Karlsruher Institut für Technologie

Institut für Technik der Informationsverarbeitung

Prof. Dr.-Ing. Dr. h.c. Jürgen Becker *(becker@kit.edu)*

Dr.-Ing. Jens Becker *(jens.becker@kit.edu)*

Institut für Technik der Informationsverarbeitung (ITIV)

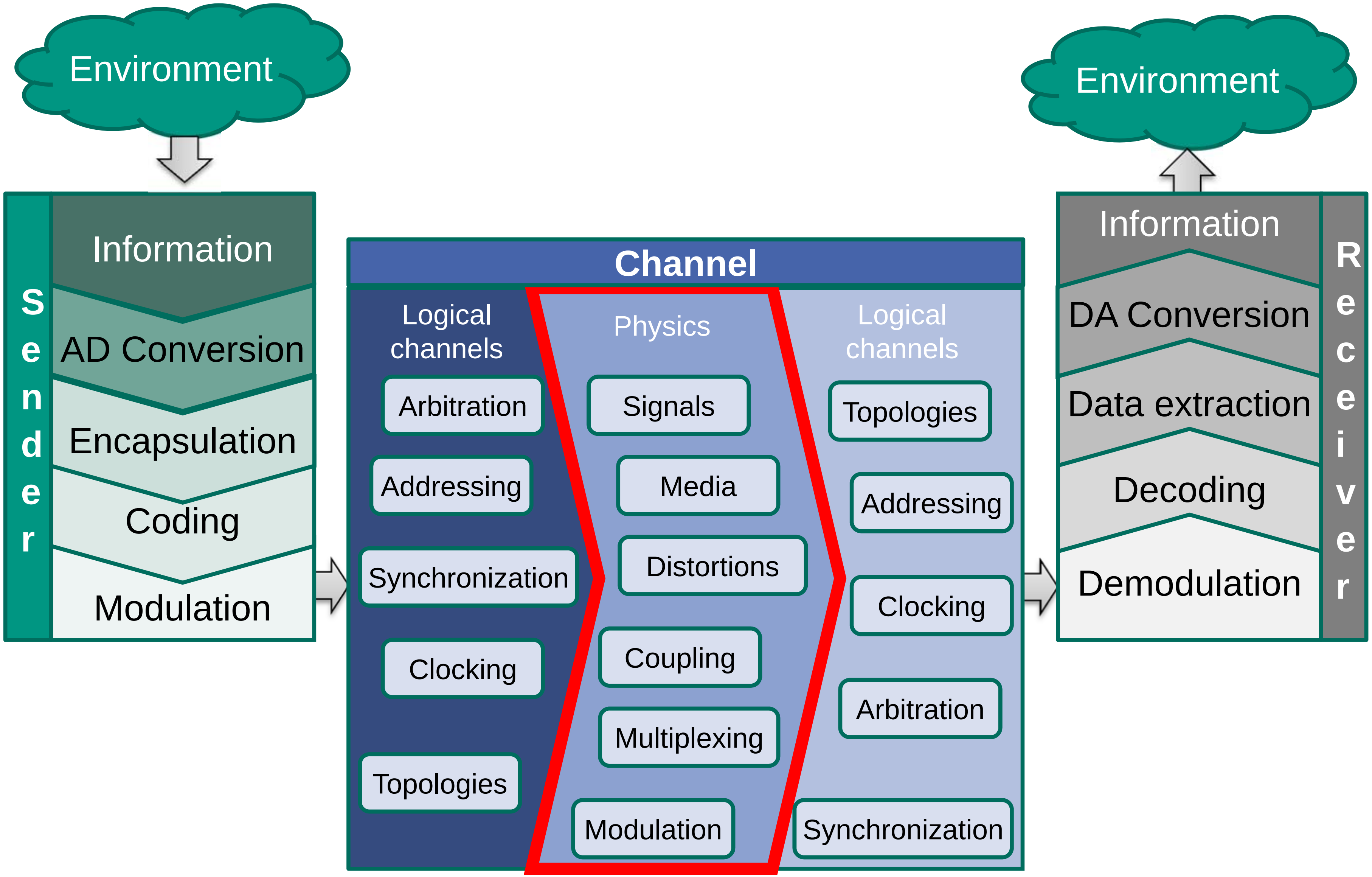
Communication Systems and Protocols

Physical Principles

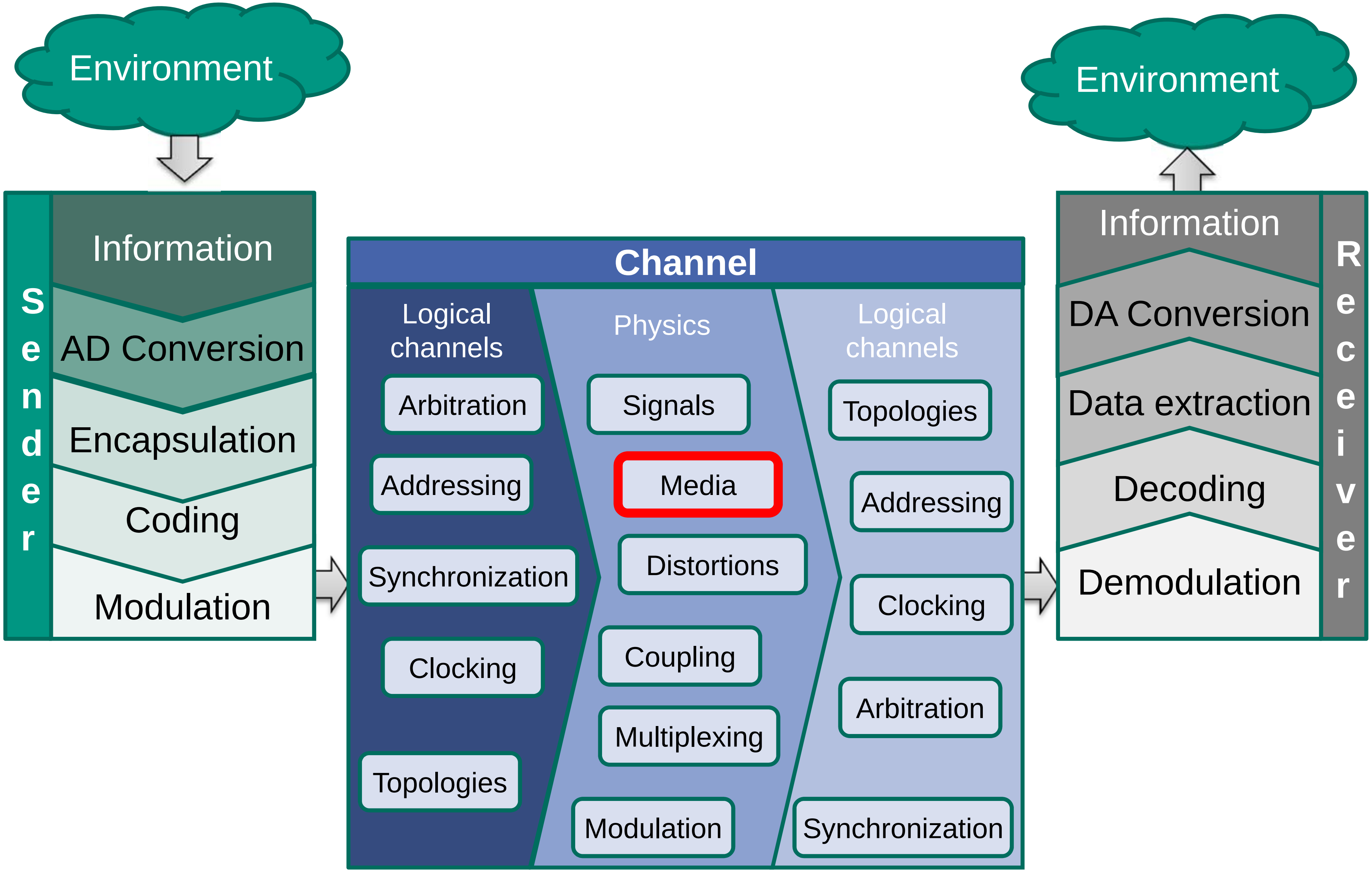
Recapitulation

- Results from Ilias survey

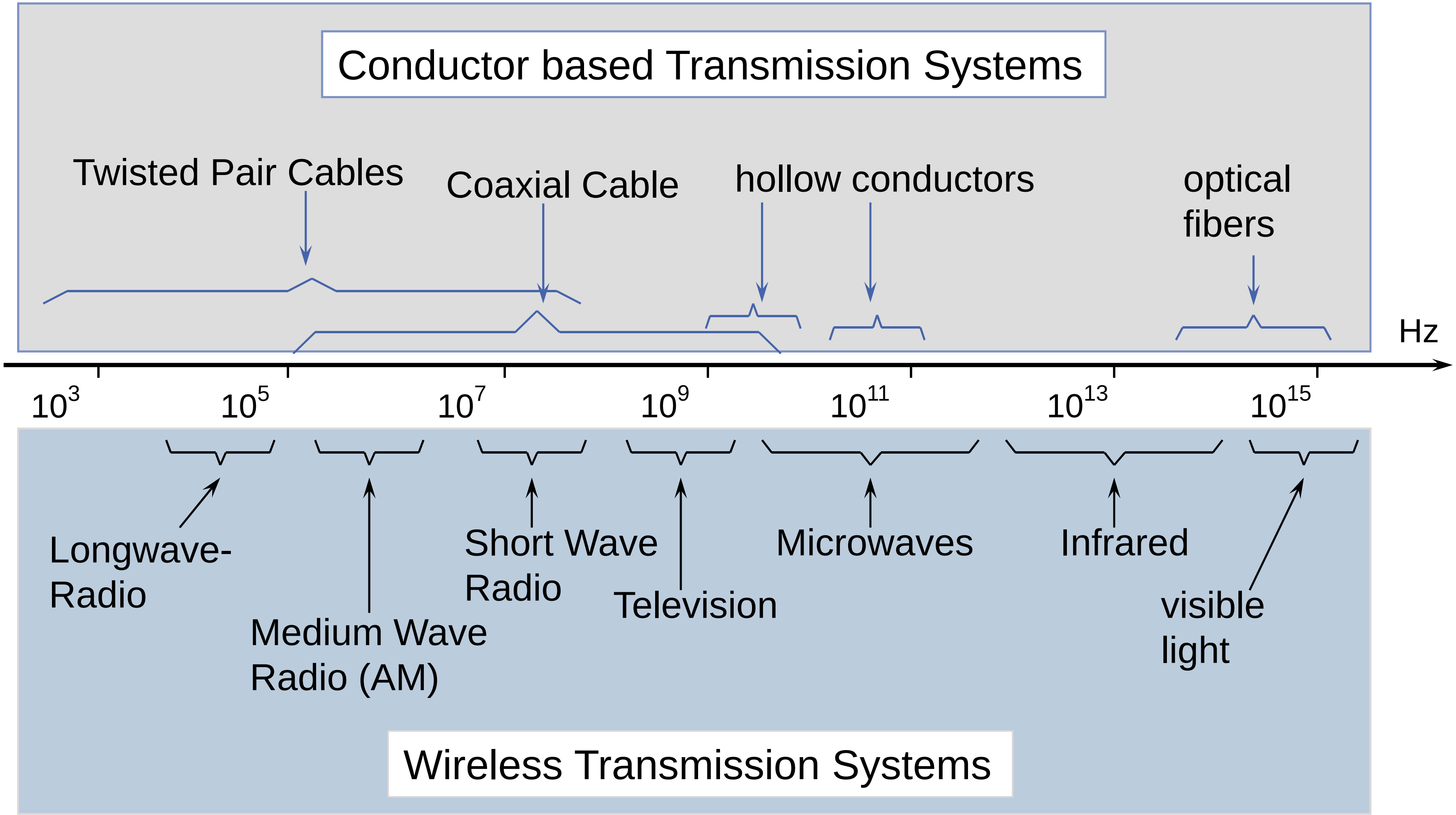
Technical Communication System (detailed)



