Project 2: Chromatic Dispersion Compensation Using Complex-Valued All-Pass filters

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1 Idea and Motivation

The Chromatic Dispersion (CD) in optical channels has an all-pass behavior, i.e only the phase of a signal is changed due to CD. Using IIR or FIR filters CD can be compensated. In this project you will get familiar with the idea of CD compensation, especially with complex valued IIR filters and design a compensation filter.

2 Task: Prepartion excercises

Read through the provided paper and answer the following questions

Discretization Using the provided continuous CD channel model

$$H_{CD}(\Omega) = \exp\left(-j\frac{\lambda_0^2}{4\pi c}DL\Omega^2\right)$$

derive the channel model $H(\omega)$ for the sampled signal (sampling rate B).

Ideal Equalizer Derive the frequency domain response of the ideal equalizer for such a channel.

Frequency Sampling Consider the following values

- B =56 GHz
- λ_0 =1550nm
- D=16 ps/nm/km
- L = 23km

and calculate the channel response $h_{CD}[n]$ for the first n=256 sampling points.

Number of taps Consider the channel response $h_{CD}[n]$. How many tabs are needed for equalization with an FIR filter. Justify your answer.

Group Delay Derive the expression for the total group delay

$$\tau_{\mathrm{IIR}}(\omega) = \sum_{i=1}^{N_{\mathrm{IIR}}} \frac{1-\rho_i^2}{1+\rho_i^2-2\rho_i\cos(\omega-\theta_i)}$$

by applying

$$\tau_{\mathrm{IIR}}(\omega) = -\frac{\partial}{\partial\omega}\phi_{\mathrm{IIR}}(\omega)$$

Group Delay extrema Consider the case $N_{\text{IIR}} = 1$. Derive the maximum and minimum value of τ_{IIR} as a function of ρ. What does this imply for ρ?

Integer factor Derive $\beta = \lceil 2\alpha\pi \rceil$

Desired phase response Derive the expression for the desired phase response.

3 Practical Examples

Abel-Smith-Algorithm Write a matlab function which implements the Abel-Smith Algorithm for the following parameters.

- B =56 GHz
- λ_0 =1550nm
- D=16 ps/nm/km
- $L = 23$km

For the division of the area under the group delay curve use the *abel_smith_divide(alpha,N_IIR)* prototype. For the calculation of parameters use the *abel_smith(alpha,N_IIR)* prototype.

Bit Error Rate Using the provided script *main_program()*, implement a CD channel, CD equalization and calculate the bit error Rate curve.
Hints

- ϕ_0, ρ_i, θ_i are provided and loaded in the main function
- Implement the channel in the function *h_tot=impulse_response_channel(alpha,freq_pts)*
- Implement the equalization in the function *output=conv_anyinput_allpass_eqaulaizer(rho,theta,phi,input)*
- For filtering use Matlabs *filter* function
- For the bit-error rate a function *bit_error_rate(h_tot,index,rho,thet,phi)* is provided

Lab Report Write a report in which you make use of the previous tasks. The report should contain theoretical insight into the problem which you got by the preparation questions, as well as the practical aspects you learned by the pracitcal examples. You may put derivations, etc. into the appendix but you should answer all questions of the previous tasks in the report.