Messages and signals

Information (message) to be transmitted (issued by a source):

- analog: e.g. speech, music, pictures -> infinite number of values
- digital (discrete): e.g. text -> finite number of values

Signals carrying this information:

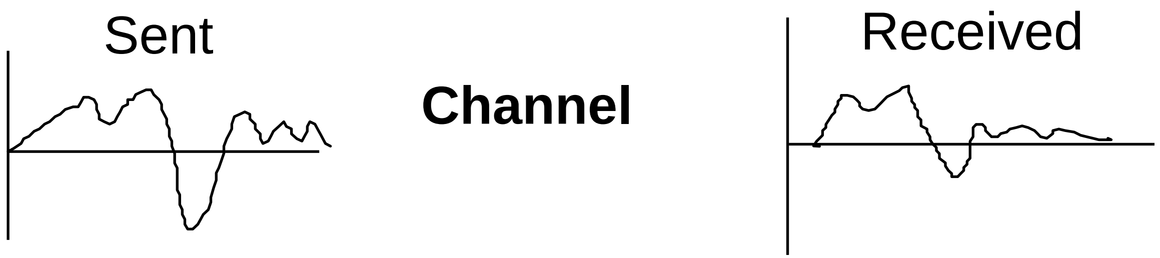
- analog signals: represent an analog message
- digital (discrete) signals: represent digital but also an analog source (Analog to Digital conversion)

Telecommunication systems:

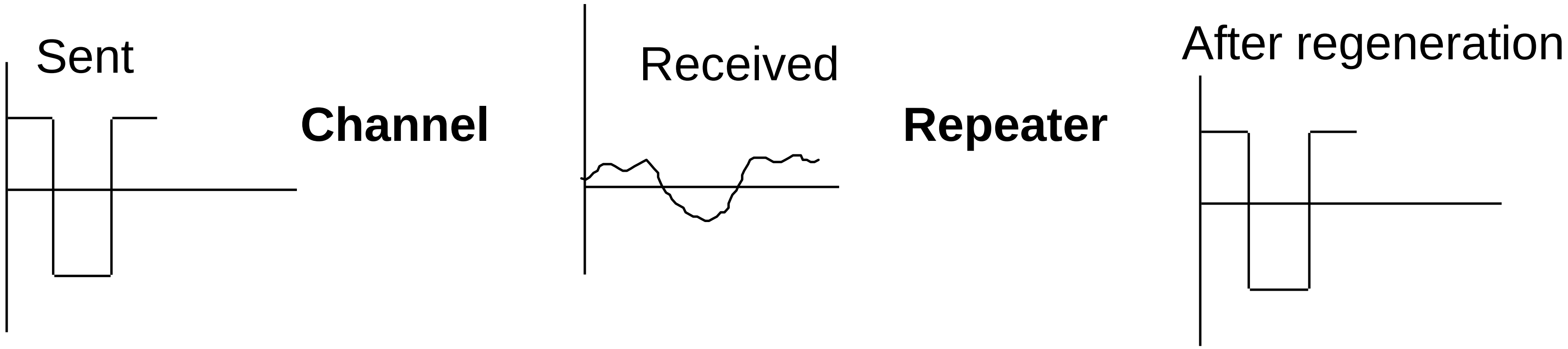
- analog, e.g. FM commercial broadcasting
- digital, e.g. GSM, LTE, DAB, DMB

Analog and digital transmission

Analog transmission



Digital transmission – better resistance to channel distortions:



In history...

