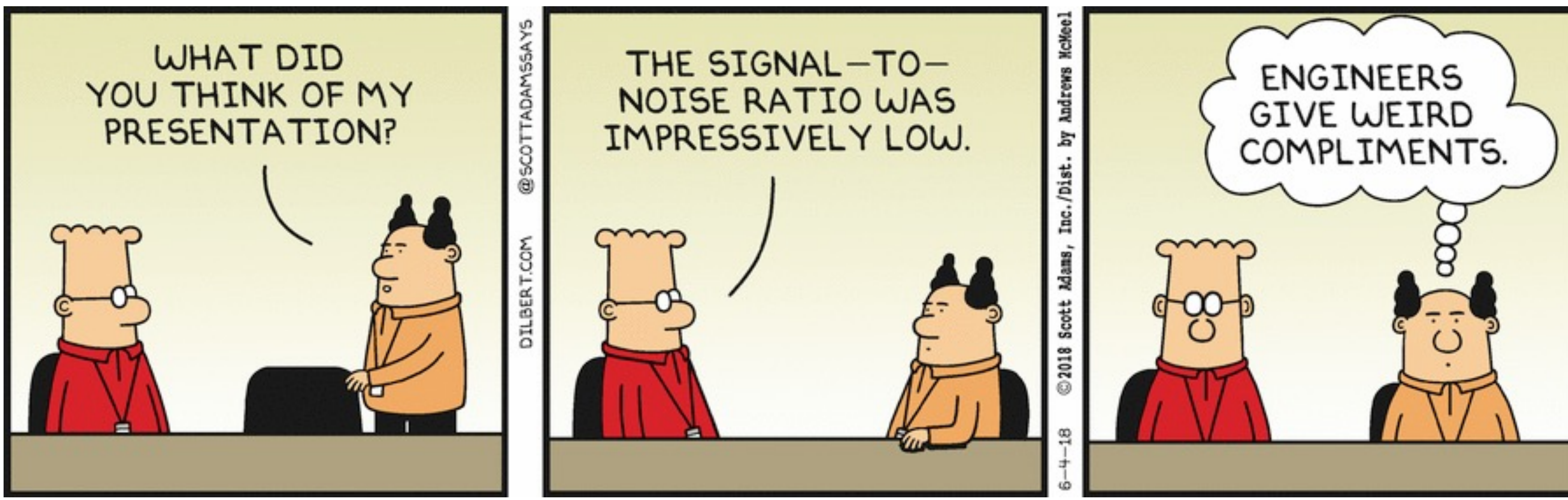
The Physical Layer – a short introduction to signals and coding



[http://dilbert.com/]

Based on slides from Prof. Dr. Martina Zitterbart (KIT)

