Mitigation of the Impact of Receiver Imperfections in DPSK Systems Using Electronic Equalization

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Motivation

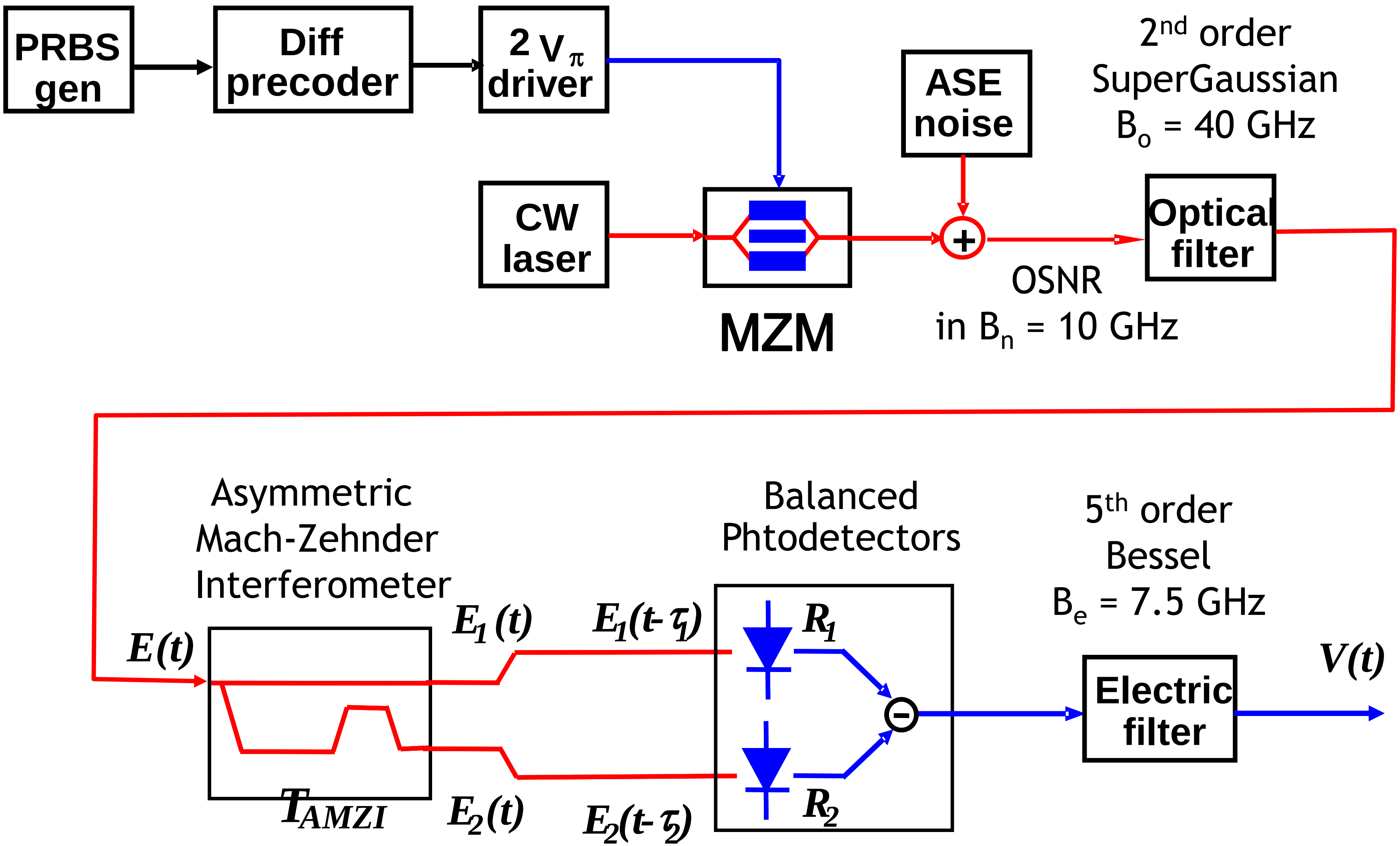
- DPSK is one of the most promising modulation formats
  - Advantages in terms of sensitivity: 3 dB on OSNR
  - Larger dispersion robustness
  - Higher tolerance to fiber nonlinerarities
  - Possibility to upgrade to multilevel (DQPSK)
- Advantages are paid in terms of technology overhead
- More sensitive to transmitter and receiver imperfections
  - Winzer *et al*, IEEE PTL, Sep 2003
  - Bosco *et al*, PTL, Feb 2005
  - Lize et al, paper Mo3.2.5, ECOC 2006
- **Need for countermeasures**