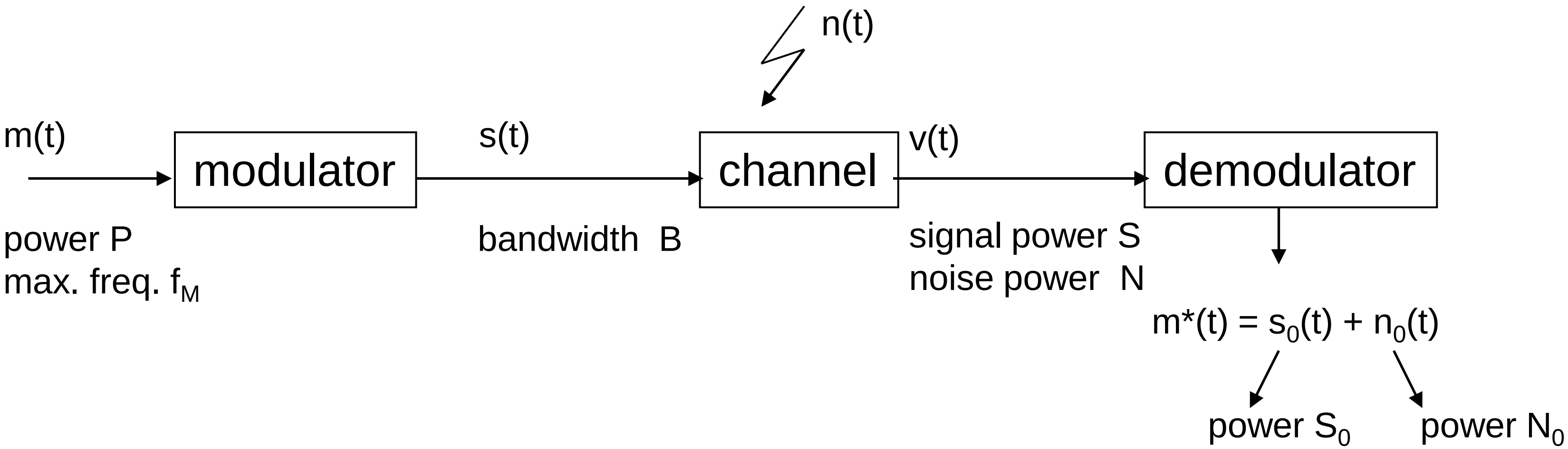
Digital transmission

- Static electricity (A. de Betancourt ~1790)
- Optical telegraph (C. Chappe ~1800)
- Electrical telegraph (Gauss, Weber, Steinheil, Morse ~1830)
- Wireless telegraph (Hertz 1888, Popov, Marconi 1899)
- PCM, digital telephony (~1950-70)

Analog transmission

- Telephone (Graham Bell 1876)
- Analog telephony (1890)
- AM/FM broadcast, terrestrial TV (1920)