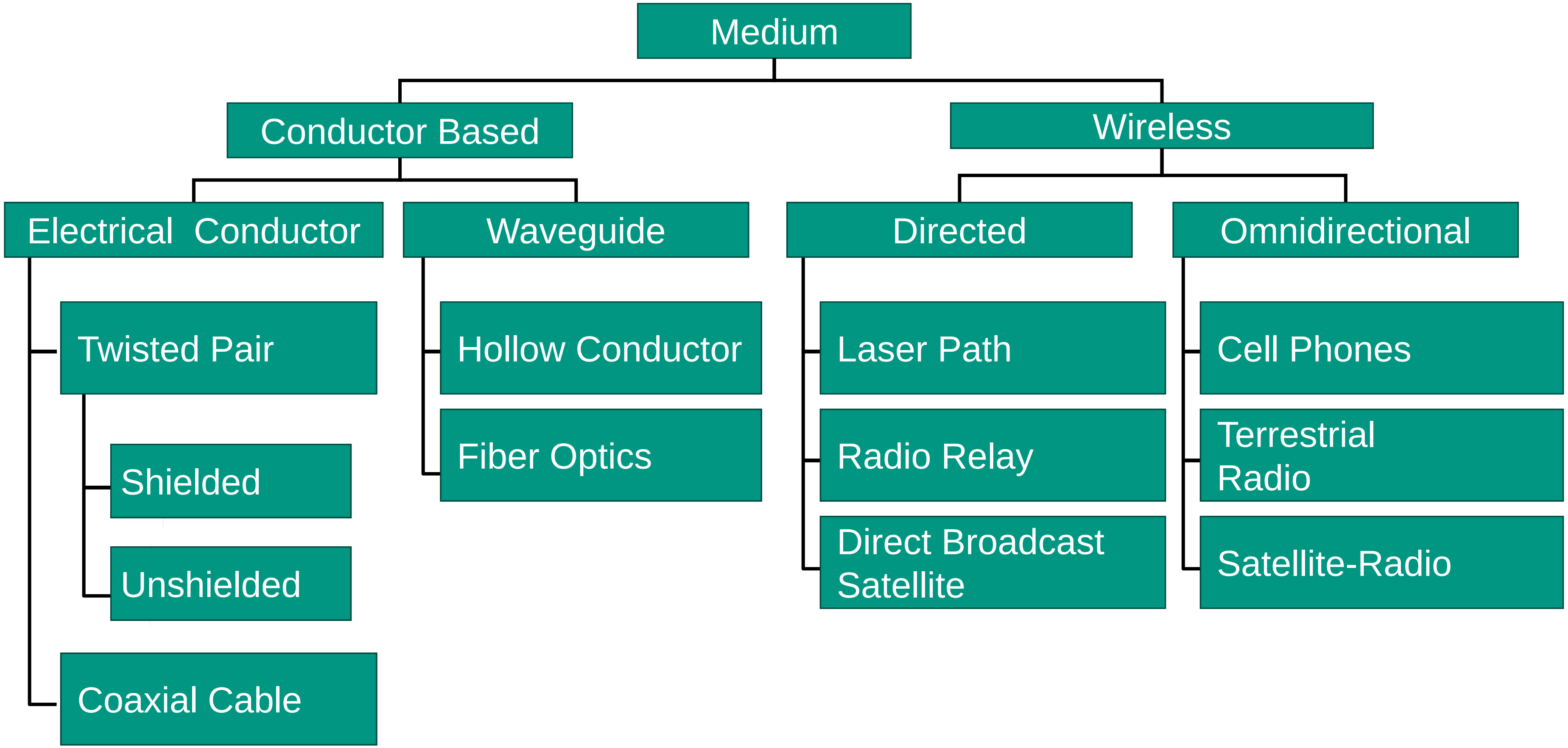
Transmission System – Media



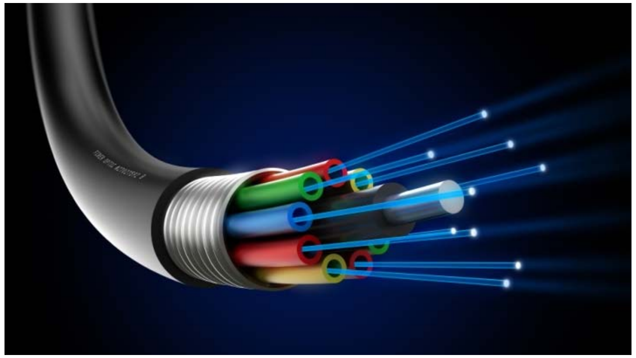
Usage of the electromagnetic Spectrum



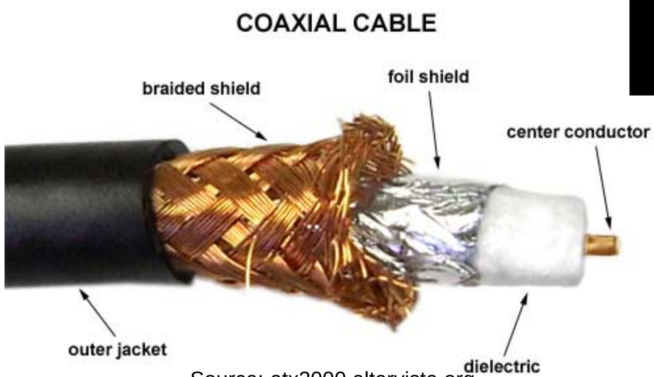
Medium: Classification



Examples for media



Source: datatalk.co



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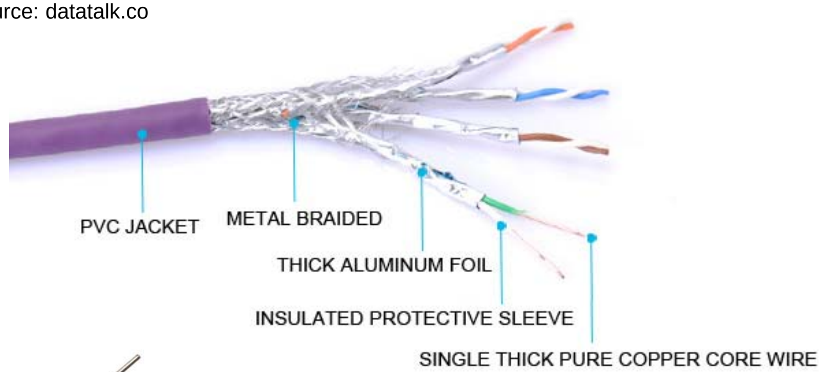
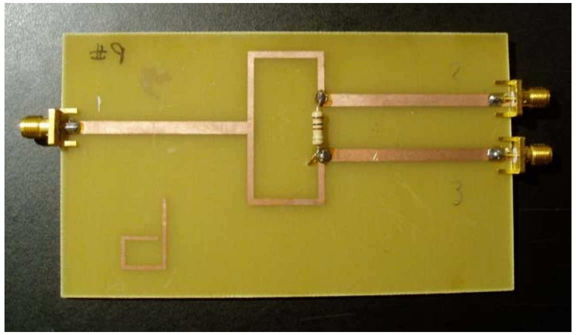
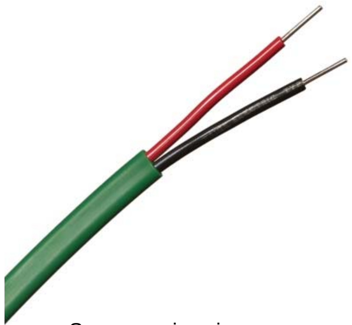


Source: vention.en.alibaba.com



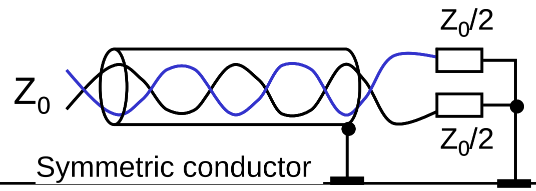
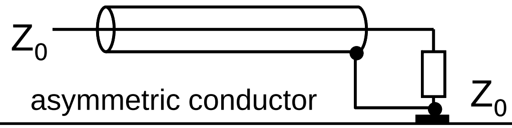
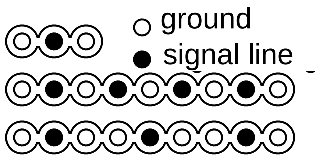
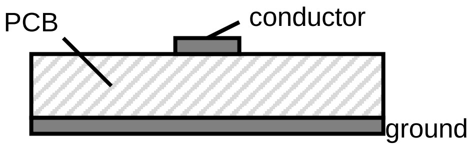
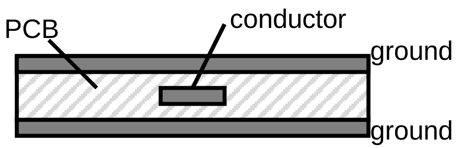
Source: individual.utoronto.ca/georgas



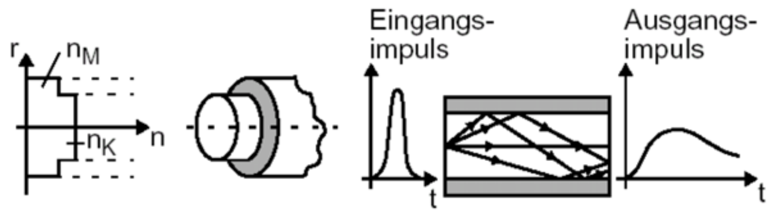
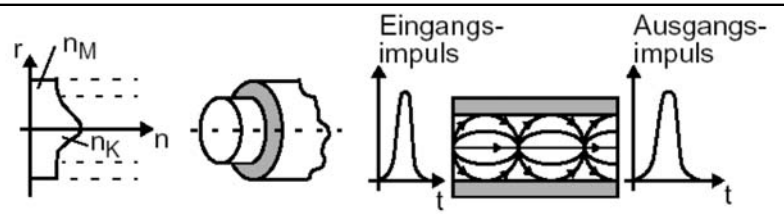
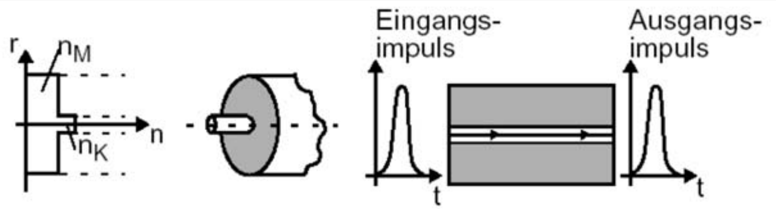
Source: paigewire.com