Outline

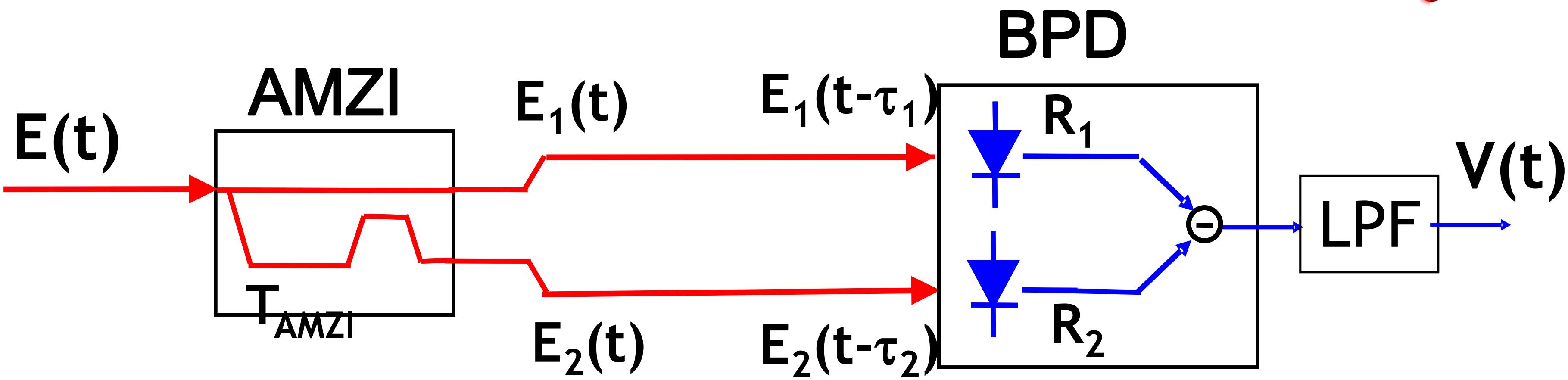
- DPSK modulation: considered setup structure
- Receiver imperfections: 4 analyzed parameters
- The considered electronic equalizer
- Simulative analyis
  - Propagation
  - Equalizer optimization
  - Performance estimate
- Results
- Conclusions