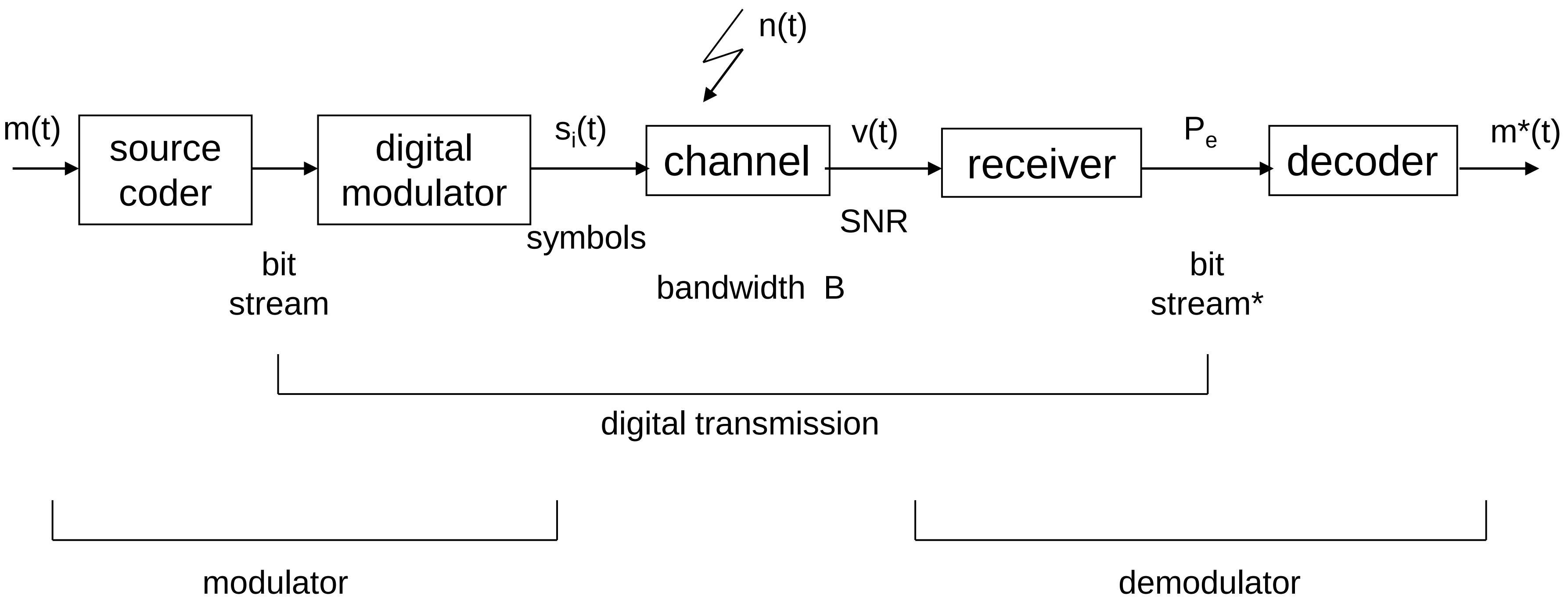
Modulation, demodulation



Signal to noise ratio

- output of the channel SNR = S/N
- output of the receiver $SNR_0 = S_0/N_0$

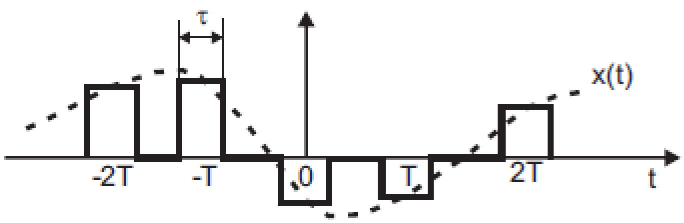
Digital transmission



P_e=BER= probability of error

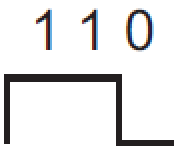
Digital transmission of analog signals basic processes (1)

Sampling

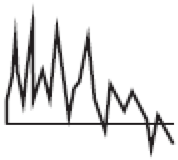


Quantizing

Modulation



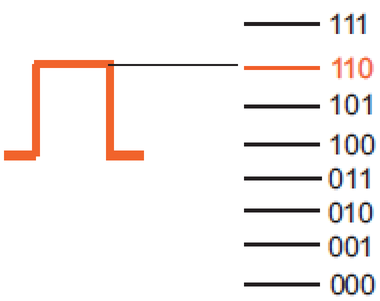
Transmission



Digital transmission of analog signals basic processes (2)