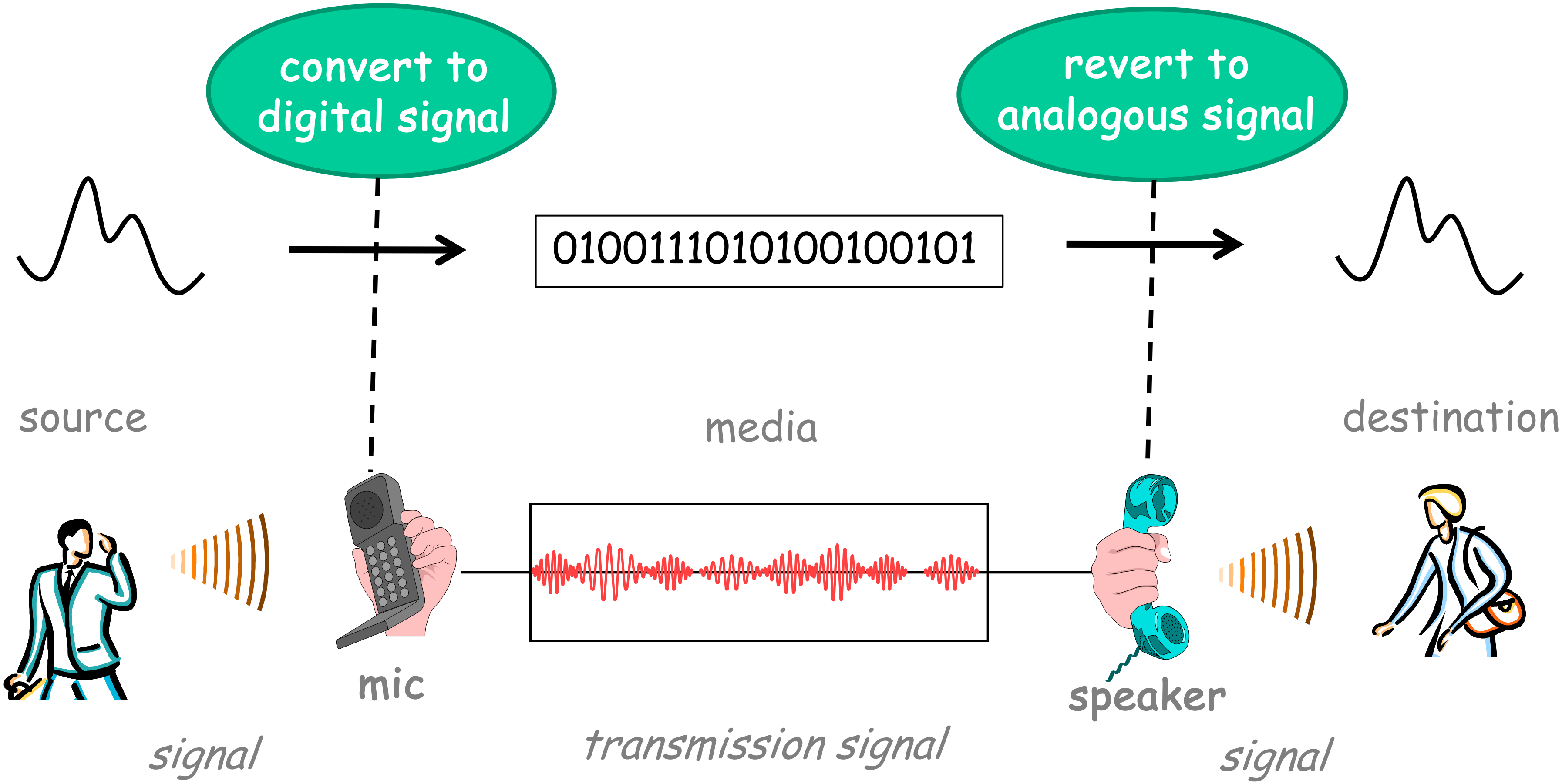
Objective

Encode data into a physical signal and decode incoming physical signals

Comms Engineering

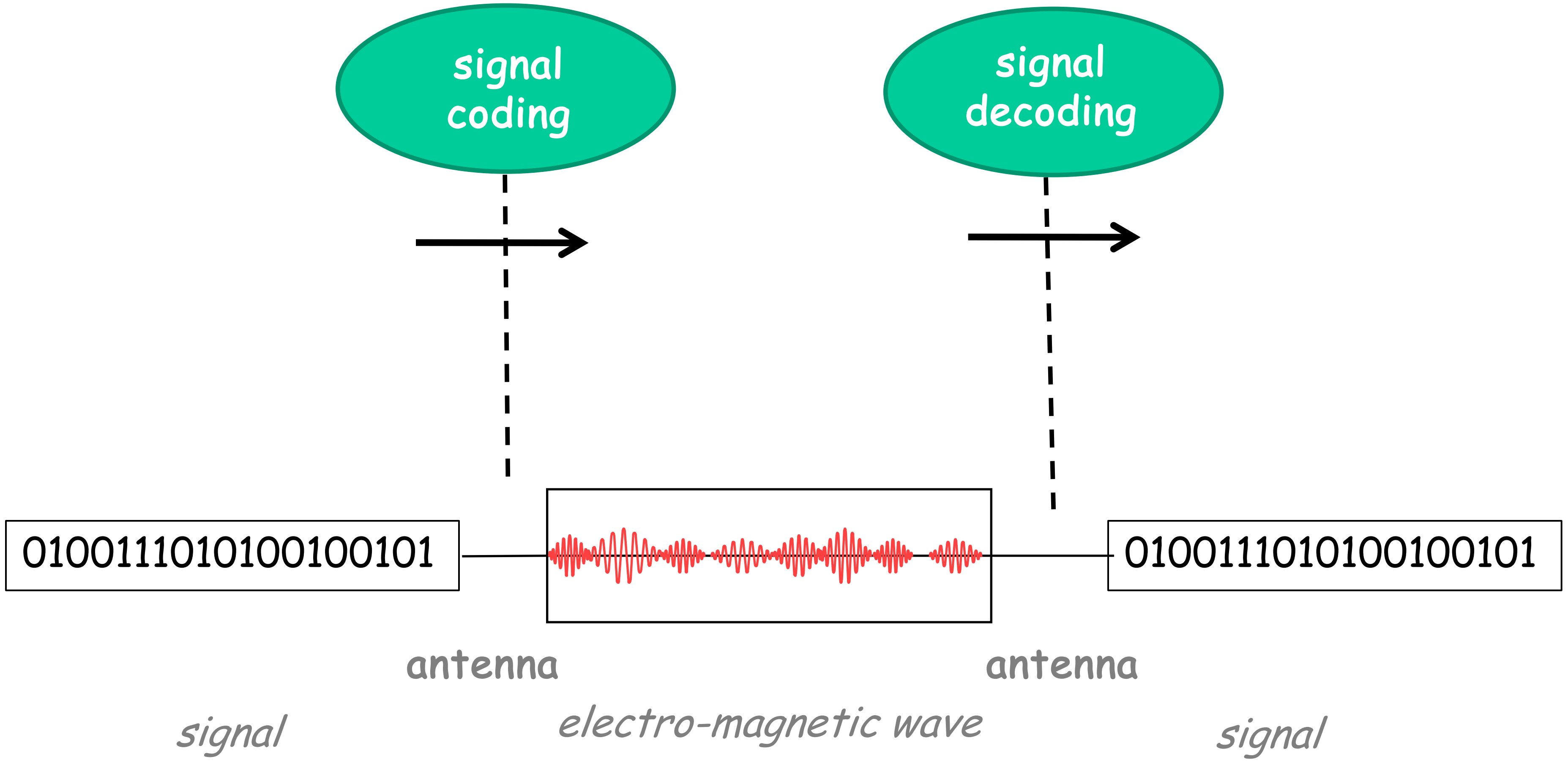
1. Modulation
2. Sampling and Quantification
3. Detection Errors

The good old telephone



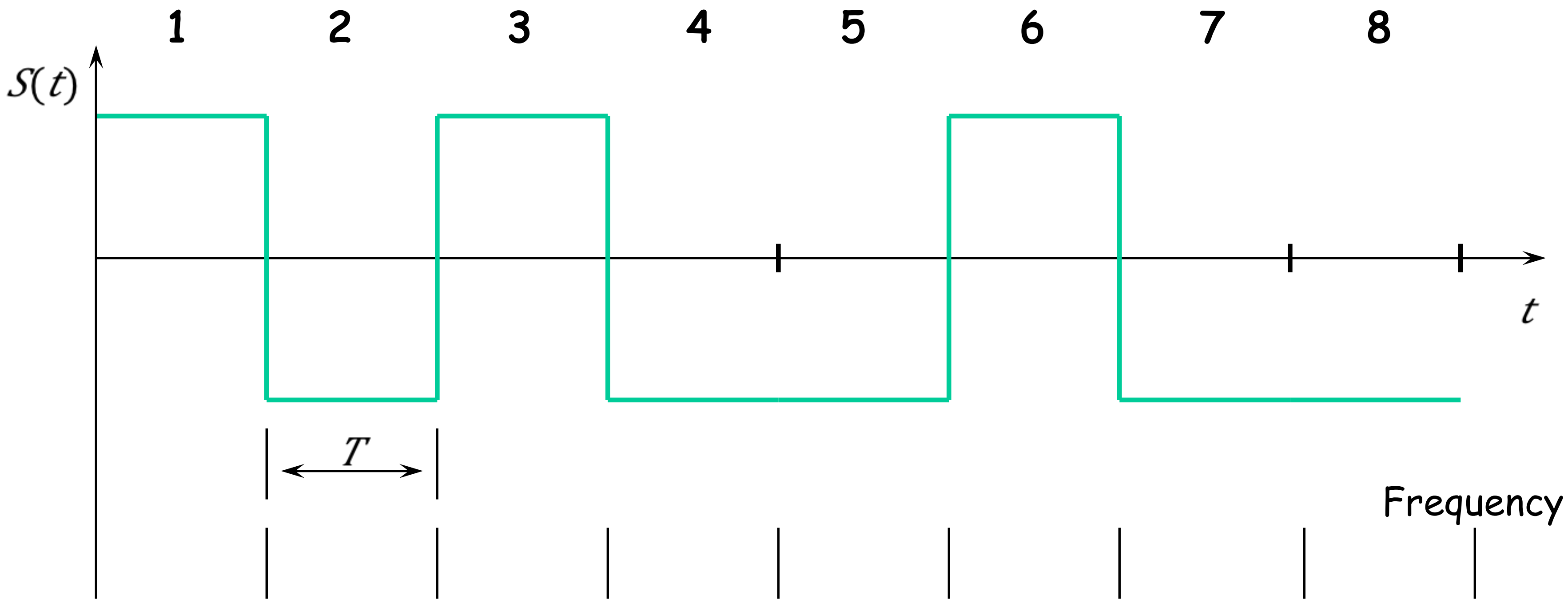
TRANSMISSION OF DIGITAL DATA

Transmission of digital data over a physical medium

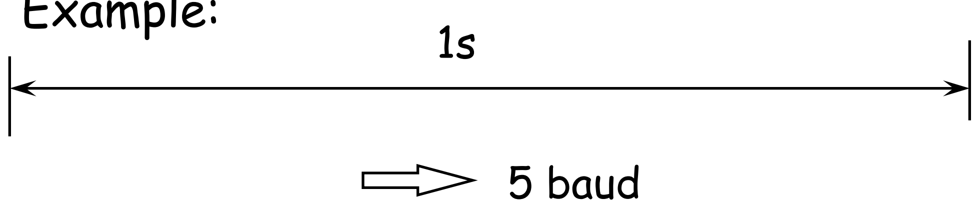


Foundation: binary signals

Time interval:



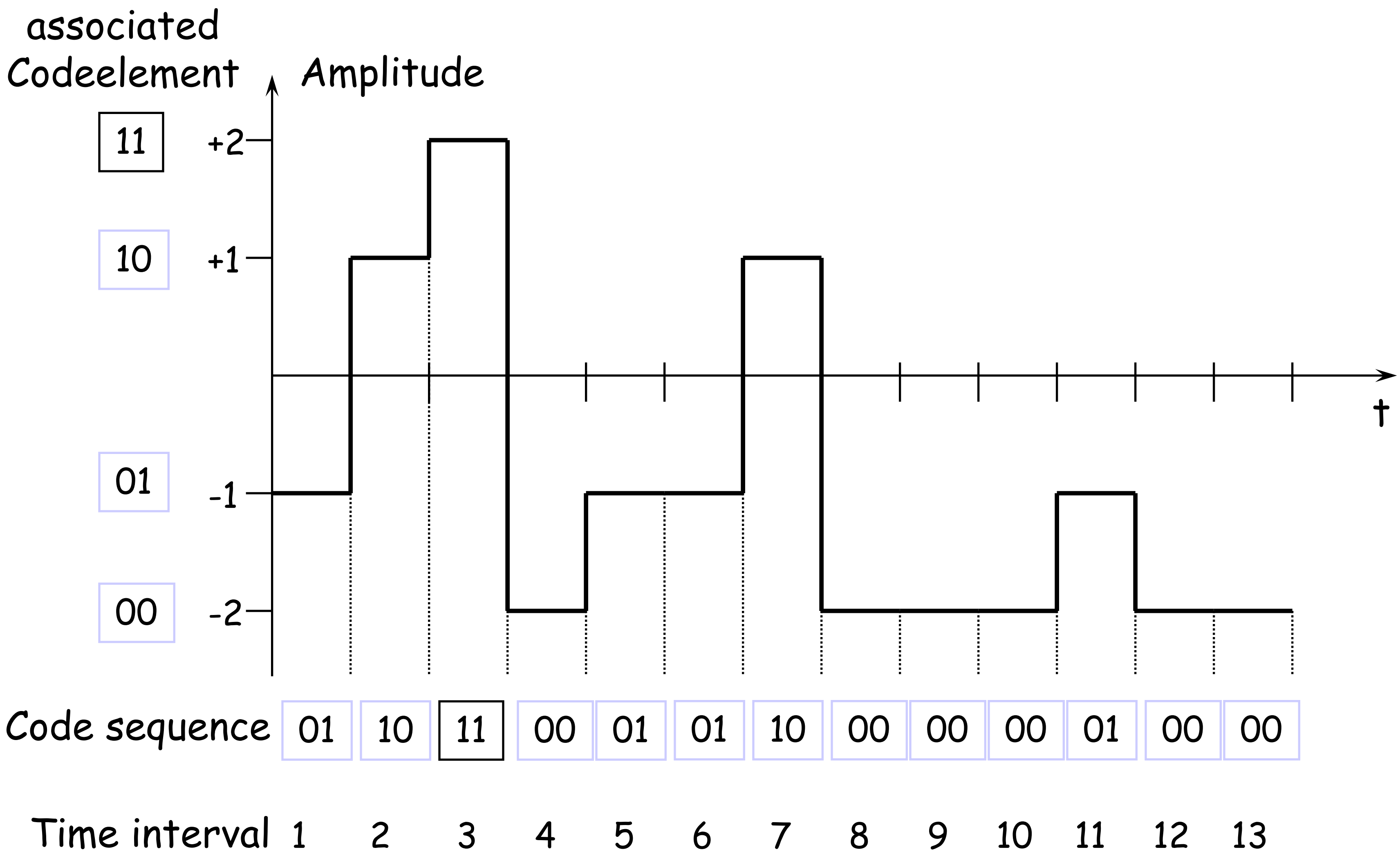
Example:



Digital Signals: Terminology

- Isochronous Signals
  - Signal changes occur at regular time intervals at the end of the time interval
- Baud
  - Unit for symbol rate: Number of distinct symbol changes per second

Multi level data signals

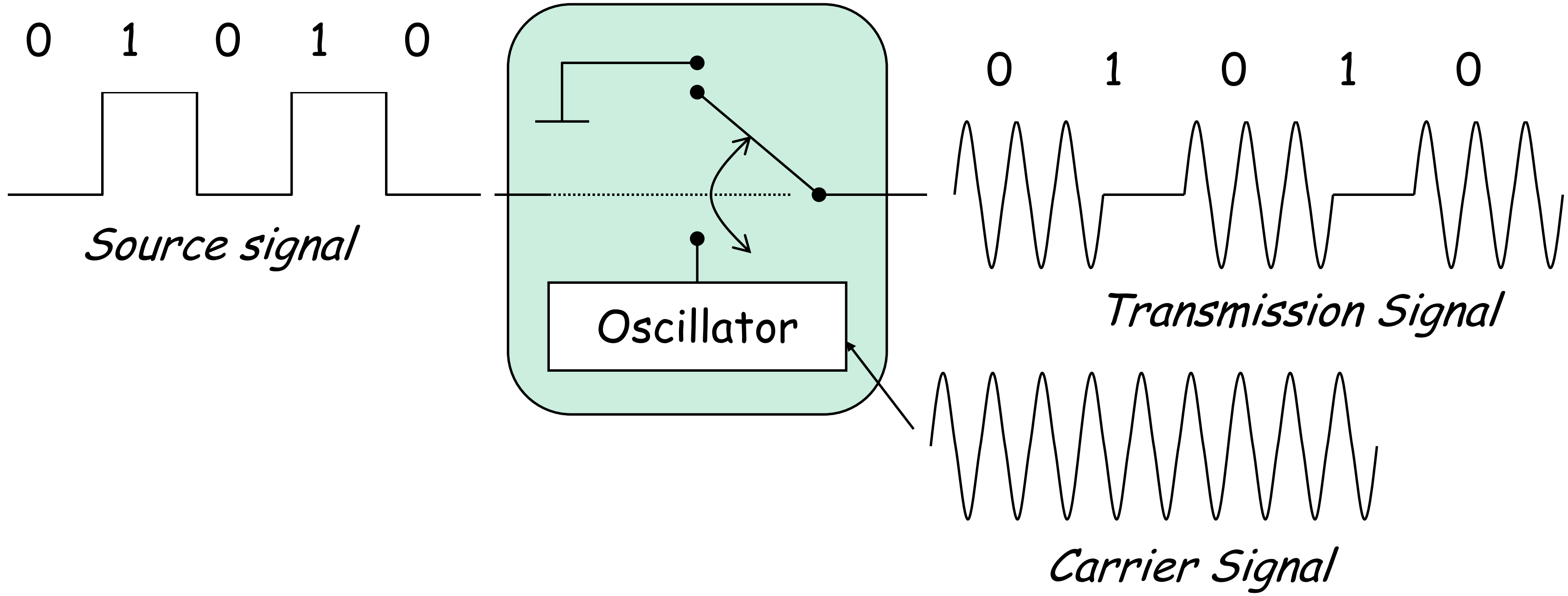


Signal transmission

- Baseband transmission
  - two power levels (+V, -V) representing 0 and 1

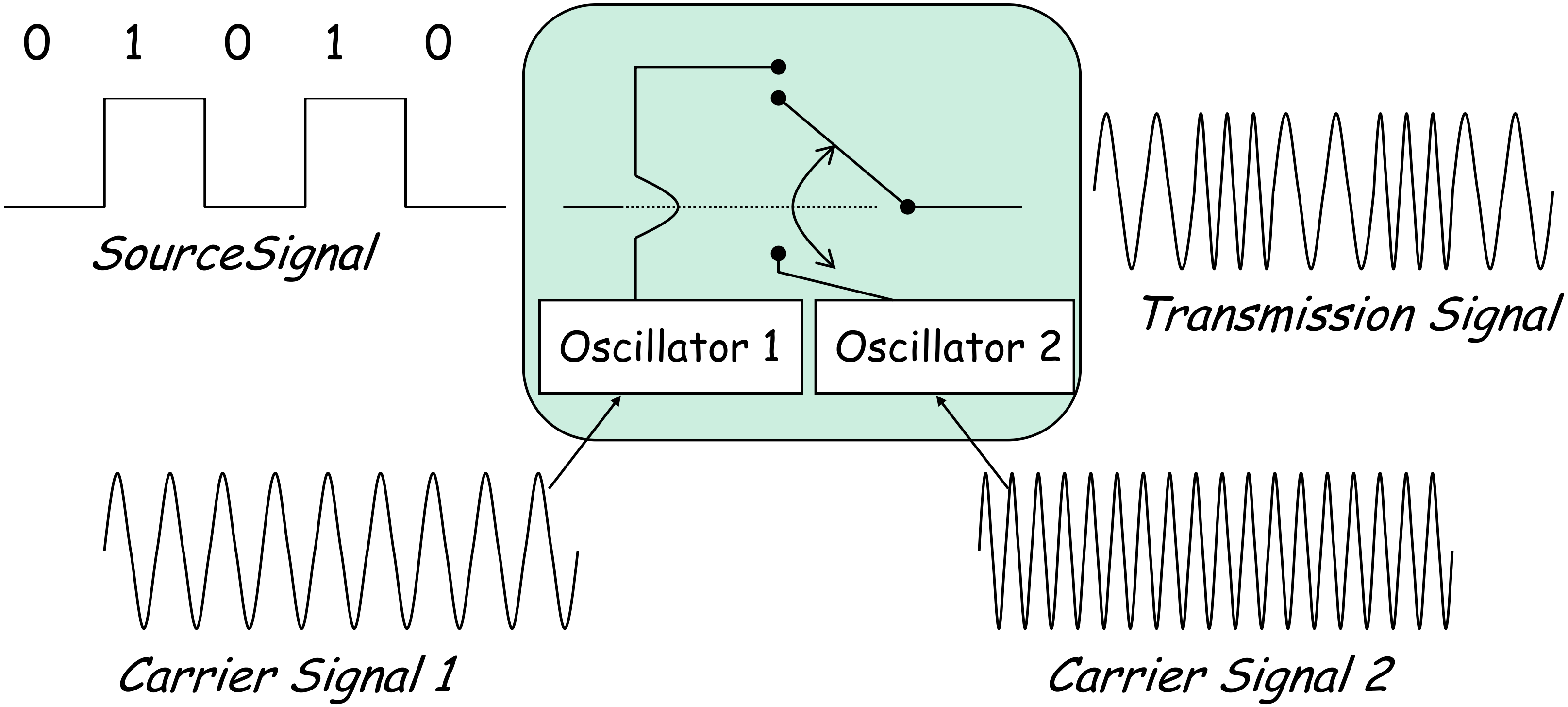
- Modulation
  - Digital: *Digital Data → analogous Signal*
    - *Amplitude Shift Keying* (ASK)
    - *Frequency Shift Keying* (FSK)
    - *Phase Shift Keying* (PSK)