DPSK setup

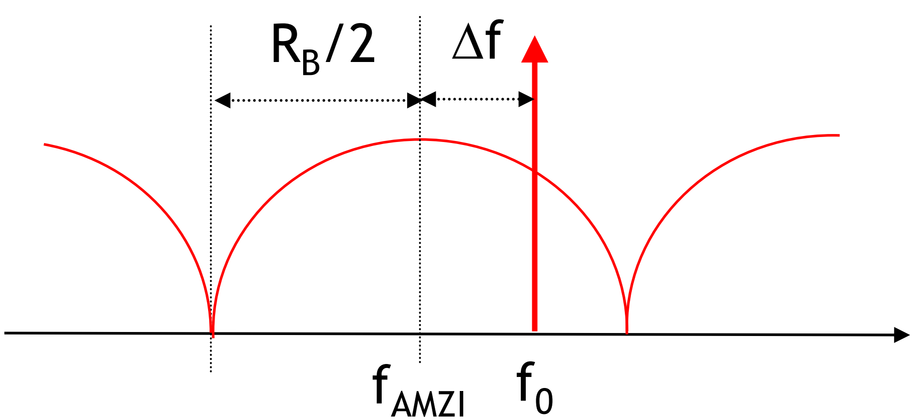
R_B = 10 Gbps



DPSK receiver imperfections: $\Delta f/R_B$

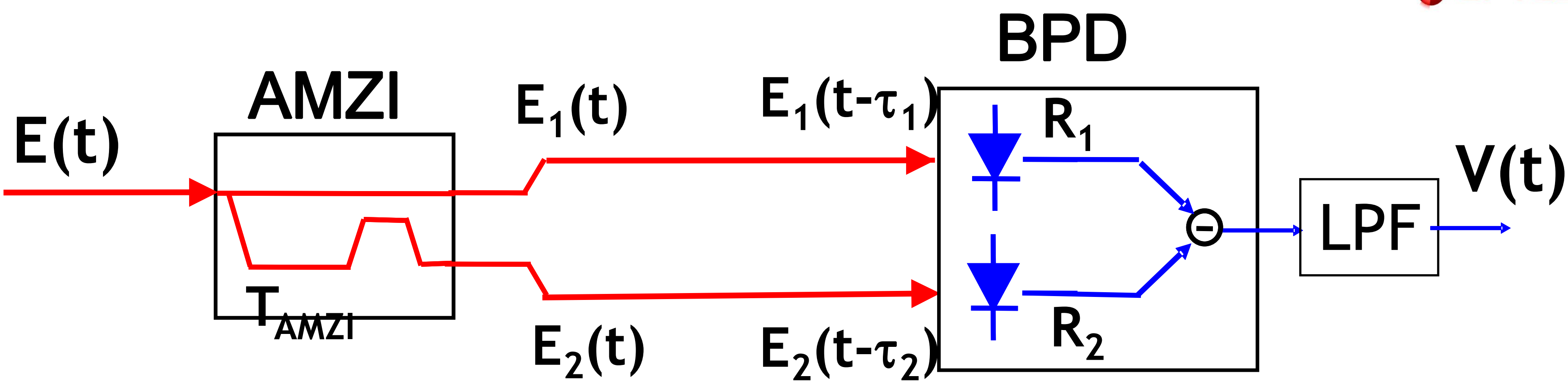


- **Laser center frequency offset percentage**
  - Center frequency of interferometer is not aligned to laser frequency



$$\frac{\Delta f}{R_B} = \frac{f_0 - f_{AMZI}}{R_B} \cdot 100$$

DPSK receiver imperfections: $\delta\tau$

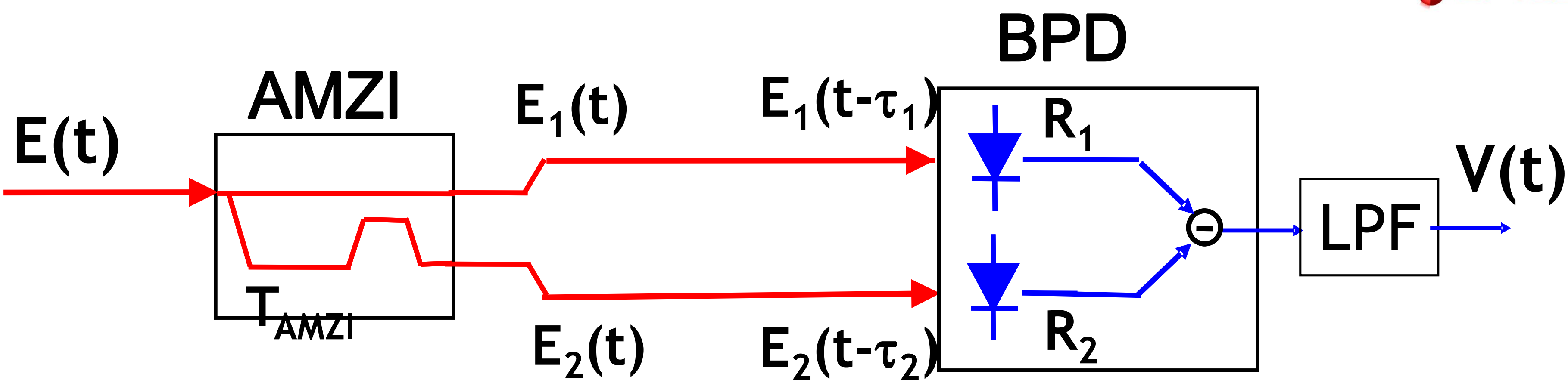


Mismatch AMZI delay

- The delay of the longer arm is not exactly equal to the bit duration T_B
- Problems in component production or enviromental/age drift
- Expressed as percentage of bit duration T_B