Source: jitmfg.com

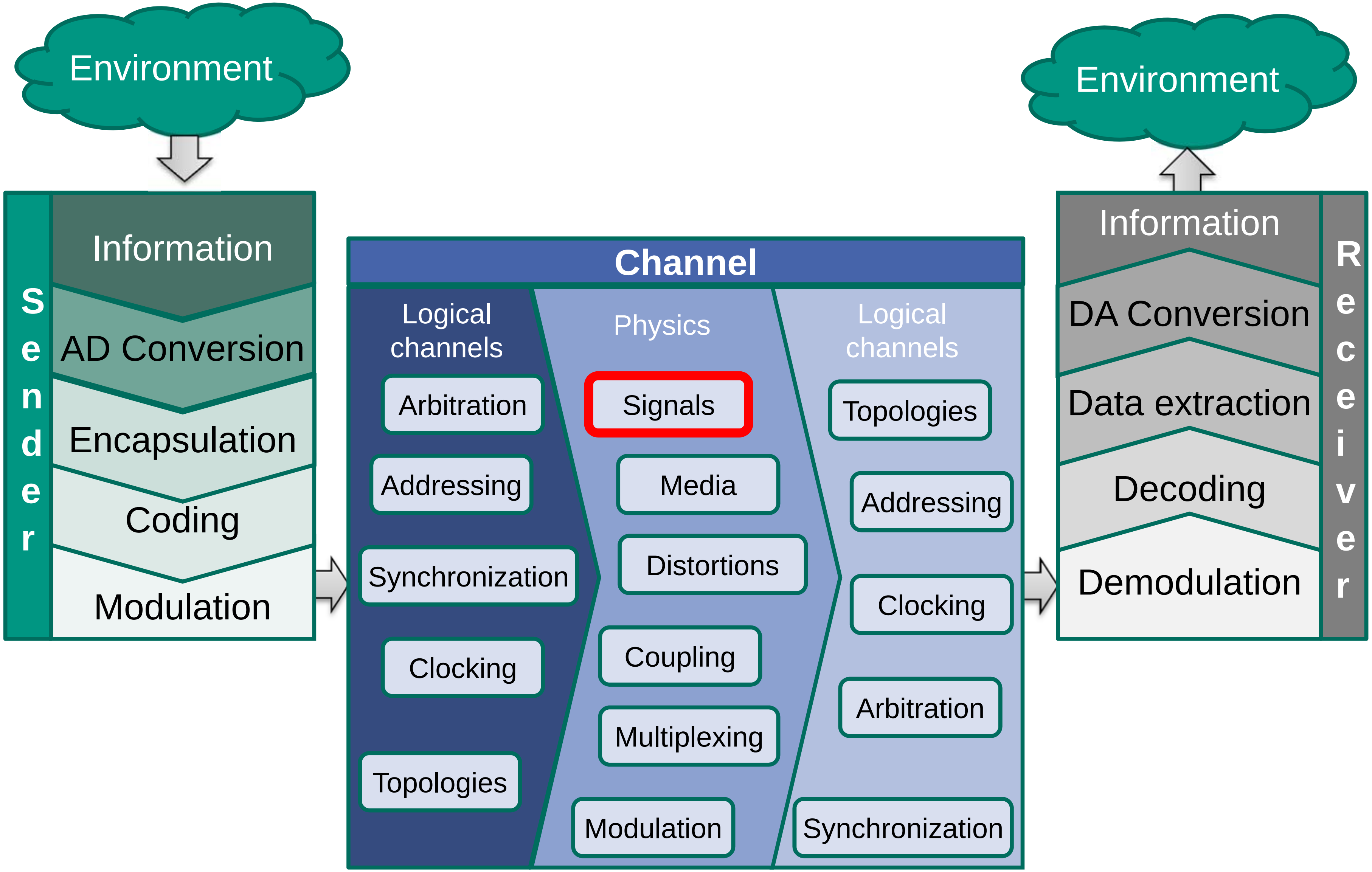
Selected Electrical Carrier Media

Type		Cross Talk	Application
Twisted Pair		medium ... low	Cheap serial busses in direct service area
Coaxial Cable			High Robustness
Ribbon Cable		high medium low	Parallel, flexible busses, Interconnects for PCBs
Microstrip		medium ... low	On PCBs and Backplanes
Stripline		low	On PCBs and Backplanes, robust

Optical Carrier Media

Type	Principle und Transmission Behavior	Characteristics
Stepindex-Multimode-Fibers		Large mode delays result in substantial pulse spreading
Gradientindex-Multimode-Fibers		Small mode delays result in minor pulse spreading
Stepindex-Monomode-Fibers		Very small mode delays result in almost accurate pulse transmission
Infrared Light	Application of infrared-LEDs und phototransistors 	Short ranged and direct line of sight is mandatory

Transmission System – Signals



Signals

- Definition:

  A **signal** is a function that conveys information about the behavior or attributes of some phenomenon.

  Roland Priemer (1991). Introductory Signal Processing. World Scientific.

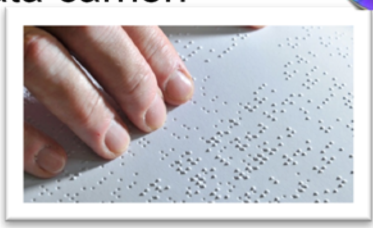
- Remarks:
  - Every physical quantity can form a signal
  - Physical quantity has to measurable and controllable in order to become a signal for communication purpose
  - Random signals do not carry information, therefore we do not treat them as signals.
  - Assignment of information to a signal is arbitrary
  - For this lecture, we focus on electrical signals

Clicker Session: Signals

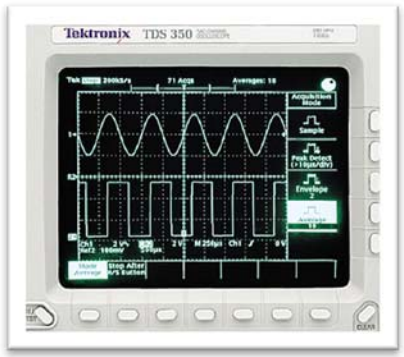
- https://arsnova.eu/mobile/#id/33969518

Signals and their Parameters

- Signal parameters
  - Physical value of a signal representing information, either through its direct value or its variance of value over time
    - With spatial signals, the value of a signal parameter is a function of its location e.g. location of data on a data carrier.

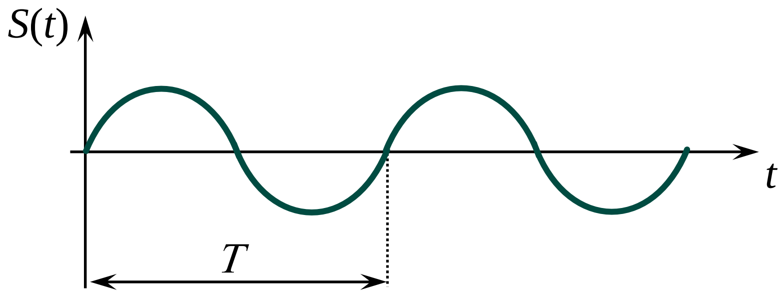



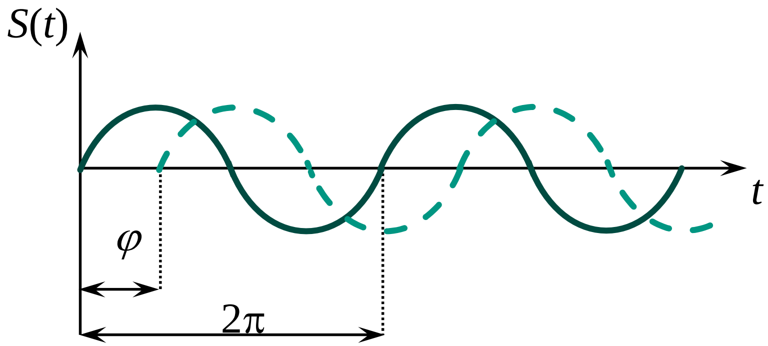

    - With time variant signals, the value of a signal parameter S is a function of time S=S(t)

Periodic and digital Signals

- Parameter of periodic signals: Period T, Frequency 1/T, Amplitude S(t), Phase φ
- Examples:
  - Sine Wave
  - Phase difference φ

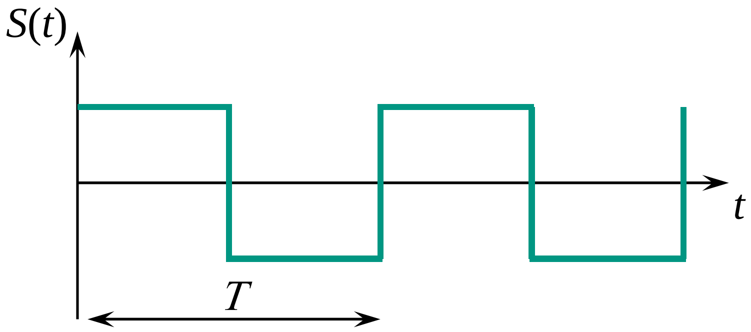




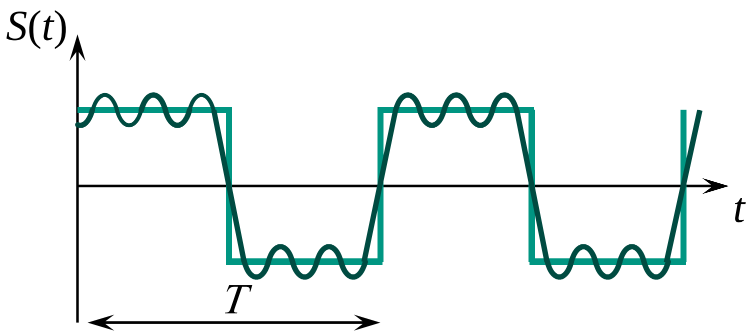
Beyond sinus

- Problem: Many signals are not sinus-formed. How do we model them?