Amplitude Shift Keying



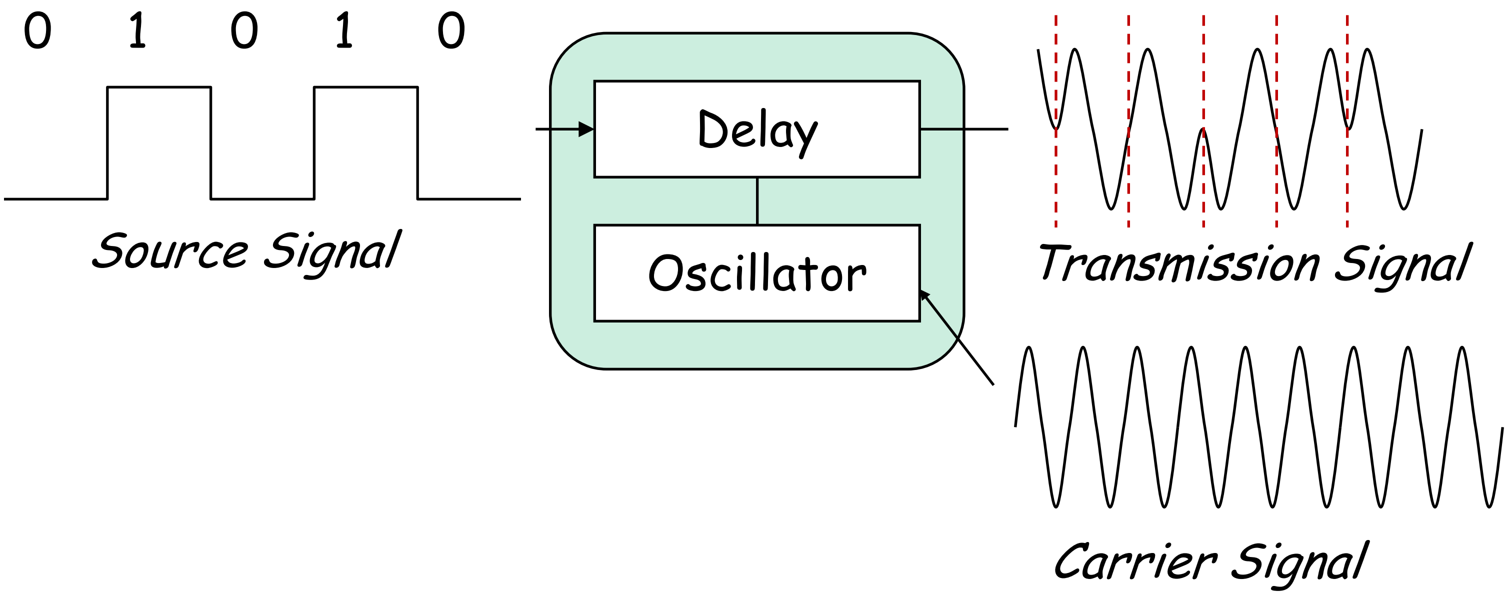
- Modification of carrier signal's amplitude
  - Simple Method: On-Off-Keying
- Application
  - DCF77 Signal for radio clocks
    - Synchronisation: periodically reduce amplitude to 25%

Frequency Shift Keying



- Switching between different carrier signals
  - Binary Frequency Shift Keying (BFSK) – two carrier signals with different frequencies
- Application
  - Wireless telegraphy (oldest app) and general telecommunicaiton