$$\delta\tau = \frac{T_{AMZI} - T_B}{T_B} \cdot 100$$

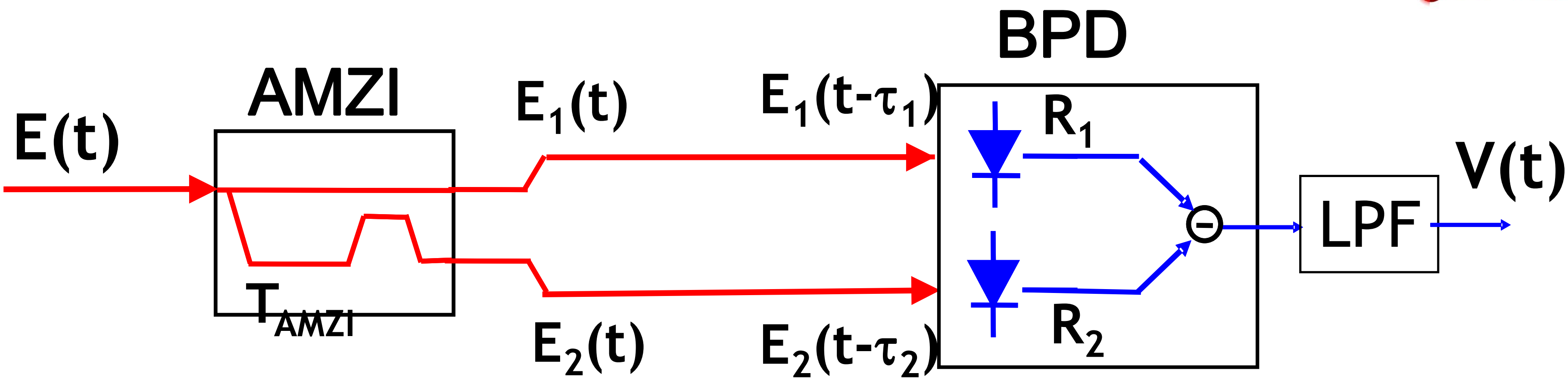
DPSK receiver imperfections: β



- **Detector amplitude imbalance**
  - The two overall responses of photodetectors are not identical
  - Responsivity of first PD_1 is differerent than R of PD_2
  - Insertion loss of fiber arm 1 is diferent than insertion of arm 2

$$\beta = \frac{R_1 - R_2}{R_1 + R_2}$$

DPSK receiver imperfections: $\delta\Phi$

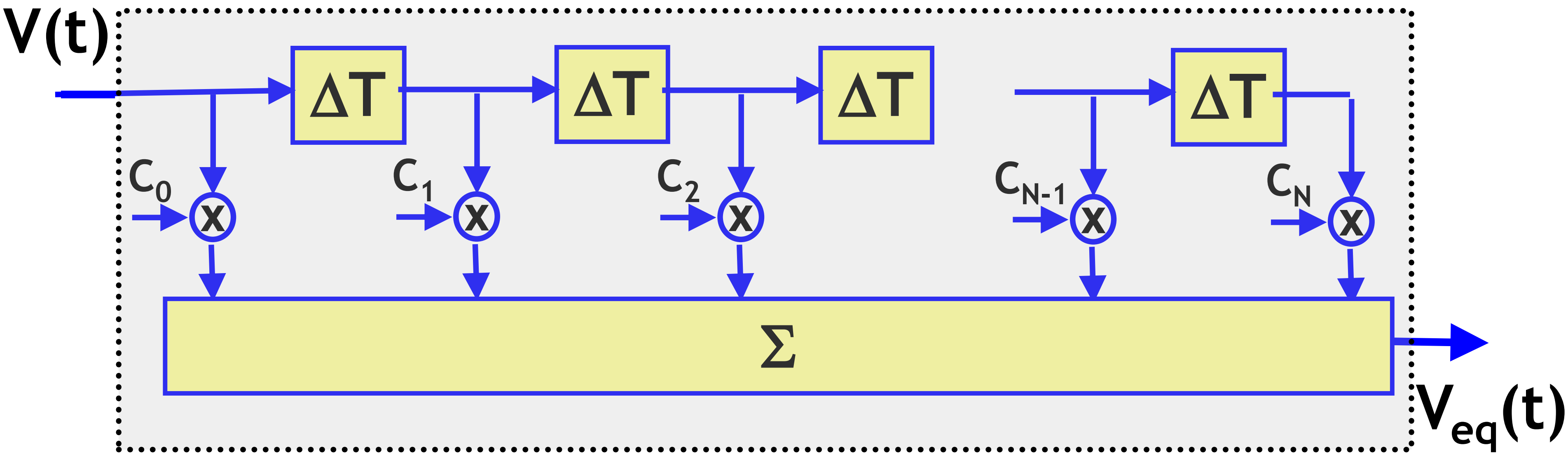


- **Detector phase imbalance**

$$\delta\phi = (\tau_1 - \tau_2) \cdot R_B \cdot 100$$

  - The two overall delays are not identical
  - Optical delay between AMZI output an BPD input
  - Electrical delay between BPD output and sum input
  - Expressed as percentage of bit duration