- Example: Square wave („idealized“)



- Solution: Approximation of other signals by sum of sinus signals → Fourier



Signal Representation via Fourier Series

Joseph Fourier, 1822: Every *periodic signal s(t)* can be described as:

- Sum of cosine- and sine-waves of varying frequencies

$$s(t) = \frac{A_0}{2} + \sum_{n=1}^{\infty} \left(A_n \cos(n\omega t) + B_n \sin(n\omega t) \right)$$

- Sum of cosine functions of varying frequencies and phase positions

$$s(t) = \frac{A_0}{2} + \sum_{n=1}^{\infty} C_n \cos(n\omega t + \varphi_n) \quad \text{with } C_n = \sqrt{A_n^2 + B_n^2}$$

$$\varphi_n = \arctan(B_n / A_n + k\pi)$$

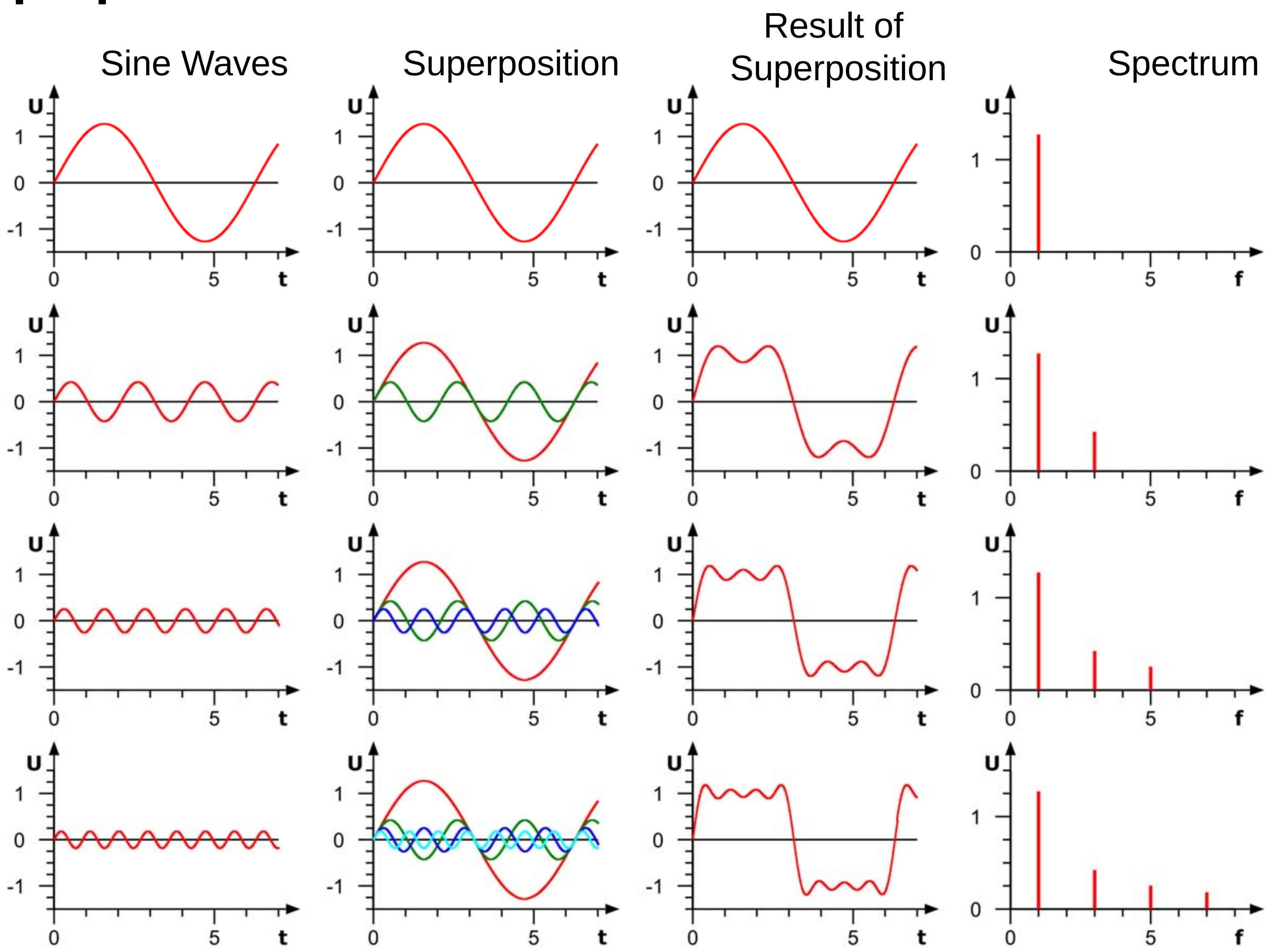
with

$\frac{A_0}{2}$ signal offset

$\omega = 2\pi f_0$ fundamental or first harmonic

$\omega_n = n 2\pi f_0$ n-*th* harmonic

Superposition of Sines



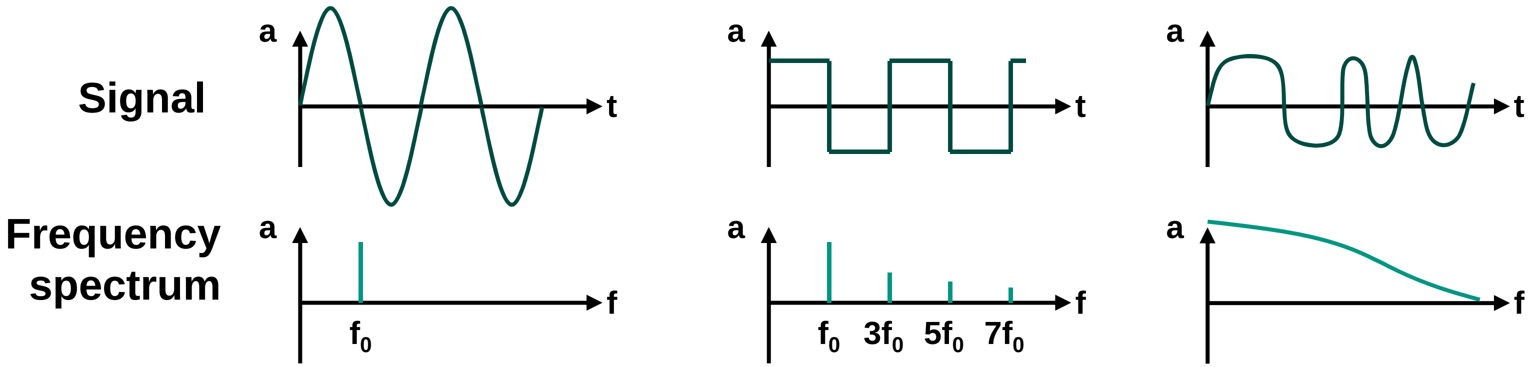
Source: wikimedia commons

Application to non-periodic Signals

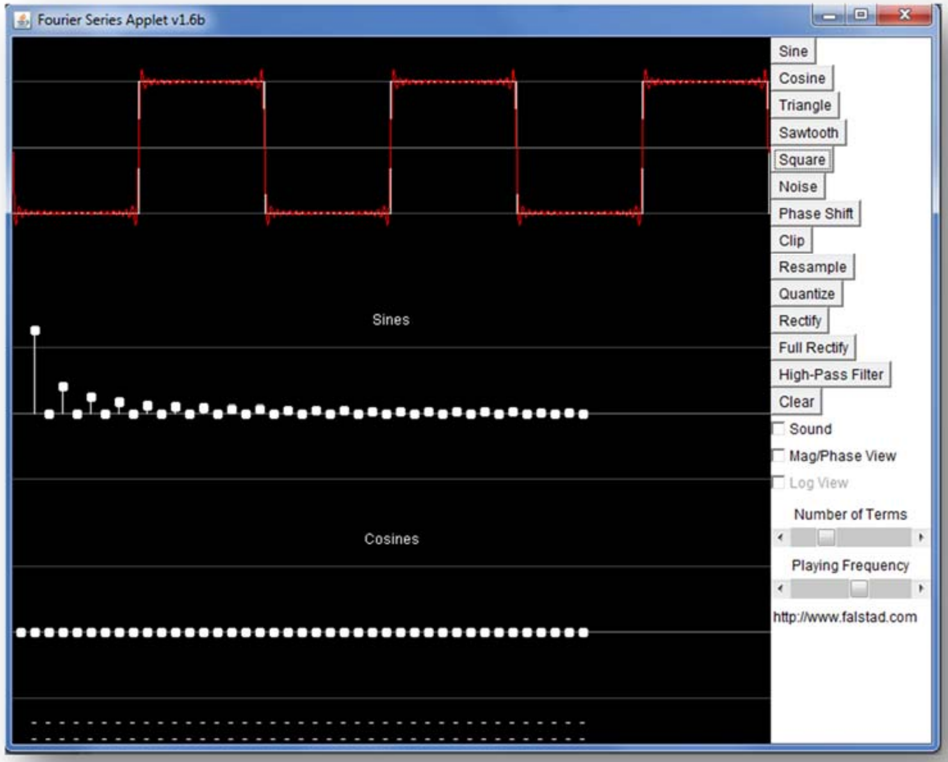
- A non-periodic, finite signal can be seen as *one* period of a periodic signal with an infinite cycle time
  - The discrete line spectrum is turned into a continuous spectrum
  - Summation of the series decomposition is transformed to an integration

$$S(f) = \int_{-\infty}^{\infty} s(t) \cdot e^{-j2\pi ft} dt \quad \text{Fourier Transform}$$

$$s(t) = \int_{-\infty}^{\infty} S(f) \cdot e^{j2\pi ft} df \quad \text{Fourier Reverse Transform}$$