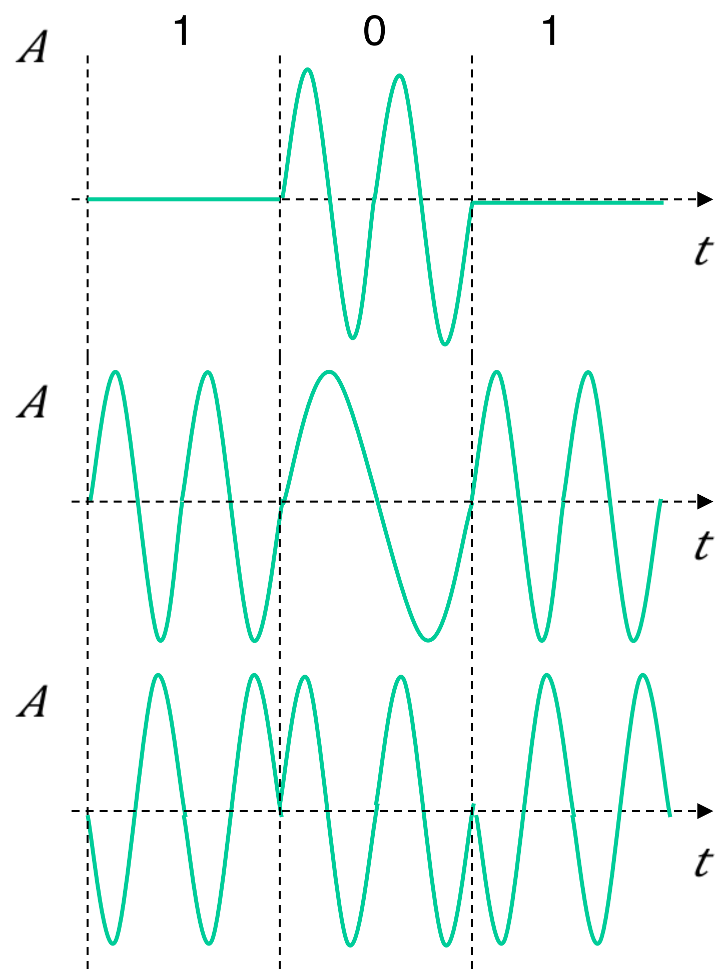
Phase Shift Keying



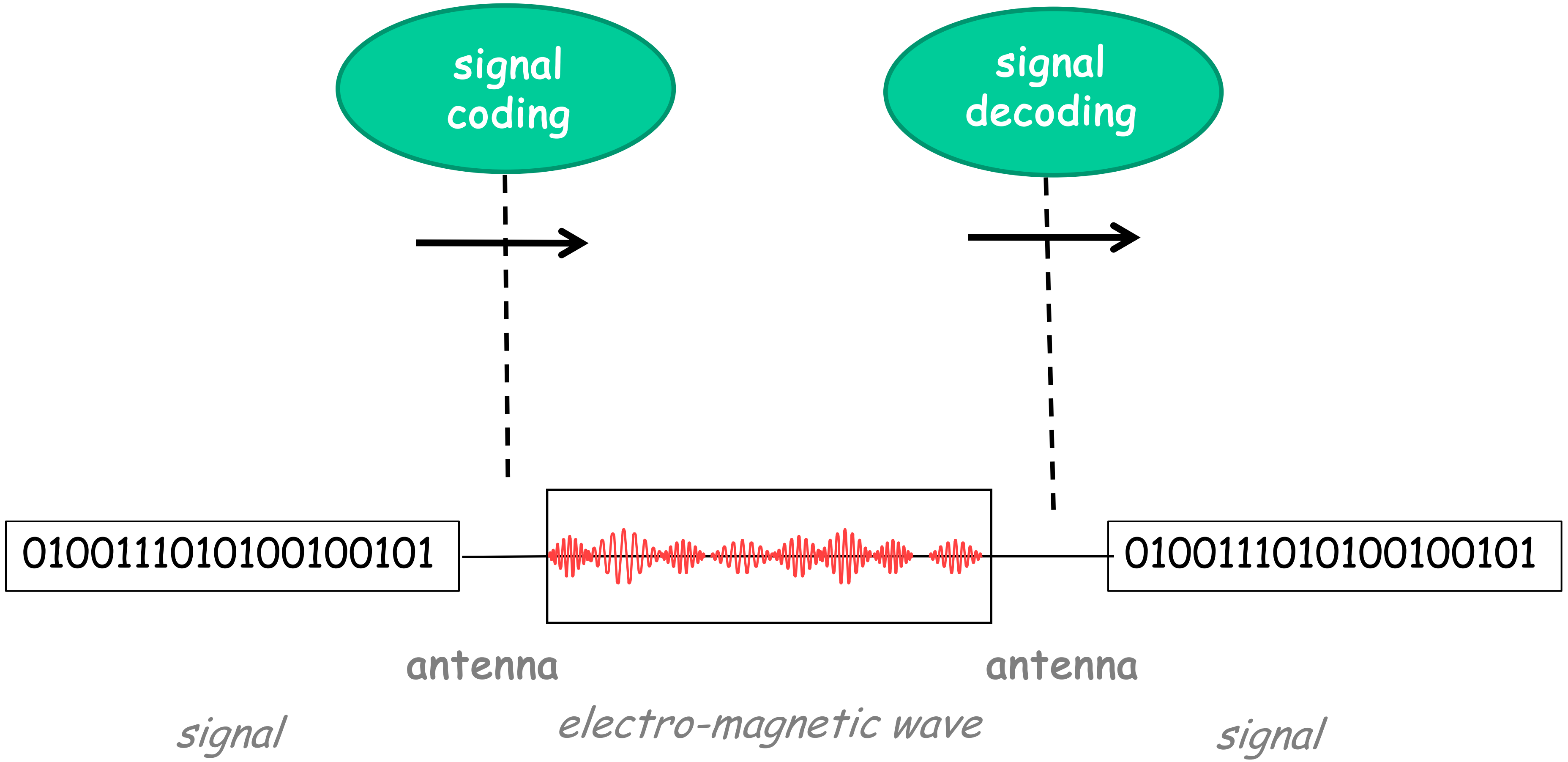
- Coding via Phase Shift
  - Transmission of „0“ leads to $\lambda/2$ phase shift

Summary

- Amplitude Shift Keying
  - technically simple
  - requires small bandwidth
  - susceptible for interference
- Frequency Shift Keying
  - higher bandwidth
- Phase Shift Keying
  - complex demodulation
  - robust against interference



Transmission of digital data over a physical medium



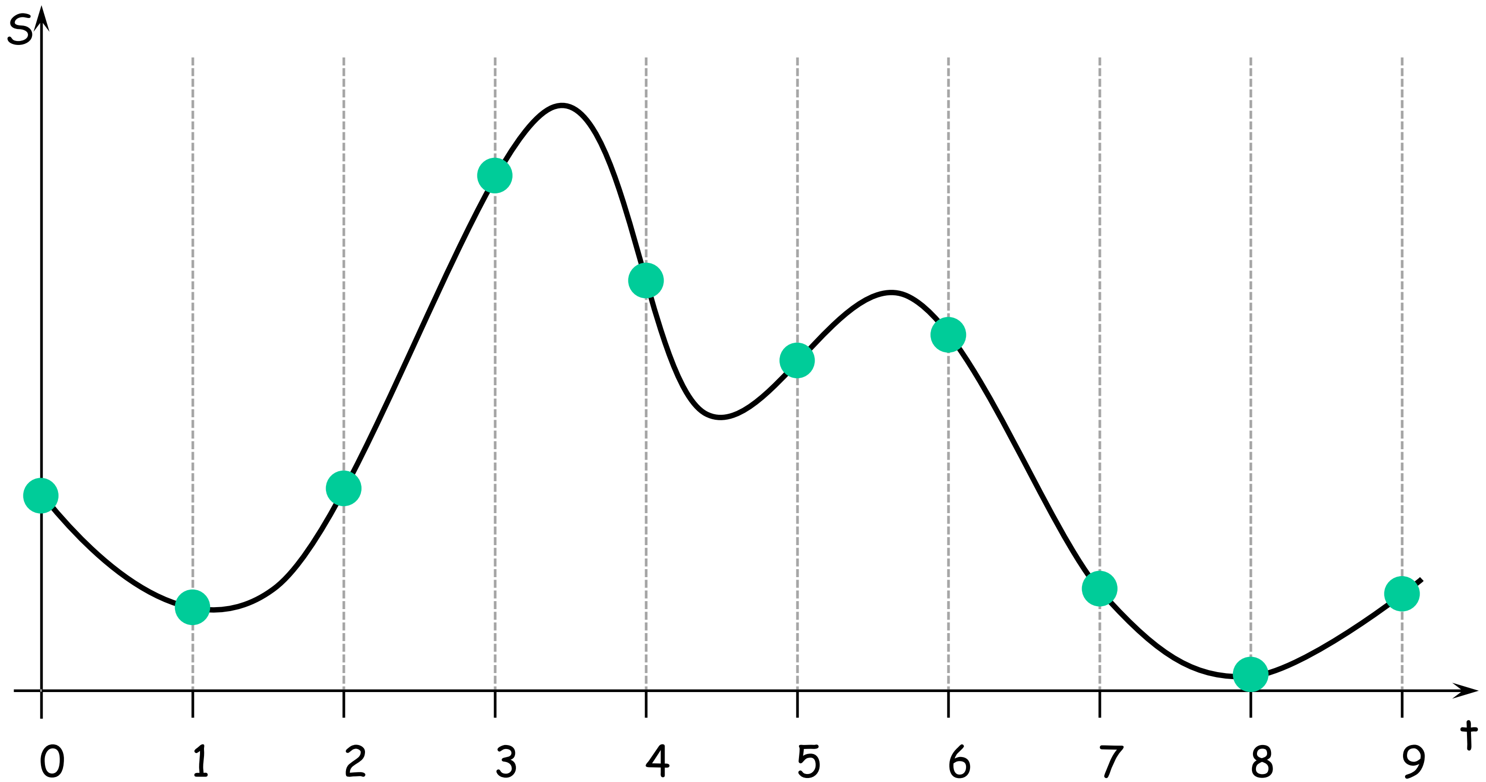
From signals to digital data

- Pulse Code Modulation (PCM)
  - Sampling ➔ time discrete signal
  - Quantification ➔ time and value discrete signal

- Theorem of Shannon and Raabe
  - Sampling frequency f must be at least twice the signal's frequency
  - In ISDN: voice signals in understandable if sampled between 0 and 4500Hz ➔ with some safety margin ISDN samples with 9600 Hz

