ENEE 785 Project

Receiver modeling

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1 Purpose of project

In this project you will compare three receiver models and use the receiver models to compute the optimal bandwidths of the optical and electrical filters in the receiver for a back-to-back dense WDM system with various modulation formats.

2 Details

2.1 The three receiver models

You will use the following three receiver models to estimate the bit-error rate BER for a back-to-back dense WDM signal with white Gaussian optical noise added prior to the receiver. Propagation effects and electrical noise are not to be considered in the models. In all cases, the receiver will consist of an optical filter, a square-law photodetector, and an electrical filter. The optical filter is used to both demux a channel and to filter out noise outside the bandwidth of that channel.

In all cases, you estimate the BER from the probability density functions (PDFs) of the marks and spaces of the received electrical current. The decision threshold should be chosen to minimize the BER.

- *Monte Carlo simulation with Gaussian extrapolation.* In this method you use Monte Carlo simulations to build histograms of the PDFs of the marks and spaces. The noise will be added to the noise-free signal using an optical amplifier from the `OptAmplifier` class. A good way to compute the PDFs is to use the class `Histogram2D` to build a 2D PDF of the eye diagram which can be post-processed in Matlab using Matlab functions written by Ron Holzlöhner and John Zweck. Because BERs are so small you will need to extrapolate the tails of the PDFs using a Gaussian as explained in the paper of Bergano [1]. Note that you fit a Gaussian to the low-probability tails of the PDFs not to the high-probability center of the PDFs.

- *Winzer's method [2] for computing the mean and variance of the PDFs of the marks and spaces.* The inputs to this receiver model are the noise-free signal, the shapes of the receiver filters and the noise spectral density. In this case, the PDFs are assumed to be Gaussian and hence are determined by the means and standard deviations of the currents in the marks and spaces. Winzer's method computes these means and standard deviations taking into account the actual shapes of the pulses and of the filters in the recievers. Winzer's method [2] has been coded up in OCS and extended in several directions by Ivan Lima [3]. Once again use Matlab to get the BER from the means and std deviations of the marks and spaces.

- *The generalized χ^2 model of Marcuse [4] and Humblet and Azizoglu [5].* The inputs to this receiver model are the noise-free signal, the shapes of the receiver filters and the noise spectral density. The outputs are the actual PDFs of the marks and spaces, which are generalized χ^2 distributions, from which we may compute the BER. This method has been coded up in Matlab by Ronald Holzöhner and will be made available to you. Details are explained in Ron's thesis [6] (available at `http://www.photonics.umbc.edu/internal/Theses_and_Papers/currentpapers.html`).

Your first task is to understand these three models from a theoretical and coding point of view. In particular we would like you to explain how the experimental method of Bergano could be implemented in simulations and to present a derivation of the generalized χ^2 model.

2.2 The modulation format

You should compare the three receivers for the NRZ, RZ, and CRZ modulation formats already coded up in the `OptSignal` class. In you like you can also add another ASK format such as CSRZ [7, 8] to `OptSignal` and do the comparison for that format too.

You should use 3 channels with channel spacings of both 50 GHz and 25 GHz and you should compute the BER for the center channel. Choose an OSNR of about 15 dB and an optical extinction ratio of 20 dB.

2.3 The receiver

You should use a fifth-order electrical Bessel filter in the receiver. Rather than simply using a Gaussian optical filter we would like you to add either a Fabry-Perot or fiber Bragg grating (FBG) or an AWG optical filter to the `OptFilter` class and use that filter in your comparison of the receiver models. Simple models of the Fabry Perot and FBG filters can be found in Winzer's paper [2].

2.4 Results

Your results should take the form of plots of the PDFs of the marks and spaces and tables of the correpsonding BERs for different choices of the parameters in the model. You should comment on how closely the three models agree. Try to find parameter regimes in which they agree well and regimes in which they do not agree well [4].

3 Optimal filter bandwidths

For this part of the project, choose a receiver model and make a contour plot of the BER versus the bandwidths of the optical and electrical filters as in Winzer [2]. Use the same DWDM signals you used in the previous section. Find the optimal bandwidths and give physical explanations for your results.

References

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[6] R.. Holzlöhner, *A covaraince matrix mnethod for the computation of bit errors in optical transmission systems*, Ph.D. thesis, University of Maryland Baltimore County, April 2003.

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