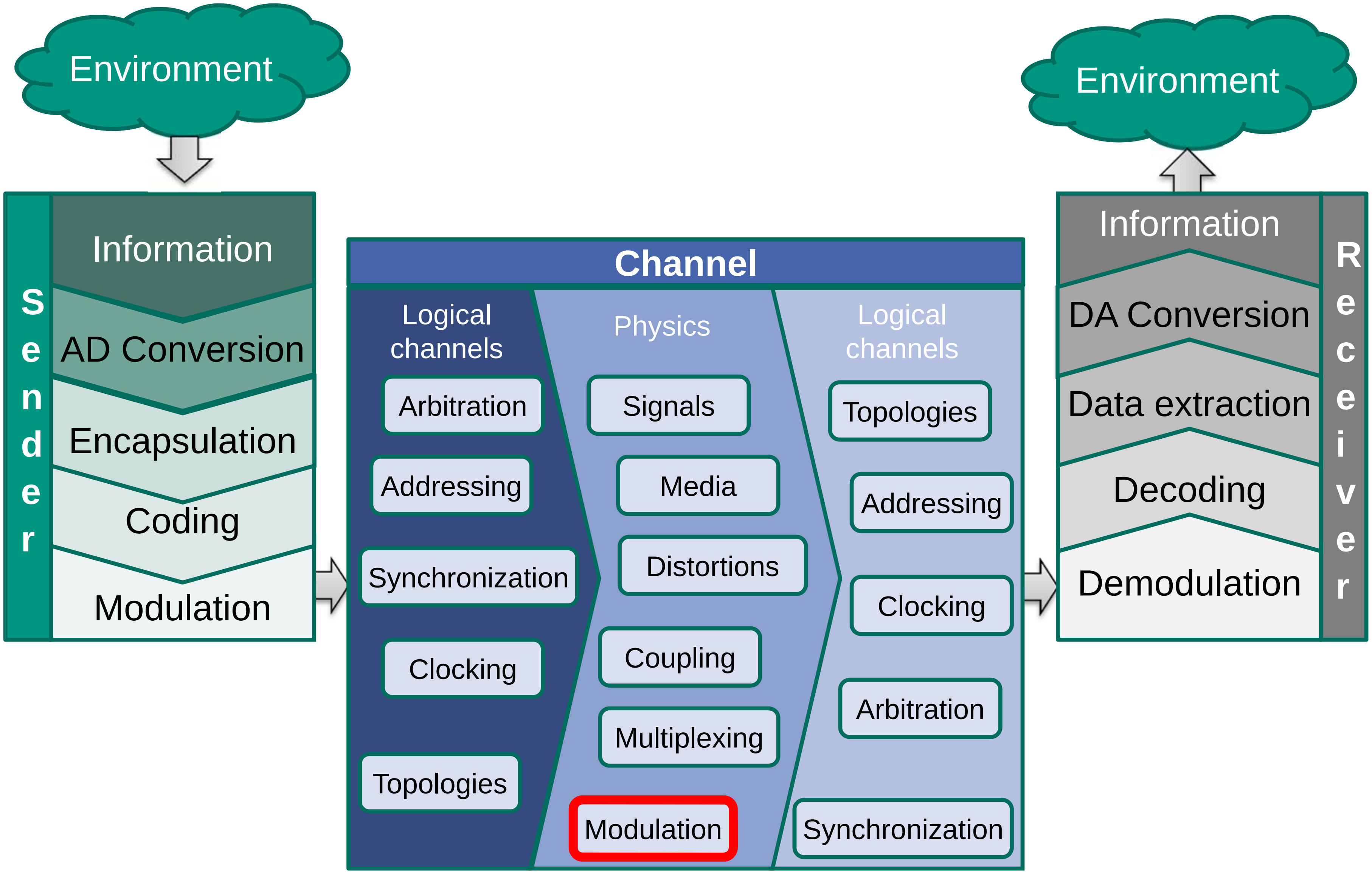


Example Applet



- http://www.falstad.com/fourier/

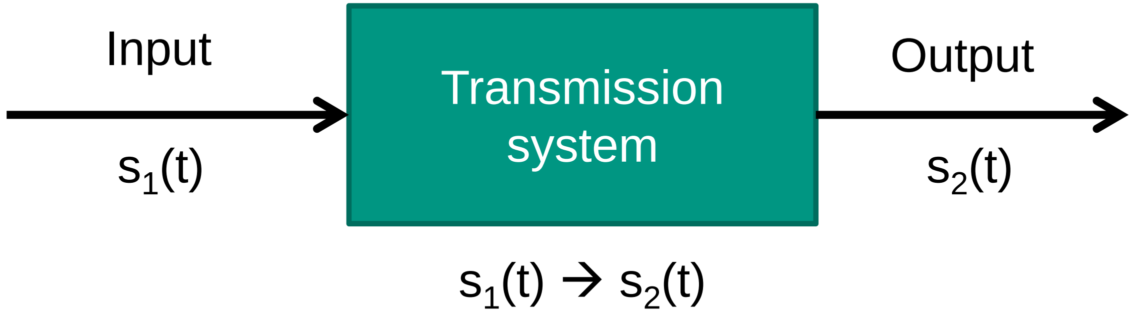
Transmission System – Modulation



System theory: Transmission system

- Definition: Transmission system

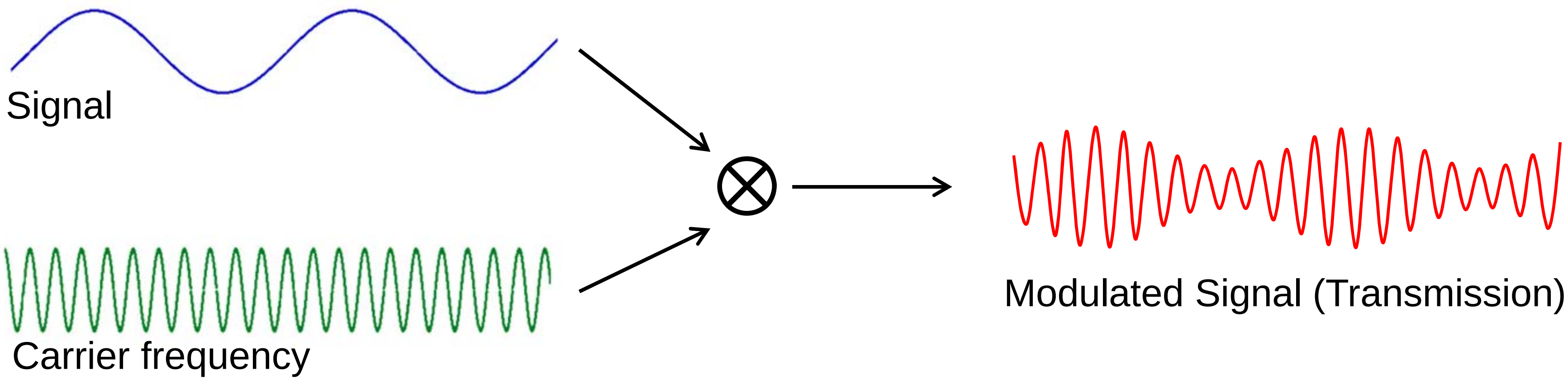
  A **transmission system** is a mathematical model that describes the transmission behavior of a complex arrangement. It provides a mathematical unique mapping of an output signal to an input signal.
  The mapping is often called *transformation*.



Modulation

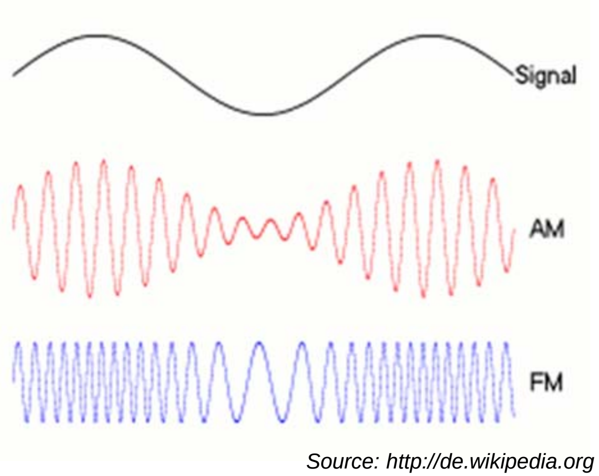
- With band limited channels it is generally not possible to use an (ideal) base band transmission

- Modulation:
  - Changing characteristics of a carrier frequency
  - Changes are proportional to control signal
  - Receiver measures characteristics and reconstructs the initial control signal from it