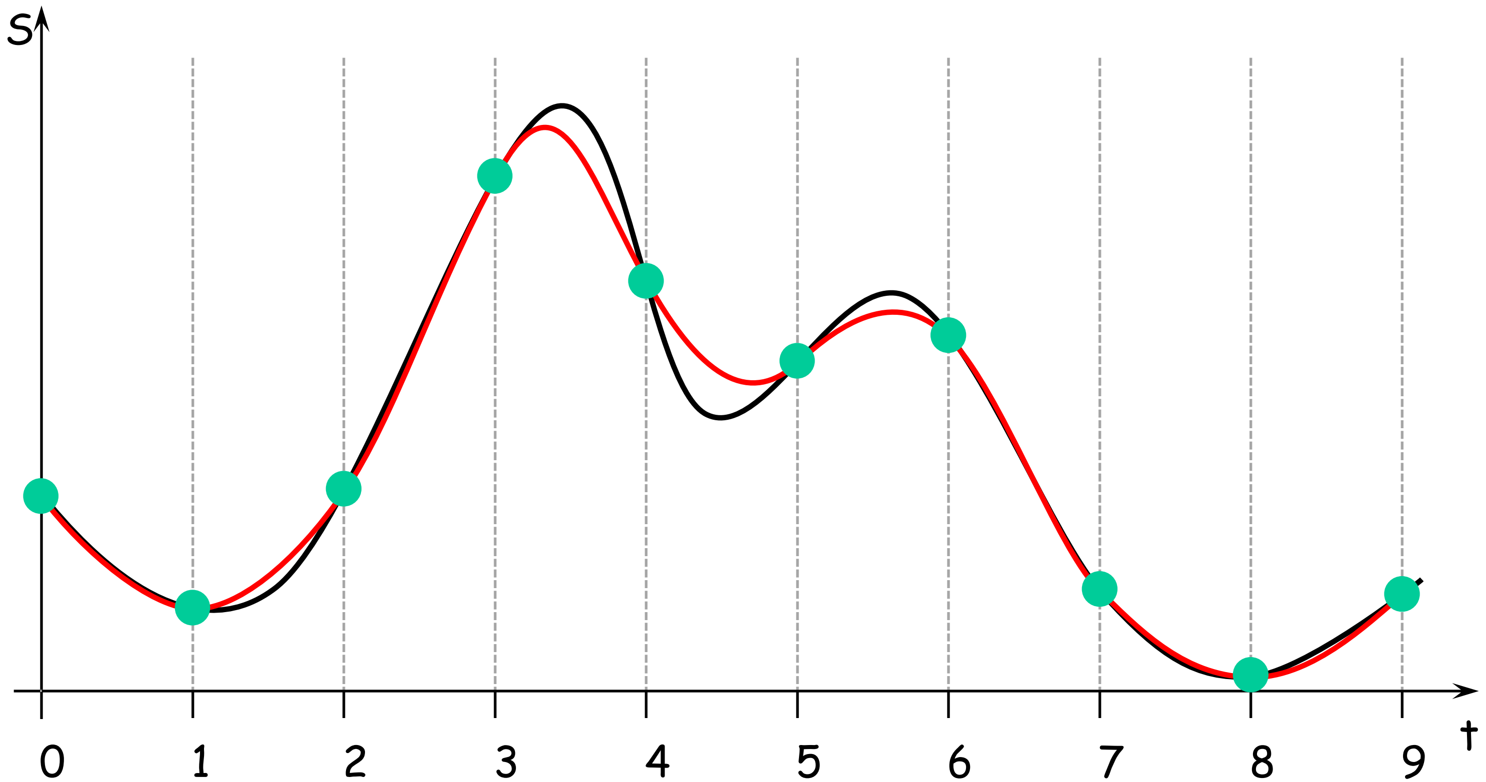
Sampling

- Sampling in discrete time intervals with frequency f



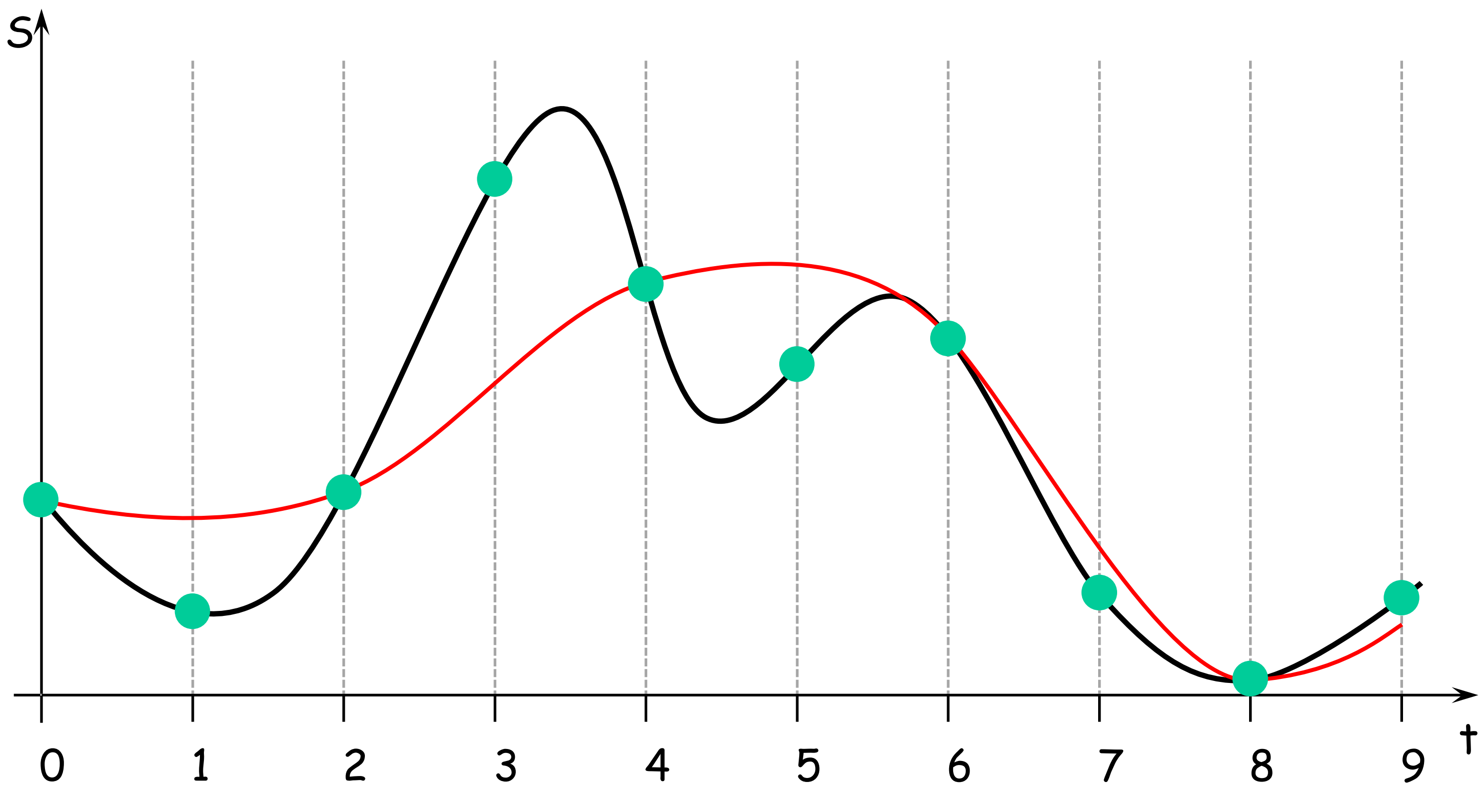
Sampling

- Different signals might result in the same digital data



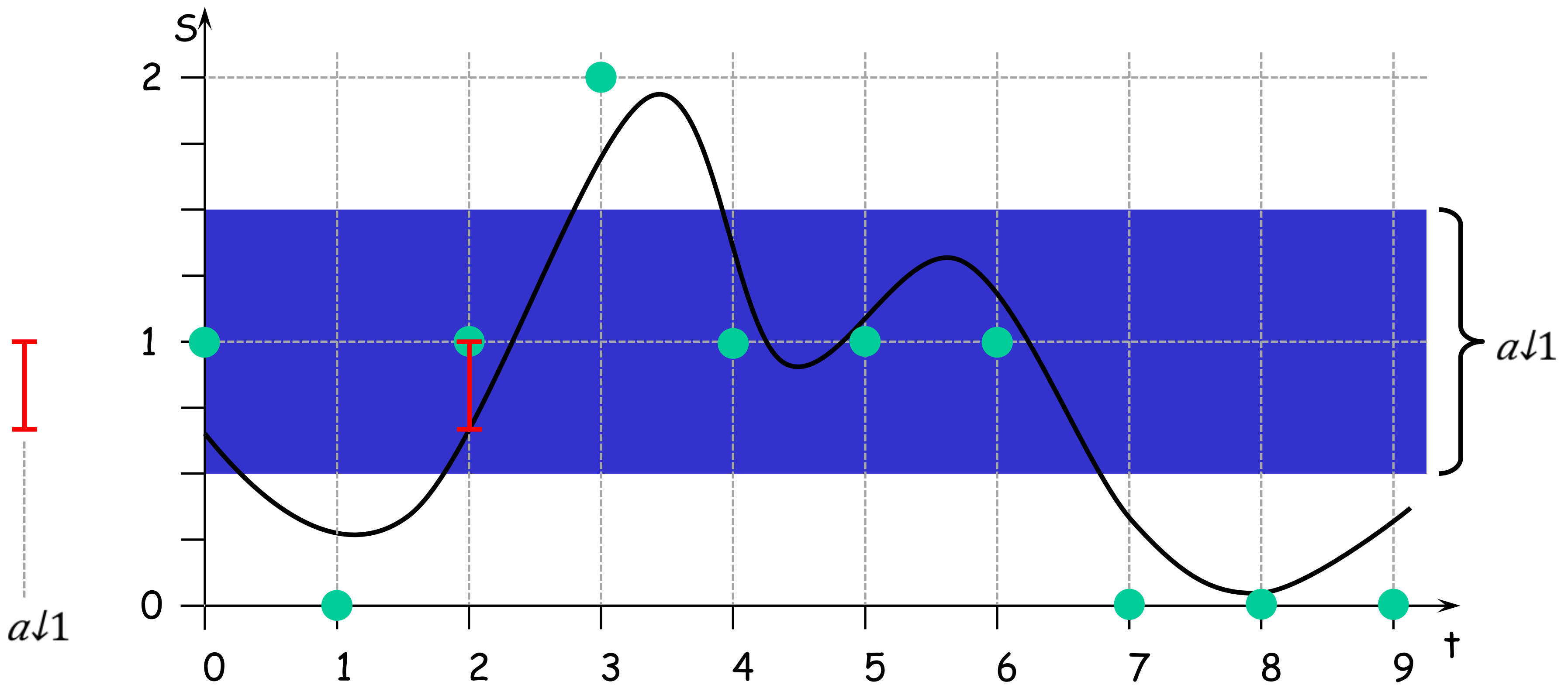
Sampling

- If f does not adhere to Shannon‘s theorem we loose information



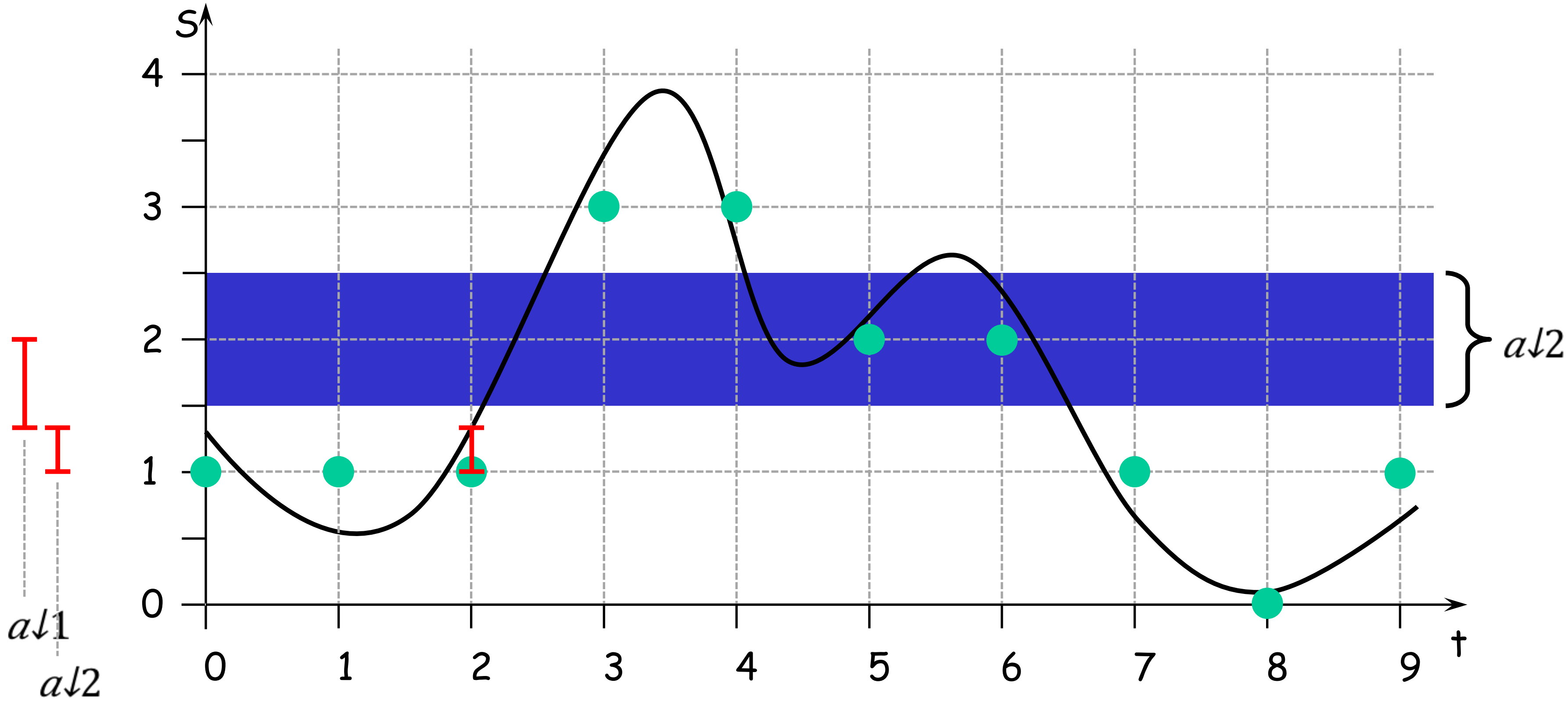
Quantification

