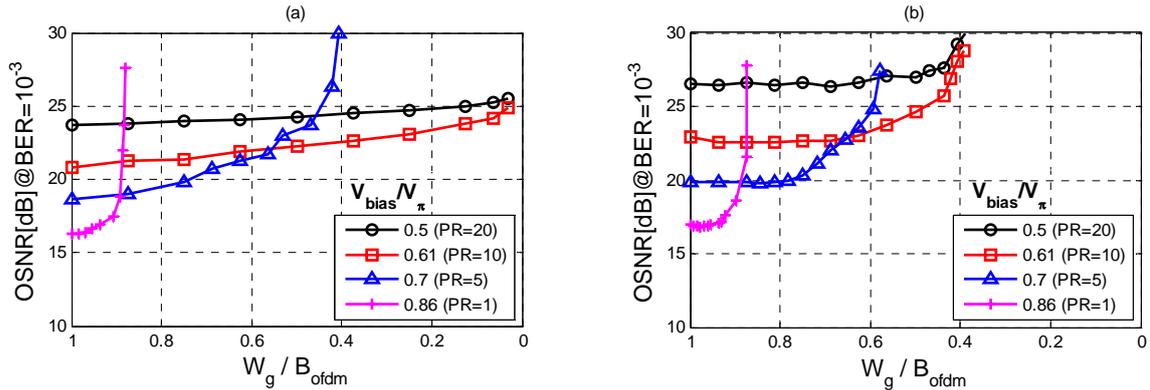


Fig.2. Required OSNR for BER=10⁻³ versus frequency gap for back-to-back (a) and 8x80km uncompensated spans link (b).

We also report on the requirements for D/A conversion at the transmitter side and the A/D conversion at the receiver. The results show, that about 5 bit accuracy at A/D and about 4 bit accuracy at D/A are required.

Finally we will report on some first experimental results, based on hardware equipment with off-line processing that confirm the simulations. We find that the experimental results are in reasonable agreement with simulations as is shown by one example given in fig 3.

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