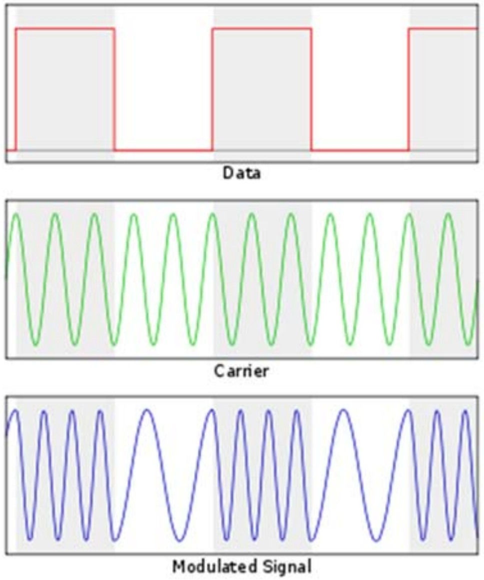
Modulation Techniques

- Modulation in the analog domain
  - unlimited number of signal values
  - continuous variation of signal values



Source: http://de.wikipedia.org

- Shift-Keying in the digital domain
  - only discrete signal values possible
  - switches from one signal value to the next

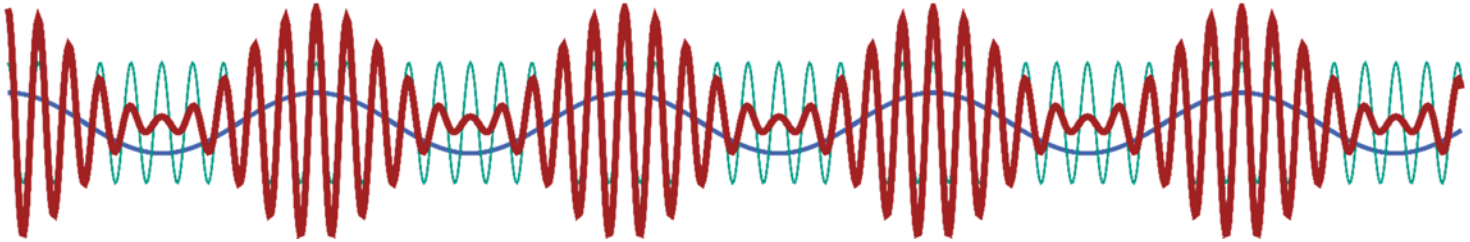


Source: http:// en.wikipedia.org

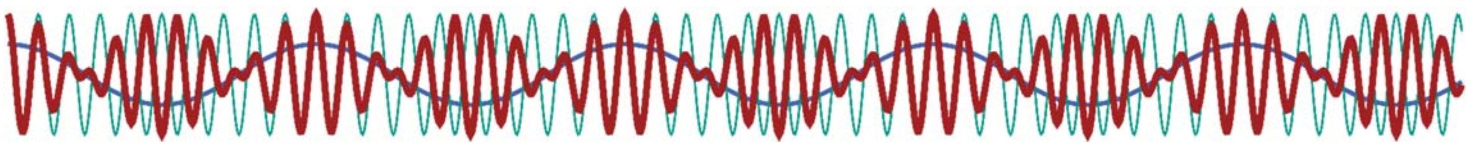
Amplitude Modulation

- Signal: $x(t) = a\ \cos(2\pi f t + \varphi)$
- carrier wave amplitude a_C and frequency f_C
- modulation index μ

- Modulated Signal: $x_c(t) = a_C\big(1 + \mu\, x(t)\big)\cos(2\pi f_C t)$



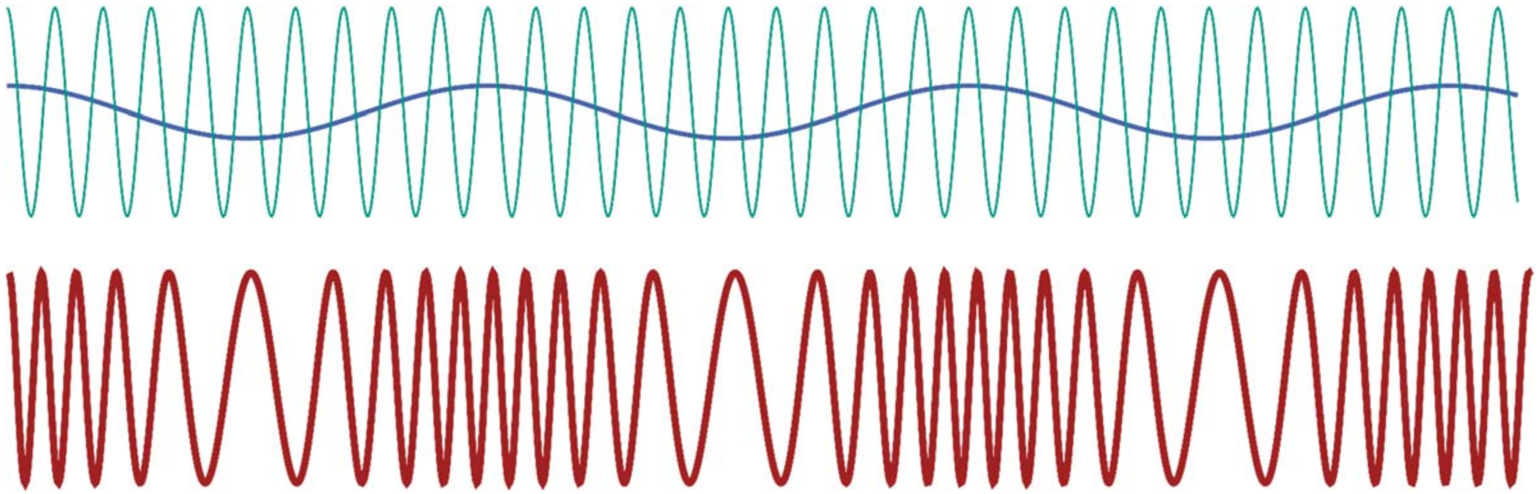
- Double side band suppressed carrier: $x_c(t) = a_C x(t)\cos(2\pi f_C t)$
  - wave carrier is not transmitted