Reception 1 1 0

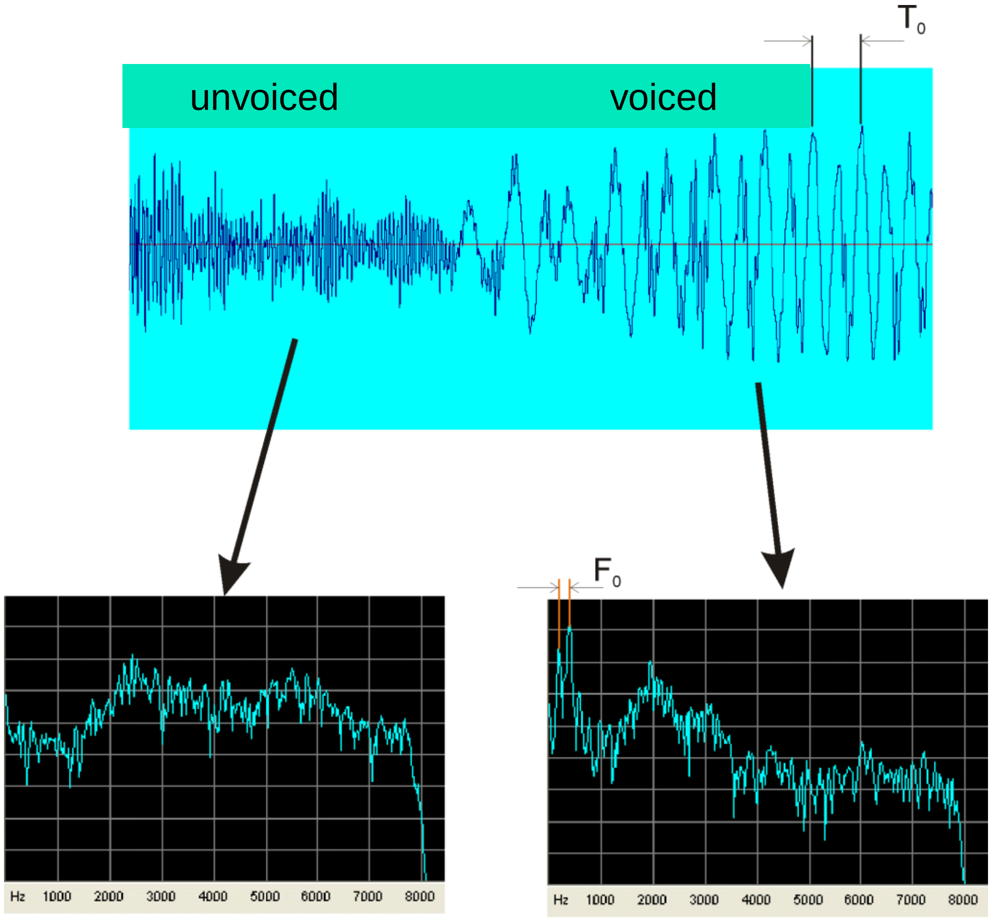
Reconstruction of the sample



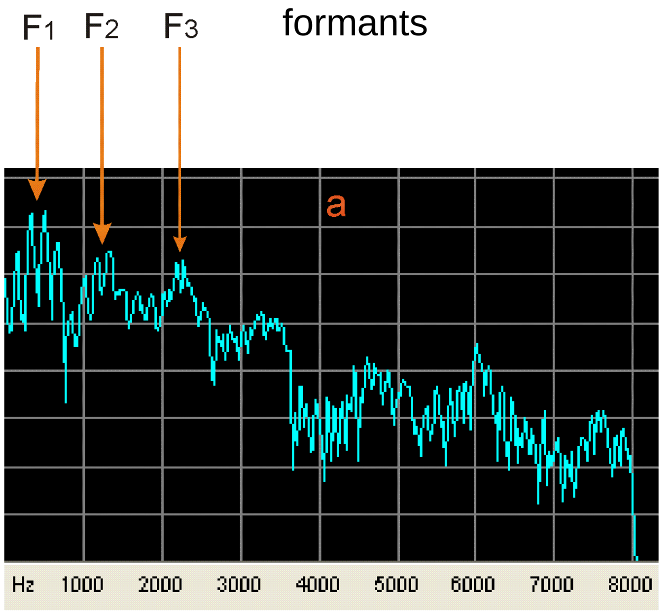
Reconstruction of continuous signal x*(t)

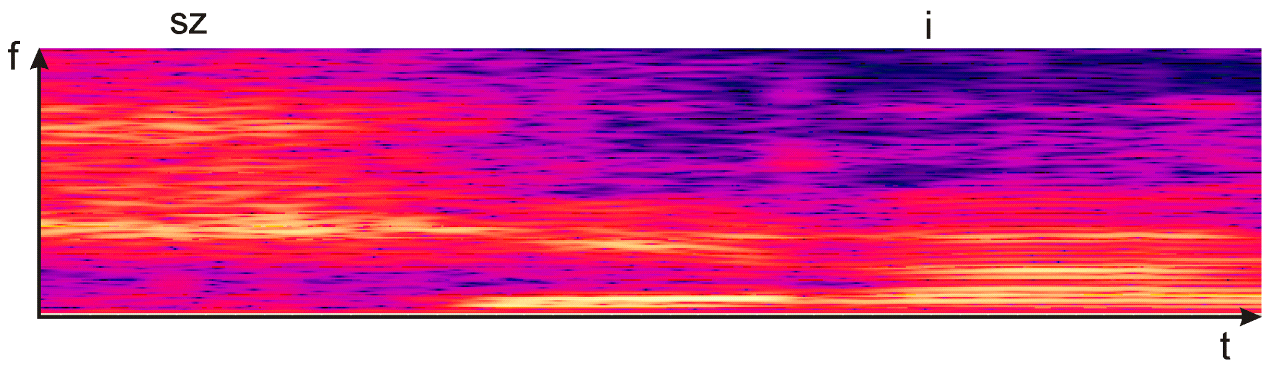
Signals and their models:
1. modulating signal m(t)