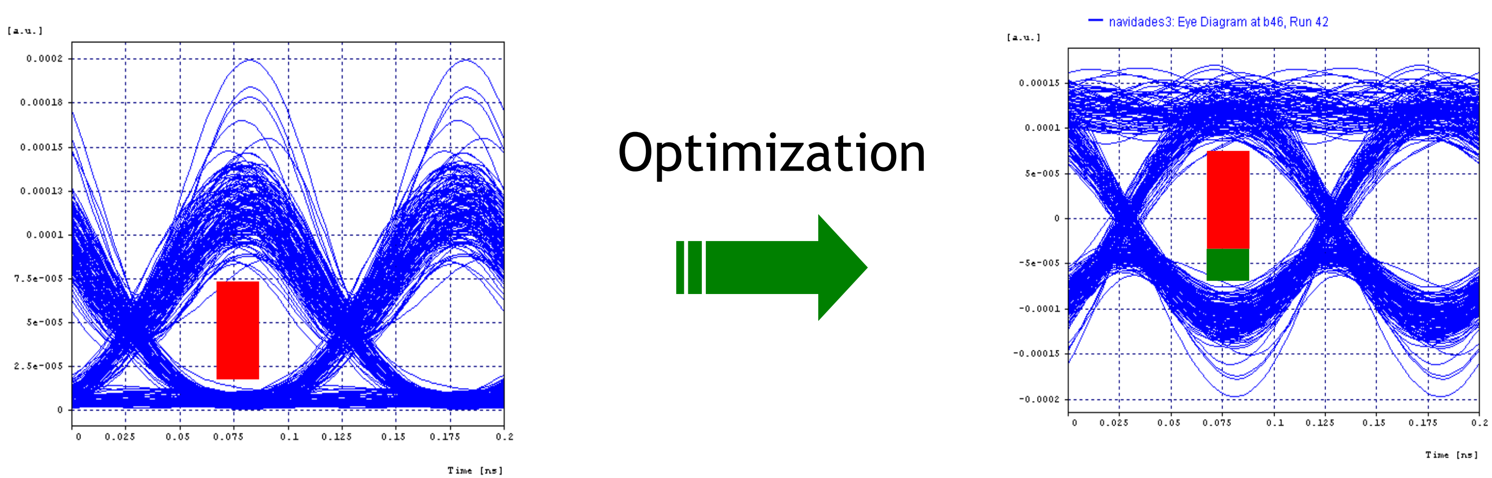
FIR filter ⟷ FFE equalizer



$$H(f) = \sum_{i=0}^{N} C_i e^{-j2\pi f \cdot i\Delta T}$$

The analysis: method

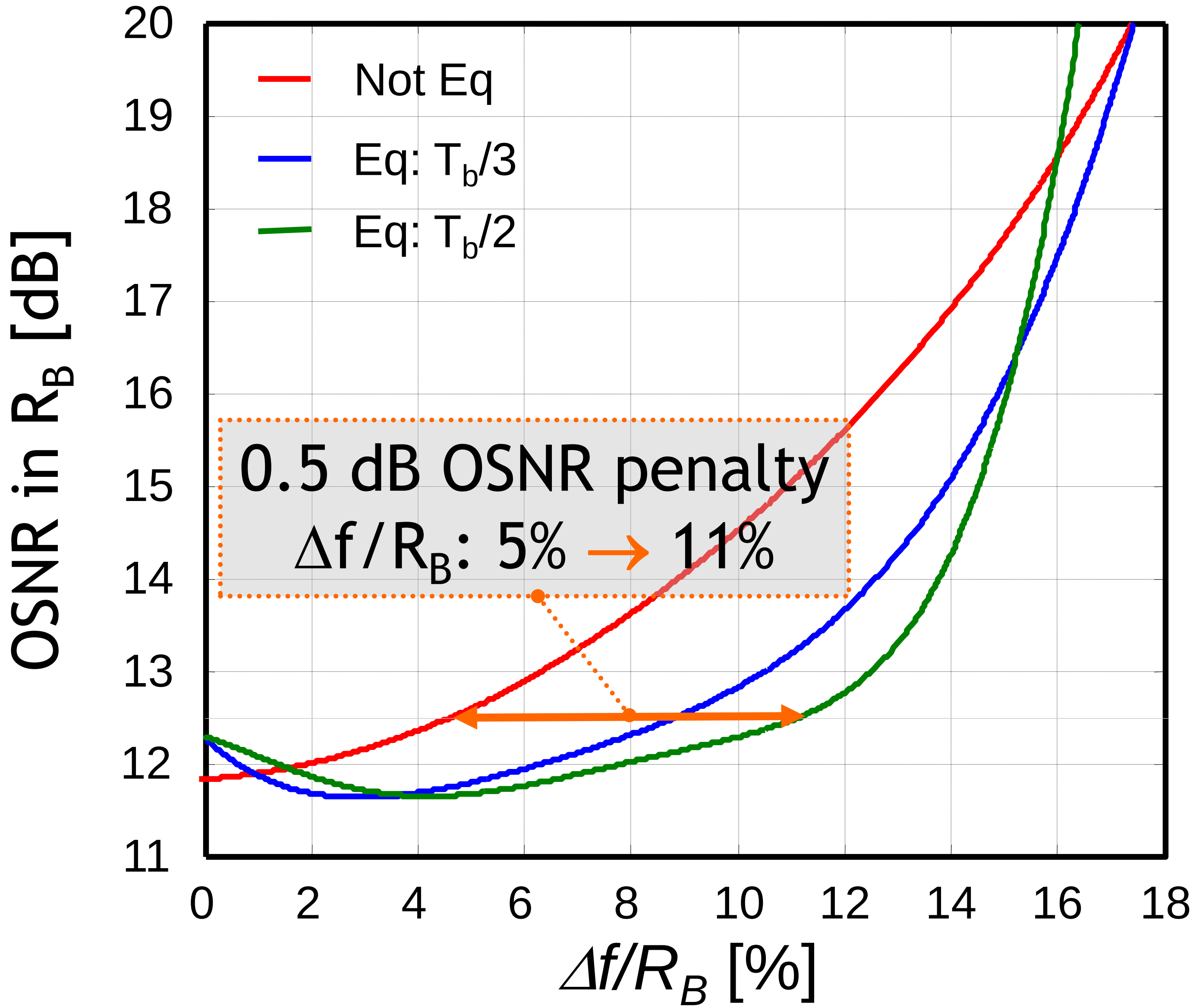
- We simulated the system setup using OptSim™
- We varied the receiver imperfection within a reasonable range
- For each value we optimized the filter coefficients
- Optimization was done in order to maximize a rectangular eye-opening mask