- Mapping the continuous value space of the signal to a finite set of predefined values
  - All values of an interval are mapped to value representing this interval
  - Error margin is half the interval size



Quantification

- Trade-off: Error margin vs. size of target number set



Summary

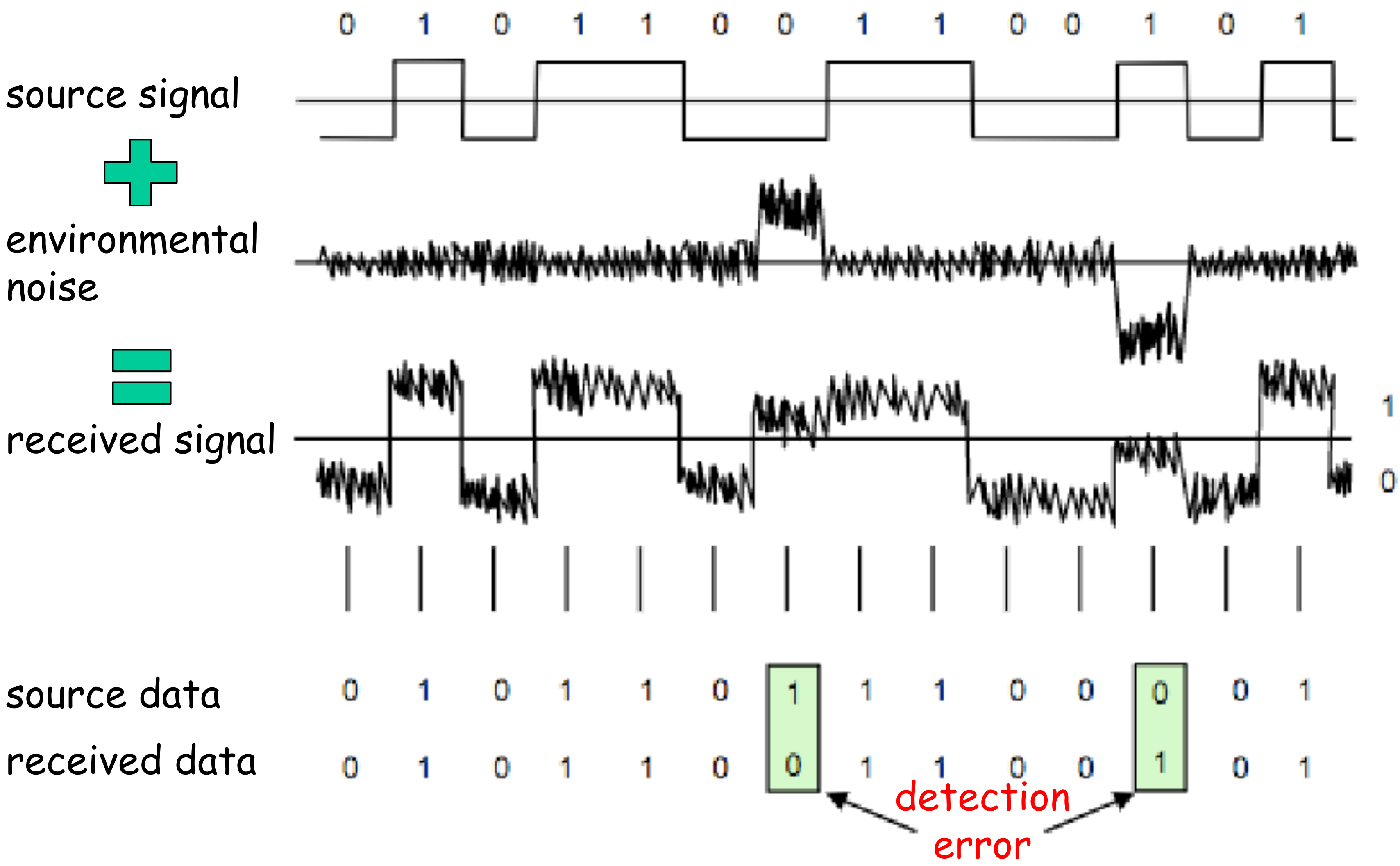
- Achievement: We mapped an analogous signal which is time and value continuous to a time-discrete signal of pre-defined values

