Photonic Systems and Technologies – Lab 5
Receivers and BER

Topics covered
- Optical detectors, and their noise characteristics

Laboratory simulations

1) Open the setup **Rx1_01**. In this simulation we will show the relationship between the photocurrent generated from PIN or APD photodiode and input optical power. The optical input light of PIN and APD photodiode is generated from a CW laser. The power of the received light is measured by a power meter. The photocurrent generated by PIN photodetector or APD is averaged by ***PowerMeterEI***. The averaged photocurrent generated from PIN photodetector and APD versus input power of the photodetector is visualized through ***NumericalAnlyzer (2D)***. The sweep varies the input optical power of the photodetector by controlling the attenuator value.

Question 1: Run the sweep of the simulation. Measure the responsivity of the PIN and APD photodiodes, and compare with the corresponding parameter values (inside the module). Is the measured value the same as the parameter value? In case they are different, explain why.

2) Open the setup **Rx1_02**. This example shows the impulse response of PIN photodetector and APD. The optical input with delta function distribution from module ***FuncImpulseOpt*** is injected into both PIN photodetector and APD. The outputs of the two photodetectors are visualized by ***SignalAnalyzer*** in *RFSA* mode, which show the impulse responses of the PIN photodetector and APD.

Question 2: Measure the 3 dB bandwidth of PIN and APD photodiode, and compare with their corresponding parameter value ***Bandwidth_BE***.

3) Open the setup **Rx1_03**. It shows how the bit error rate (BER) of the received signal is affected by the response bandwidth of the detector. After the 10 Gbit/s return to zero (RZ) optical signal is generated from an externally modulated laser ***TxExtModLaser***, it propagates through 50 km single-mode fiber and is detected by a PIN photodiode. The BER of the received signal is measured by clock recovery circuit ***ClockRecoveryIdeal*** and BER measurement module ***BER_OOK_Stoch***. The sweep varies the 3 dB cutoff frequency ***Bandwidth_BE*** of the PIN photodiode. The bit error rate of the received signal versus the 3 dB cutoff frequency of PIN photodiode is visualized by the ***NumericalAnlayzer2D***.

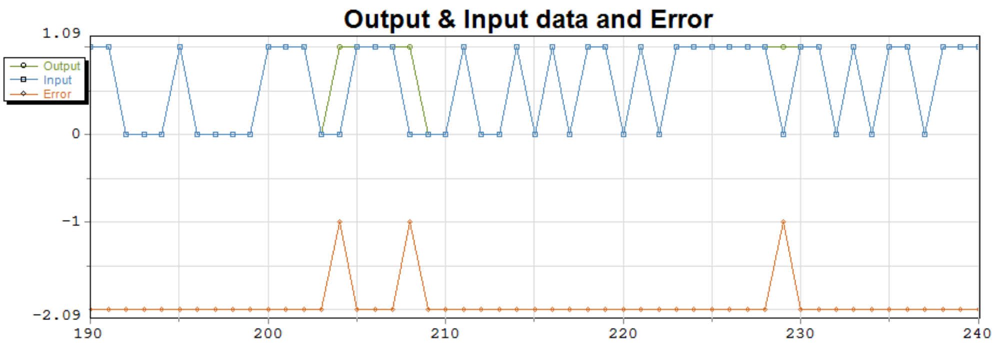
Question 3. Run the sweep. Measure the minimum 3 dB cutoff frequency of PIN photodiode for which the bit error rate of received signal is less than 10e-9.

4) Open the setup **TAM2_01** which simulates how BER is measured in a real experiment using a BER test set. The setup works by counting the number of error bits and received bits. The ratio of the number of error bits to the total number of bits received is the BER. The output of a PRBS generator is split into two, with one portion transmitted through a "system under test". The other portion is connected directly to an error detector. The error detector compares the received bits (those that have been transmitted through the system under test) with the ones directly from the PRBS

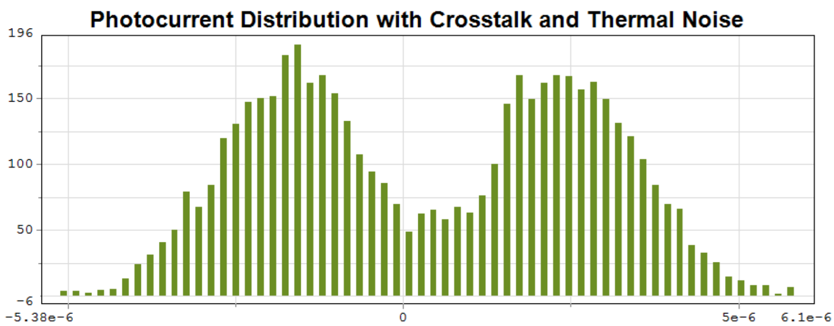
generator. The comparison is done by a logic circuit (an Exclusive OR or XOR gate), and a mismatch indicates that a bit has been received incorrectly (an error bit).

The system under test is a typical amplified optical transmission link. The transmitter in the setup is an externally-modulated semiconductor laser, where ***ModulatorMZ*** is the modulator and ***LaserCW*** is the semiconductor laser. The optical channel comprises an optical fiber ***FiberNLS***, an optical amplifier ***AmpSysOpt*** and an optical filter ***FilterOpt***. The attenuator is used to reduce the performance of the system so that actual errors can be counted in the period it takes the simulation to complete. The receiver consists of a PIN diode ***Photodiode***, an electrical filter ***FilterEl*** (low pass), a ***DCBlock*** and a clock recovery circuit ***ClockRecoveryIdeal***. The error detector consists of a quantifier ***Quant*** and a logic circuit ***Logic***. The number of error bits and received bits are counted here, and from this information, BER is calculated.

Run the simulation. The ***NumericalAnalyzer2D*** (below) shows the input bit stream and the output bit stream. Any error bits that are detected are also displayed, but these are offset (y axis) from the input and output bit streams so that they be clearly discerned.



The figure below shows the amplitude histogram of the received signal. The received signal is quantized into voltage bins (horizontal axis), while the vertical axis shows the % of samples that fall into the respective voltage bin. The histogram shows two distinct peaks, corresponding to the distribution of '0's and '1's. If the distributions can be modelled as a Gaussian distribution, the BER and Q can be calculated easily. Note that 10 different bit patterns (iteration) are computed.



Question 5: Re-run the simulations, changing the attenuation (in the attenuator of the optical channel) from 19 to 23 dB in 1 dB step. Compare the results and comment on the effect of varying the attenuation on the distribution of '0s' and '1s' in the histogram and BER.

Question 6: Repeat the simulation for an attenuation of 24 dB, but vary the bandwidth of the electrical filter after the receiver instead (1, 0.75, 0.5, 0.25 of ***SymbolRate***). Describe the influence of the filter bandwidth on BER and on the distribution of '0s' and '1s', and possible reasons of this influence.