# Some useful formulas

- Fourier series: $$s(t) = C_0 + \sum_{n=1}^{\infty} C_n \cdot \sin(2\pi nft + \varphi_n)$$

- Sampling frequency $f_s$ for a signal of maximum frequency $f_{max}$:

$$f_s \geq 2 f_{\max}$$

# Multilevel modulation

- Relation between levels L of a digital modulation and number of bits n used

$$L = 2^n \ , \ \mathrm{n} = \log_2 L$$

- Relation between bit rate (R) and symbol rate (S) for a multi-level signal (modulated or baseband)

**Bit rate = symbol rate * no. of bits per symbol**

$$\boldsymbol{R = S \cdot n}$$

$$\boldsymbol{or}$$

$$\boldsymbol{R = S \cdot log_2 L}$$

# Some useful formulas

- Bit rate for a **baseband** multi-level modulation, where B is the bandwidth

$$\boldsymbol{R = 2 \cdot B \cdot n} \quad \boldsymbol{or} \quad \boldsymbol{R = 2 \cdot B \cdot log_2 L}$$

- Bandwidth of **modulated** M-ASK, M-PSK, M-QAM, where L is the number of levels and d accounts for non-ideal conditions

$$B = (1+d) \cdot S \ , \mathrm{B} = (1+d) \cdot \frac{R}{\log_2 L} \cdot$$

# Some useful formulas

- Bandwidth of **modulated** M-FSK, where L is the number of Levels and d accounts for non-ideal conditions

$$B = S \cdot (L + d)$$

# dBm and dBs

- Decibel calculation for power gain

$$G_{dB} = 10log_{10}\left(\frac{P_{out}}{P_{in}}\right)$$

Negative gain = loss!

- Decibel calculation for launch power (dBm)

$$P_{dBm} = 10log_{10}\left(\frac{P}{1mW}\right) = 10log_{10}\left(\frac{P}{0.001W}\right)$$

# Link design

Received power for non-amplified links:

$$\boldsymbol{P_{Rx} = P_{Tx} - Loss - Margin}$$ calcualated in dBm & dBs

Loss= l $_{[km]}$ x $\alpha_{[dB/km]}$

$\boldsymbol{P_{Rx} >= P_{Rx\_min}}$ Receiver sensitivity constraint

Received power for amplified links:

$$\boldsymbol{P_{Rx} = P_{Tx} - Loss + G - Margin}$$

OSNR in amplified systems:

$$\boldsymbol{OSNR_{Rx} = P_{Tx} - \alpha \cdot L - NF + 58 - M}$$

$\boldsymbol{OSNR_{Rx} >= OSNR_{Requr.}}$ OSNR constraint

$$dB = dBm - \frac{dB}{km} \cdot km - dB + dB - dB$$

For chain of amplifiers $\boldsymbol{NF = NF_{chain} = NF_{amp} + 10logN}$

# Capacity of a noisy channel

**Capacity = bandwidth x $\log_2(1 + SNR)$**

Where capacity is measured in bit/s, the bandwidth in Hz, and the SNR is a linear value (i.e. not in dB)