➔A digital representation of the analogous signal

- Loss of signal quality to meet channel limits

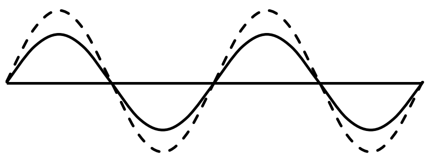
REAL WORLD APPLICATION

Environmental noise

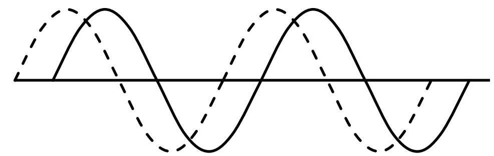


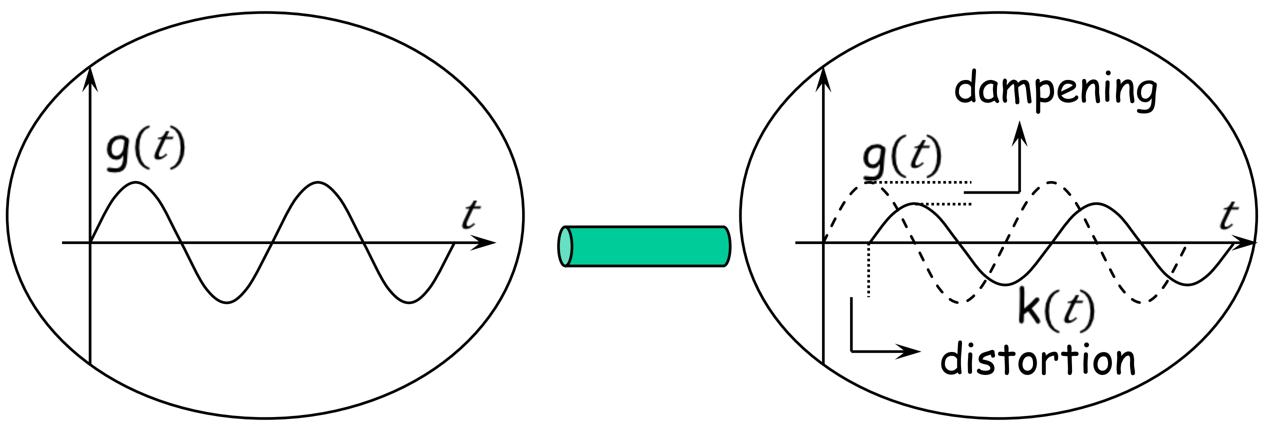
Environmental challenges on signal transmission

- Signal Dampening



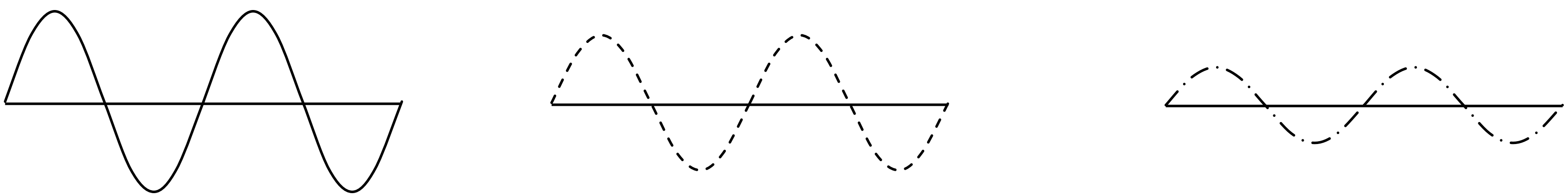
Signal distortion





Signal fading

- Signal amplitude fades quadratic with distance for undirected senders



Original Signal Signal at receiver 1 Signal at receiver 2

- Distance from sender to receiver 2 is twice the distance from sender to receiver 1
- The signal strength received at receiver 2 is ¼ of that received at receiver 1!

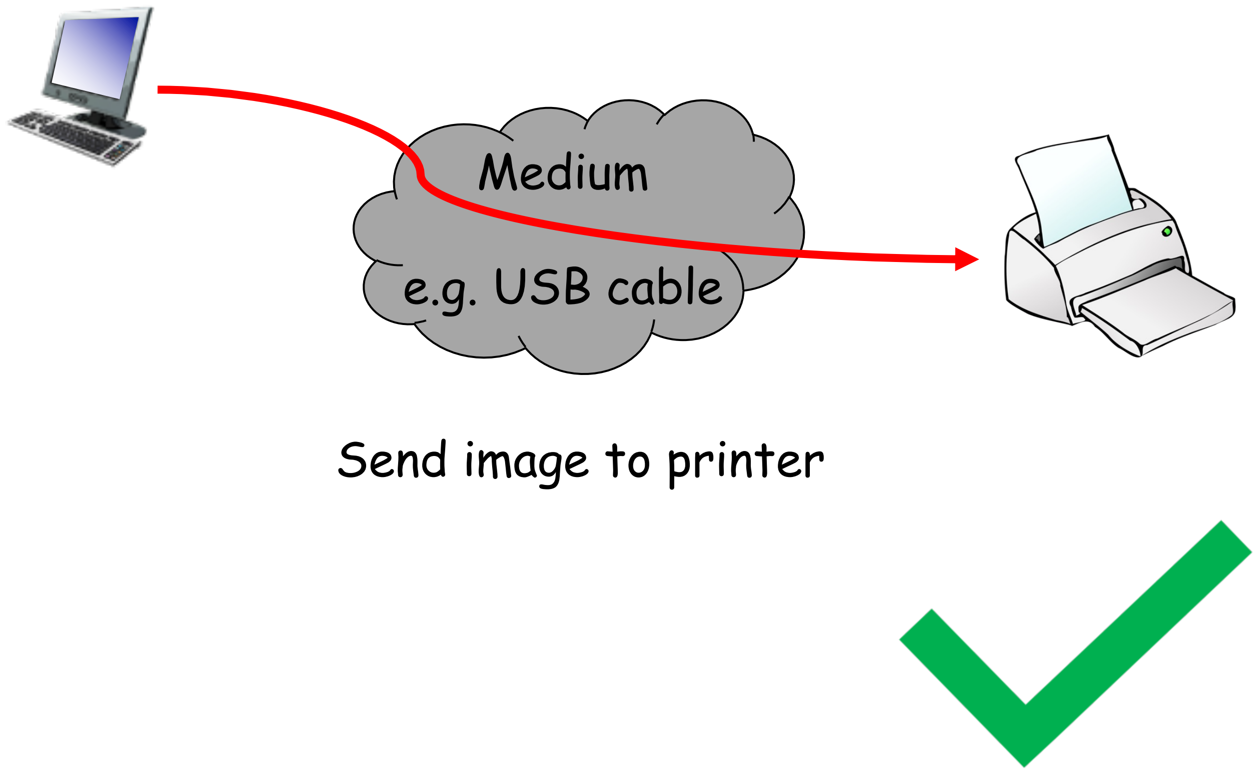
More challenge sources

- Interference from other signals
  - Bluetooth on WiFi
  - WiFi on cellular
  - Current on Ethernet
- Echo, multi path fading
- Clock drift
- Hum signals (low frequency signals)
- Peak impulses (short but high amplitude)
- …

Summary

- Communications is a subject on its own
  - We only scratched the surface!
- Communication engineers have developed many tricks to increase probability of detecting incoming signals correctly
  - Dynamic adaptation of code and modulation
- Important take-away
  - Coding and de-coding of physical signals
  - Multiple physical phenomena impact the quality of the received signal

Real world application



Problems and solution ideas

PHY layer provides coding and de-coding mechanisms for various interface types (wired, wireless, optical, …)

- What problems remain?
  - Discussion in small groups (10 minutes)
  - Presentation of findings (oral, no slides)