Example:
speech signal



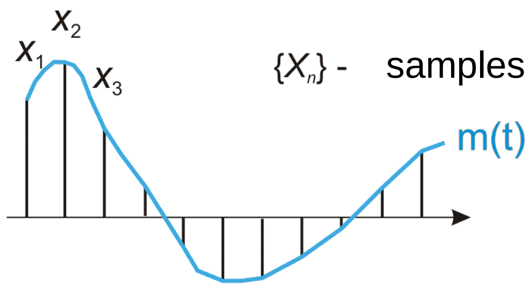
Speech signal





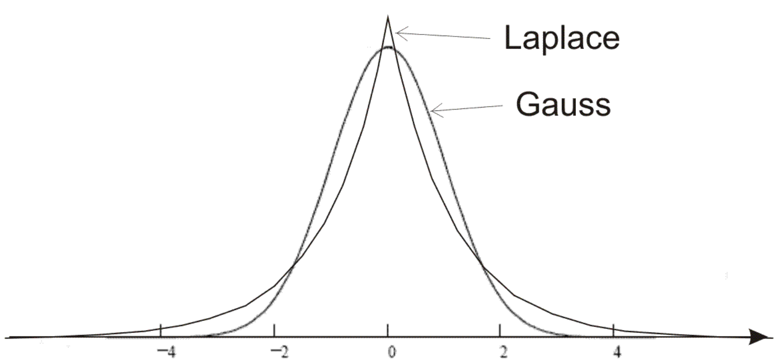
sonogram

Models of the speech waveform m(t)



$\{X_n\}$ - samples

$p_m(x)$ - probability density function (pdf)



Gauss

$$p_m(x) = \frac{1}{\sqrt{2\pi\sigma_m^2}} \exp\left(-\frac{x^2}{2\sigma_m^2}\right)$$

Laplace

$$p_m(x) = \frac{1}{\sqrt{2\sigma_m^2}} \exp\left(-\sqrt{2}\,\frac{|x|}{\sigma_m}\right)$$

σ_m^2 - variance

Spectrum, power spectral density (psd)

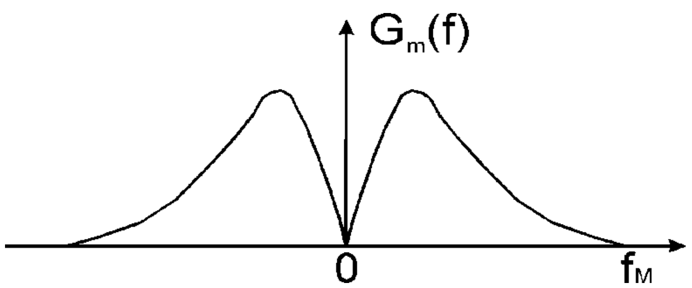
Spectrum (Fourier transform) $$M(f) = \int_{-\infty}^{\infty} m(t)\, e^{-j2\pi f t}\, dt$$

Amplitude spectrum $|M(f)|$

Energy spectrum $|M(f)|^2$

Power spectrum (psd) $\frac{1}{T}|M_T(f)|^2, \quad M_T(f) = \int_{-T/2}^{T/2} m(t)\, e^{-j2\pi f t} dt, \quad T \to \infty$

