Minimization of the Receiver Sensitivity of Cost Efficient Multilevel ASK Modulation Formats for Metro Networks by Filter Optimization

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Abstract: Receiver sensitivity of multilevel unipolar and bipolar ASK modulation formats is minimized by optimizing the filter bandwidth of optical and electrical filters. Comparisons attest bipolar ASK formats a superior sensitivity performance compared to unipolar ASK.

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1. Introduction

Multilevel modulation formats such as multilevel amplitude and phase shift keying (*m*ASK and *m*PSK) or combinations of both are promising candidates to meet the demand of increased line rates and bandwidth efficiency in today's optical communication systems [1-3]. Multilevel ASK formats have attracted attention, especially for metro networks, where cost efficiency is a critical issue and the requirements concerning the available optical signal-to-noise-ratio (OSNR) are not as strict as for long-haul transmission [1]. For attaining the optimum receiver sensitivity, the bandwidths of optical and electrical filters in the transmission system have to be optimized carefully. We perform this optimization, considering two optical filters which model the multiplexer and demultiplexer (MUX/DEMUX) in a WDM transmission system, and one electrical filter at the receiver electronics. As modulation formats 2-, 4-, and 8-ASK in their unipolar and bipolar (ASK-DPSK combination) forms are taken into account.

2. Multiplexer and Demultiplexer Optimization - System Setup

In a direct detection system, the optical and the electrical bandwidths cannot be regarded as independent from each other, since the system is nonlinear due to the absolute square operation performed by the photo diode. Filter dependent beat noise components are generated from the originally white Gaussian optical amplifier noise. Therefore, a joint filter investigation has to be carried out. The simulation setups are the same as in [4]. The optical signal is generated using a Mach-Zehnder modulator (MZM) with multilevel electrical driving signal. To save implementation cost, a directly modulated laser (DML) could be applied instead of the MZM. For bipolar ASK formats a phase modulator (PM) is added in series. The data rate R_b is set to 112 Gb/s. This leads to a symbol rate R_s of 1/2 R_b for 4-ary formats and 1/3-R_b for 8-ary formats. The modulation part of the transmitter is followed by an optical bandpass filter which emulates the MUX. An EDFA (erbium doped fiber amplifier) is used for noise loading and OSNR variation. After the EDFA another optical bandpass filter forms the DEMUX. For unipolar *m*ASK the detector is a simple photodiode followed by an electrical lowpass filter and a multilevel decision logic [5]. For bipolar formats the DBPSK and the *m*ASK parts are detected in two different branches, where the DBPSK part consists of a Mach-Zehnder delay interferometer followed by a balanced receiver. The ASK part uses either a simple photo diode (4-ASK bipolar) or a 4-ASK decision logic (8-ASK bipolar). The amplitude levels are chosen in a way to achieve maximum sensitivity, i.e. equal spacing in the optical domain [5, 6].

The two optical filters are assumed to have the same bandwidth. Moreover, for bipolar formats, the electrical filters, located in the ASK and the DBPSK branch, respectively, are identical. The optical bandpass filters are Gaussian filters of 3rd order and the electrical filters are Bessel filters of 5th order.

3. Results and Discussion

We determine the required OSNR for a bit error ratio (BER) of 10^{-3}. Figure 1 shows the simulation results for 2-, 4- and 8-ASK formats in unipolar and bipolar form with non-return-to-zero (NRZ) pulse shape. Note that, since all formats require different bandwidths, each plot uses different axis scaling. Optical and electrical bandwidths are dependent on each other; therefore the plot can help to choose an appropriate electrical filter for a fixed MUX/DEMUX configuration or vice versa.

Each increase of modulation level count leads to a sensitivity degradation of about 4-5 dB. However, bipolar formats offer a better performance than unipolar formats of about 3-6 dB. This gain rises with increased modulation levels count. E.g. 8-ASK bipolar offers a line rate reduced by factor 3 compared to 2-ASK by increasing the required OSNR by 5.7 dB to 23.7 dB which is well tolerable by a metro network [1].