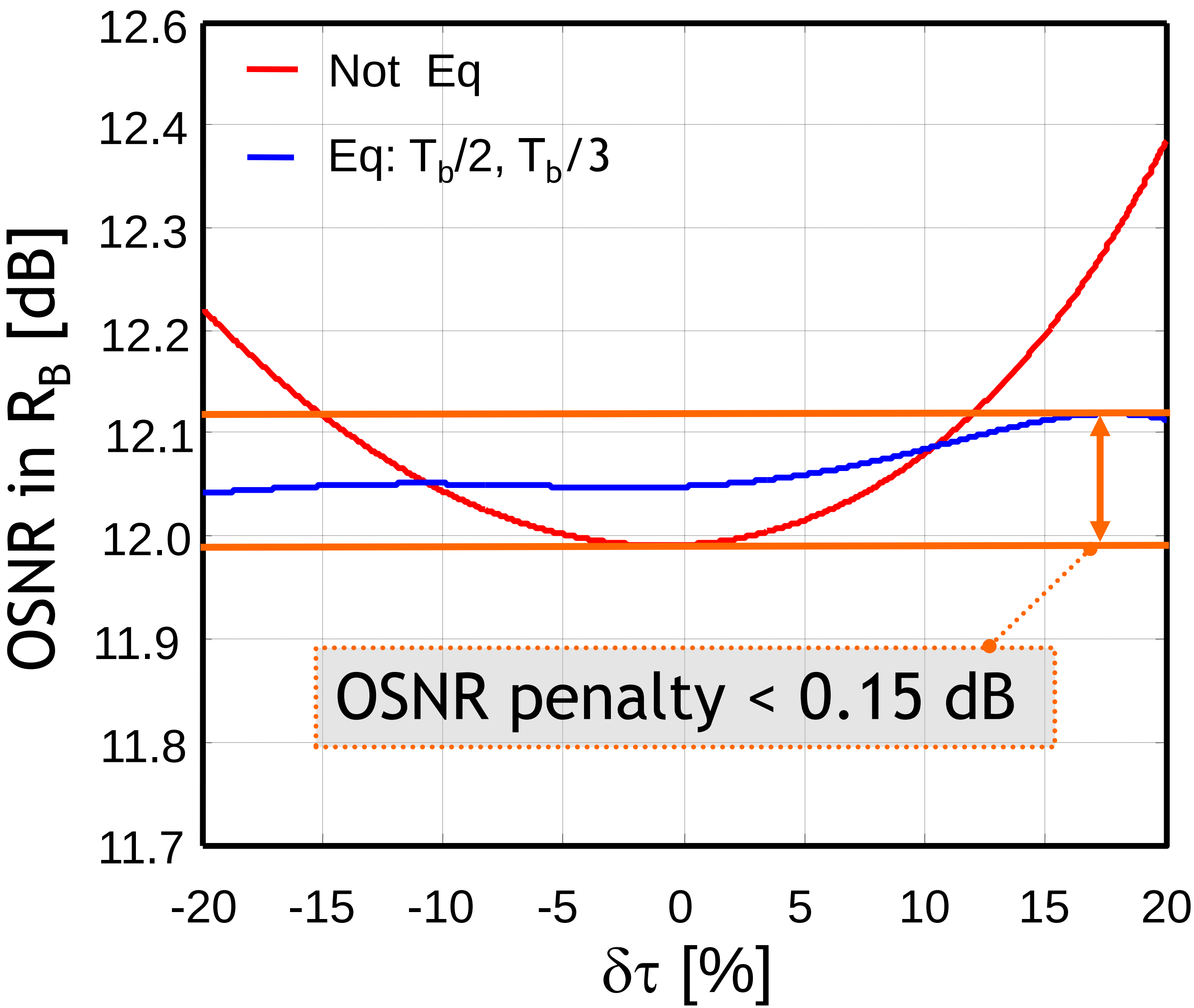
The analysis: results

- We applied the optimized filter
- OSNR (measured in B_n = 10 GHz) was varied in order to obtain target BER = 10^{-12} (No FEC)
- We evaluated the BER with and without EE using a semi-analytical technique based on Karhunen-Loève (KL) series expansion