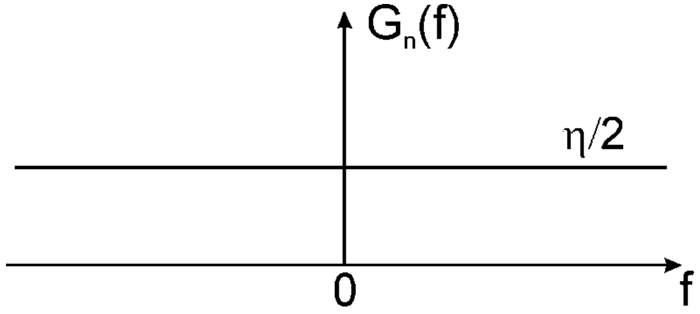
Psd $$G_m(f) = \lim_{T\to\infty} \frac{1}{T} |M_T(f)|^2$$



Power $$P = \int_{-\infty}^{\infty} G_m(f)\, df = \int_{-\infty}^{\infty} x^2\, p_m(x)\, dx = \lim_{T\to\infty} \frac{1}{T} \int_{-T/2}^{T/2} m^2(t) dt$$

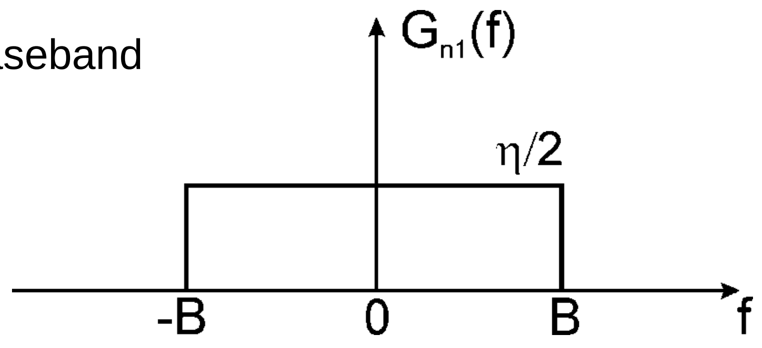
Signals and their models:
2. noise n(t)

In the channel:
white gaussian noise (AWGN)