The bandwidth requirements strongly depend on the modulation format. Unipolar formats prefer a broader electrical bandwidth (0.65-1.1 x the symbol rate) and small optical bandwidths (1.5-1.7 x symbol rate), while bipolar multilevel formats require broad optical bandwidths (2.3-4.2 x symbol rate) and small electrical ones (0.5-0.7 x symbol rate). The signal part which is detected by the ASK branch basically determines these requirements. Especially, since the lowest level of the ASK signal is not zero; it is more susceptible to ISI than the part which is detected by the DBPSK branch. Therefore, the results for DBPSK (2-ASK bipolar) show a different trend. An individual adjustment of the electrical filter of the DBPSK branch would slightly improve the total required OSNR.

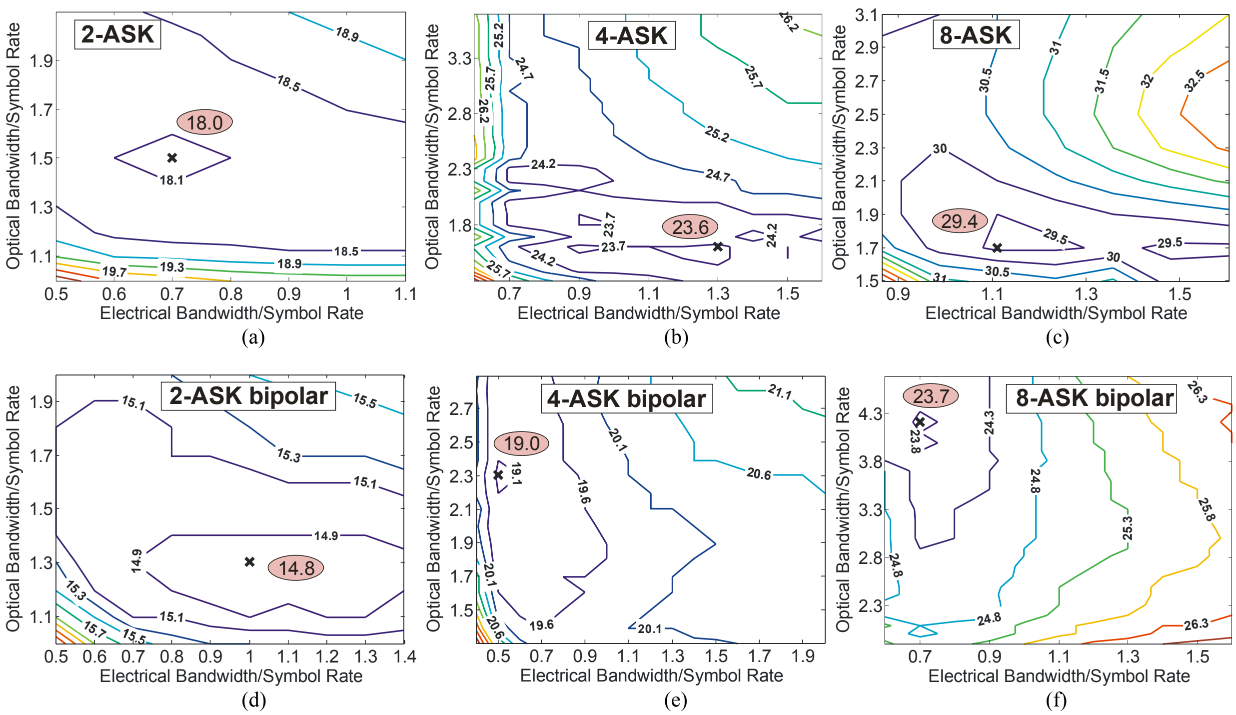

Fig. 1: Optimization of optical multiplexers, demultiplexers and electrical receiver bandwidth for WDM transmission. Required OSNR [dB] for BER 10^{-3} is displayed. Bandwidths are normalized to symbol rate R_s. Symbol rate $R_s=R_b$ for 2-ASK formats, $R_s=R_b/2$ for 4-ASK formats and $R_s=R_b/3$ for 8-ASK formats. (a) 2-ASK unipolar, (b) 4-ASK unipolar, (c) 8-ASK unipolar, (d) 2-ASK bipolar (=DBPSK), (e) 4-ASK bipolar, (f) 8-ASK bipolar.

4. Conclusion

We optimized the filter bandwidth for unipolar and bipolar multilevel ASK modulation formats for the use in cost efficient metro networks at 112 Gb/s with WDM transmission. The attainable receiver sensitivity for bipolar formats is notably better than for unipolar formats, but comes at the expense of increased complexity including an additional phase modulator, a balanced receiver and a Mach-Zehnder delay interferometer.

6. References

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