- For each value of imperfection parameter: OSNR required for BER = 10^{-12}
- We varied the number of taps, best trade-off: N_{tap}=15
- We considered $\Delta T = T_b/2$ and $\Delta T = T_b/3$

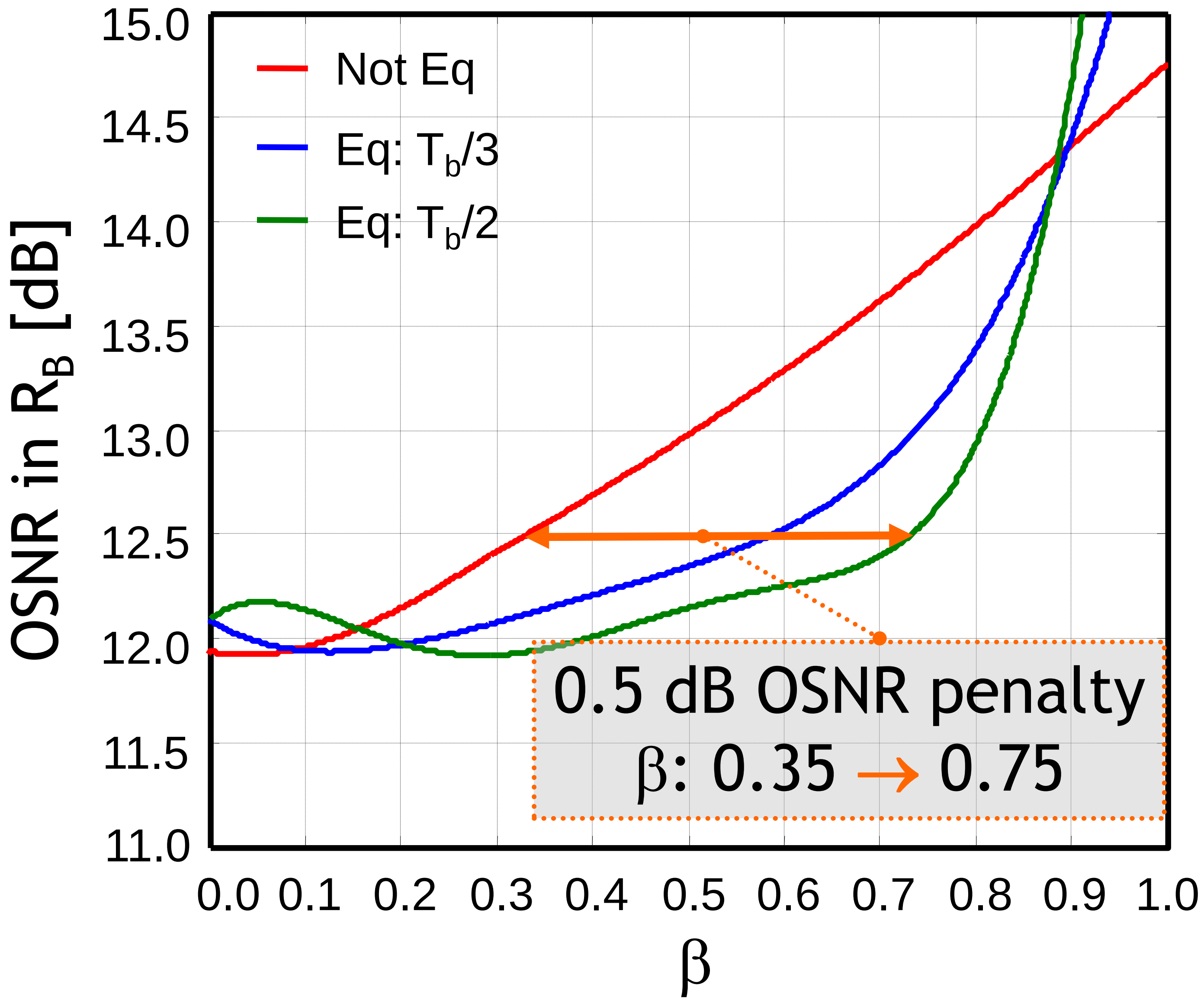
OSNR laser center frequency offset percentage