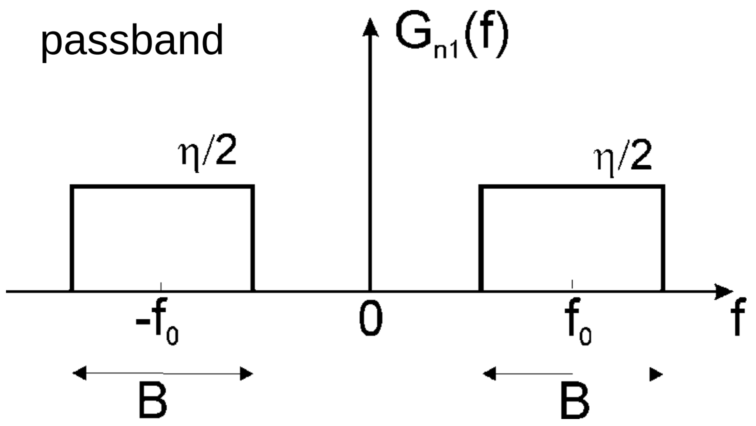


in the output of the channel – noise $n_1(t)$, power $N=\eta B$

baseband



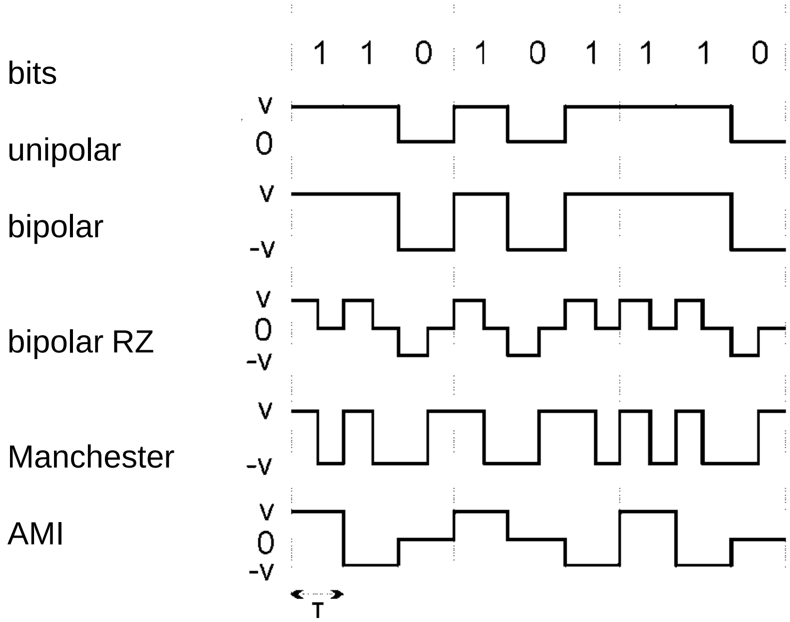
passband



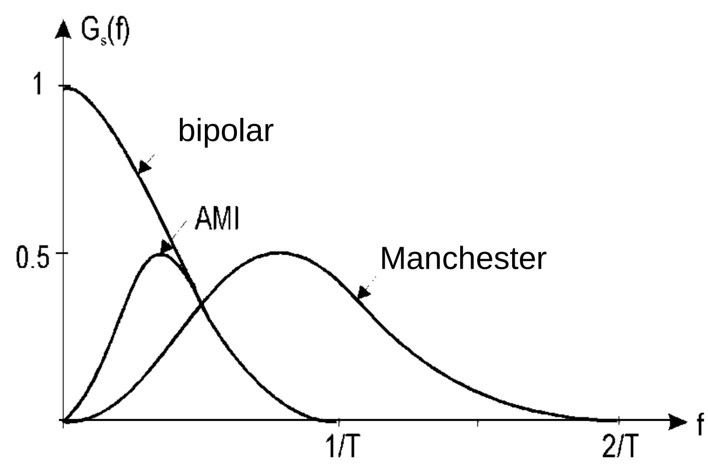
Signals and their models:
3. modulated signal s(t)

It depends on the modulation: s(t) may be a baseband, passband, analog or digital signal

Power: S, Bandwidth B



e.g. baseband, digital signals

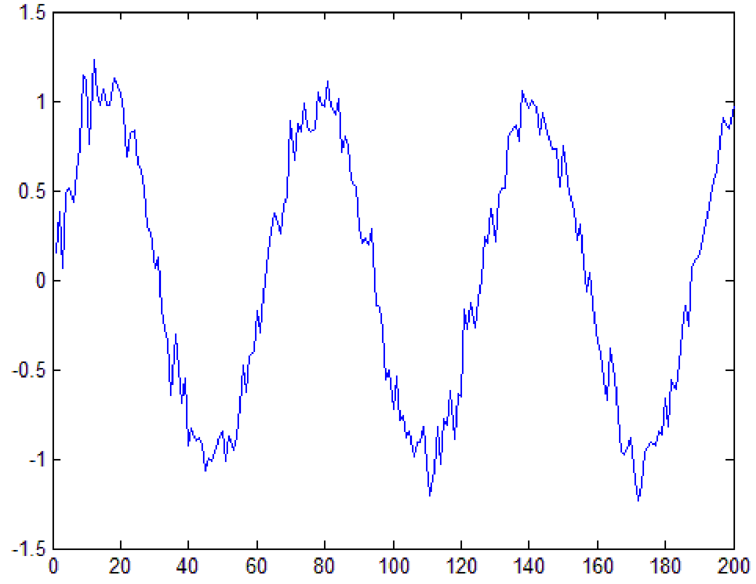


Signals and their models:
4. the output signal $m^*(t)=s_0(t)+n_0(t)$

A (distorted) copy of the modulating signal
signal power: S_0
noise power: N_0

$$SNR_0 = \frac{S_0}{N_0} = \frac{\sigma_x^2}{\sigma_e^2}$$

$$SNR_0\,[dB] = 10\log_{10}\left[\frac{\sigma_x^2}{\sigma_e^2}\right]$$

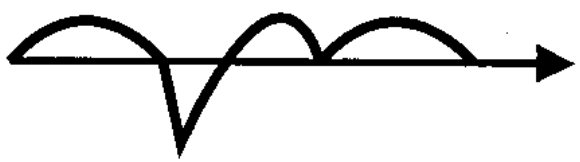


Telecommunication channels

DISTORTIONS:

additive noise

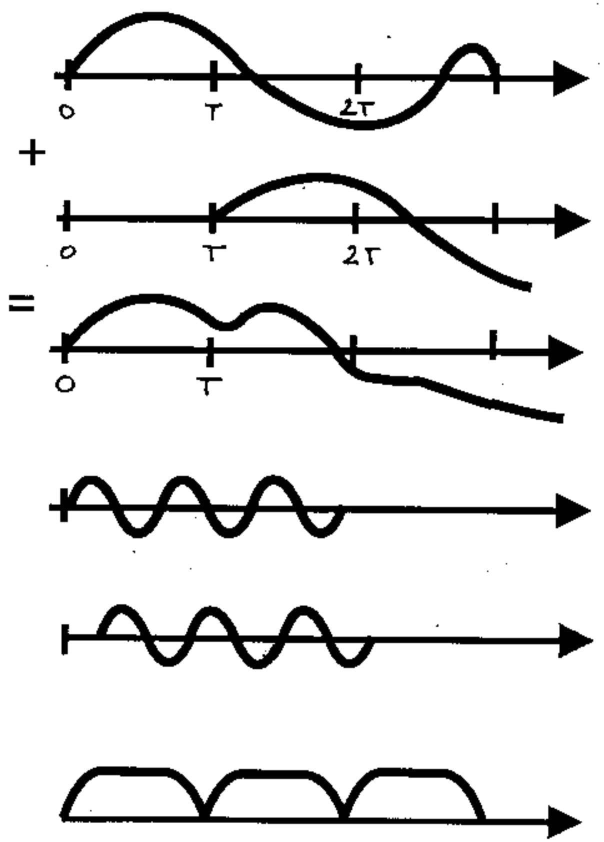
pulses



fading

Telecommunication channels

DISTORTIONS:

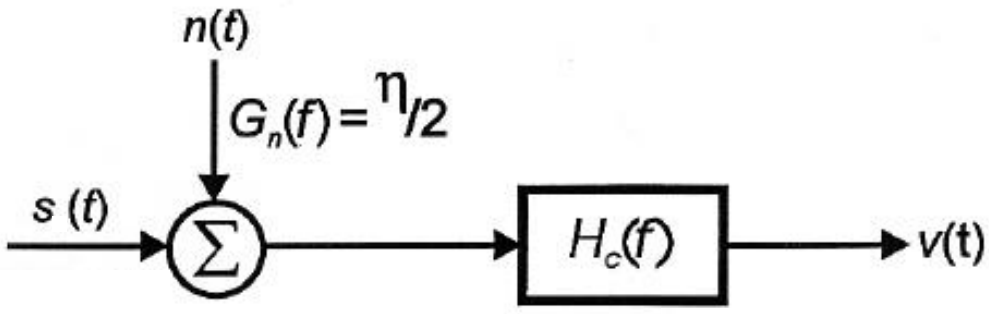


intersymbol interference

phase errors

nonlinear distortions

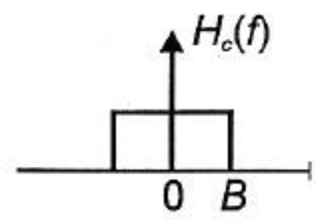
Simplified model of a channel



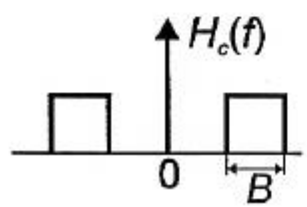
AWGN

$$G_n(f) = \frac{\eta}{2} = \frac{N_0}{2}$$

$$f \in < -\infty, +\infty >$$



lowpass



bandpass

Noise power at the output of the channel: $N = \eta B$

Why do we use modulations?

- Adaptation of the modulating signal (e.g. speech, music) to the transmission channel
- Sharing the same channel: (FDM – frequency division multiplexing, TDM – time division multiplexing)