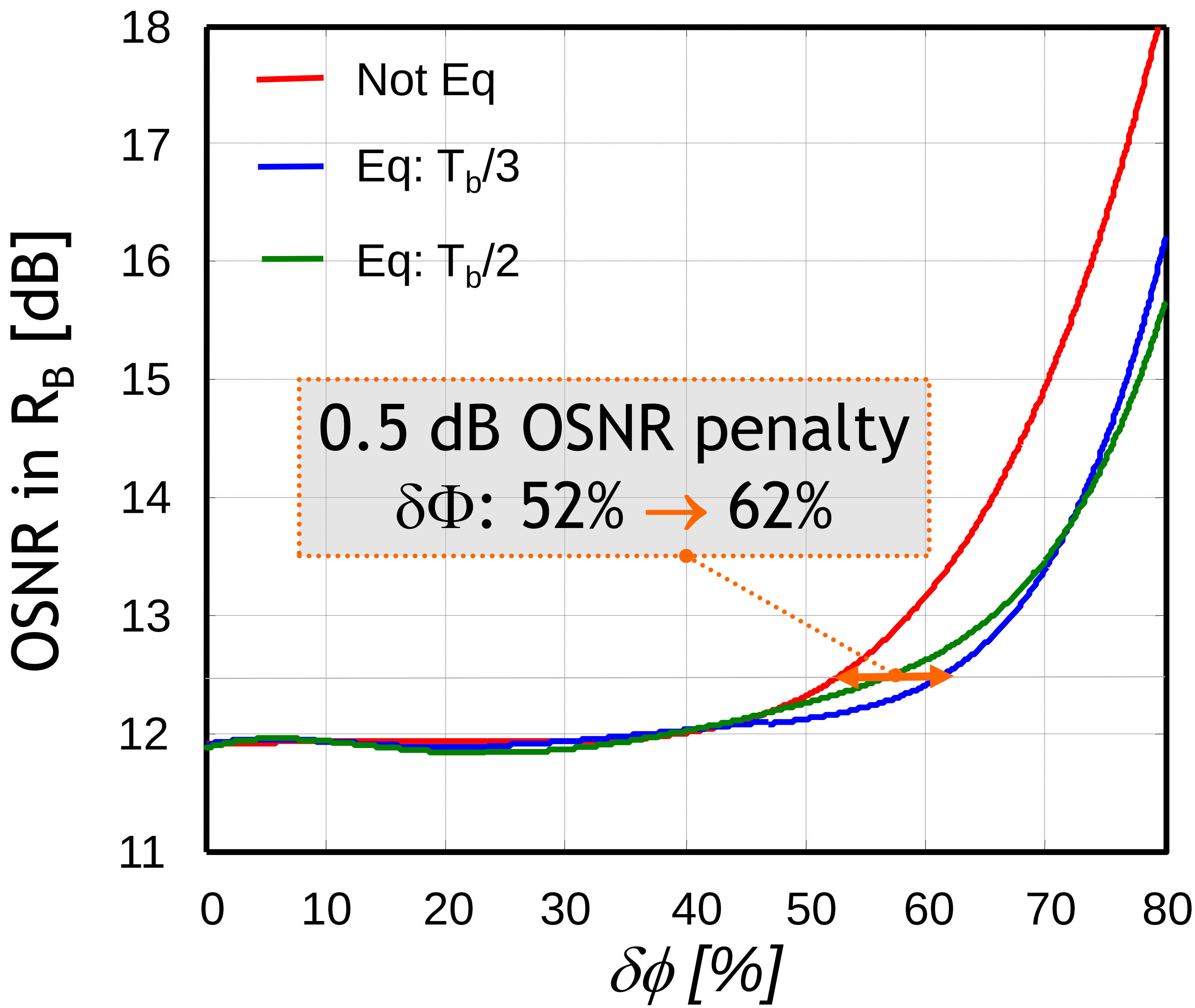
OSNR vs. mismatch in the interferometer delay



OSNR vs. detector amplitude imbalance β



OSNR detector phase imbalance



Conclusions

- Tolerances to DPSK receiver imperfections can be effectively improved using FFE electronic equalization
- In particular, good efficiency for
  - BPD unbalancing
  - AMZI center frequency offset
- Best tradeoff efficiency-complexity: $N_{taps} = 15$ and $\Delta T = T_B/2$
- Further investigations: FFE efficiency on degradation due to combined effects of propagation and RX imperfections

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- For any further questions, please, contact the authors by e-mail to curri@polito.it