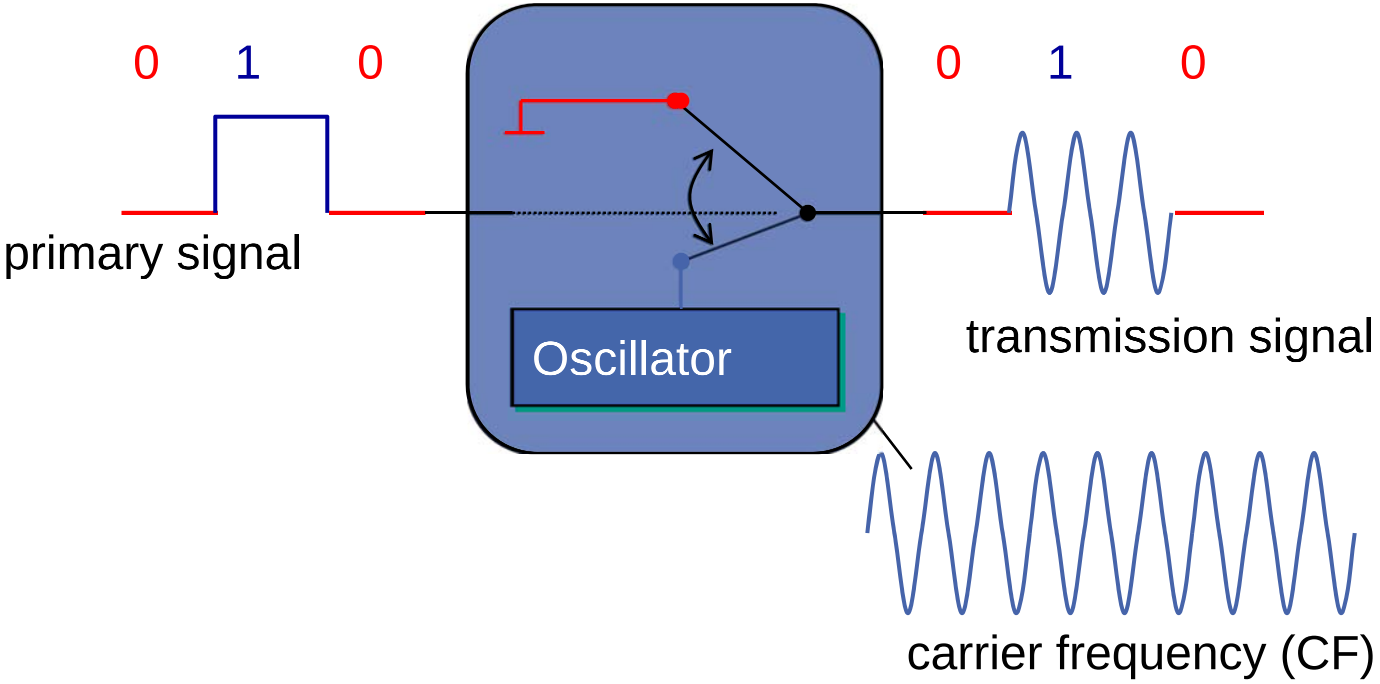
Frequency Modulation

- Signal: $\mathrm{x(t)} = a\ \cos(2\pi f t + \varphi)$
- carrier wave amplitude a_C and frequency f_C
- modulation index β

- Modulated sinusoidal Signal: $x_c(t) = a_C \cos(2\pi f_C + \beta \sin(2\pi f t))$

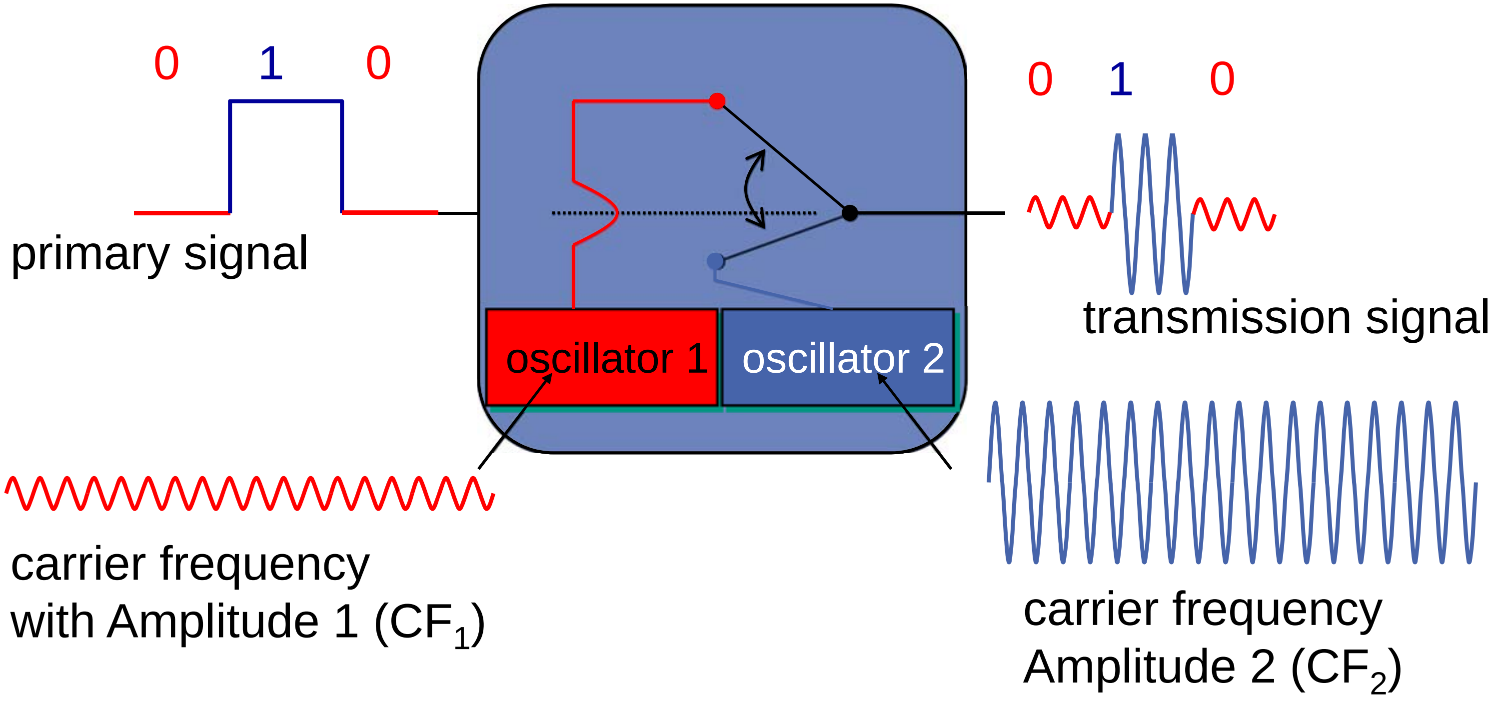


Amplitude Shift Keying I



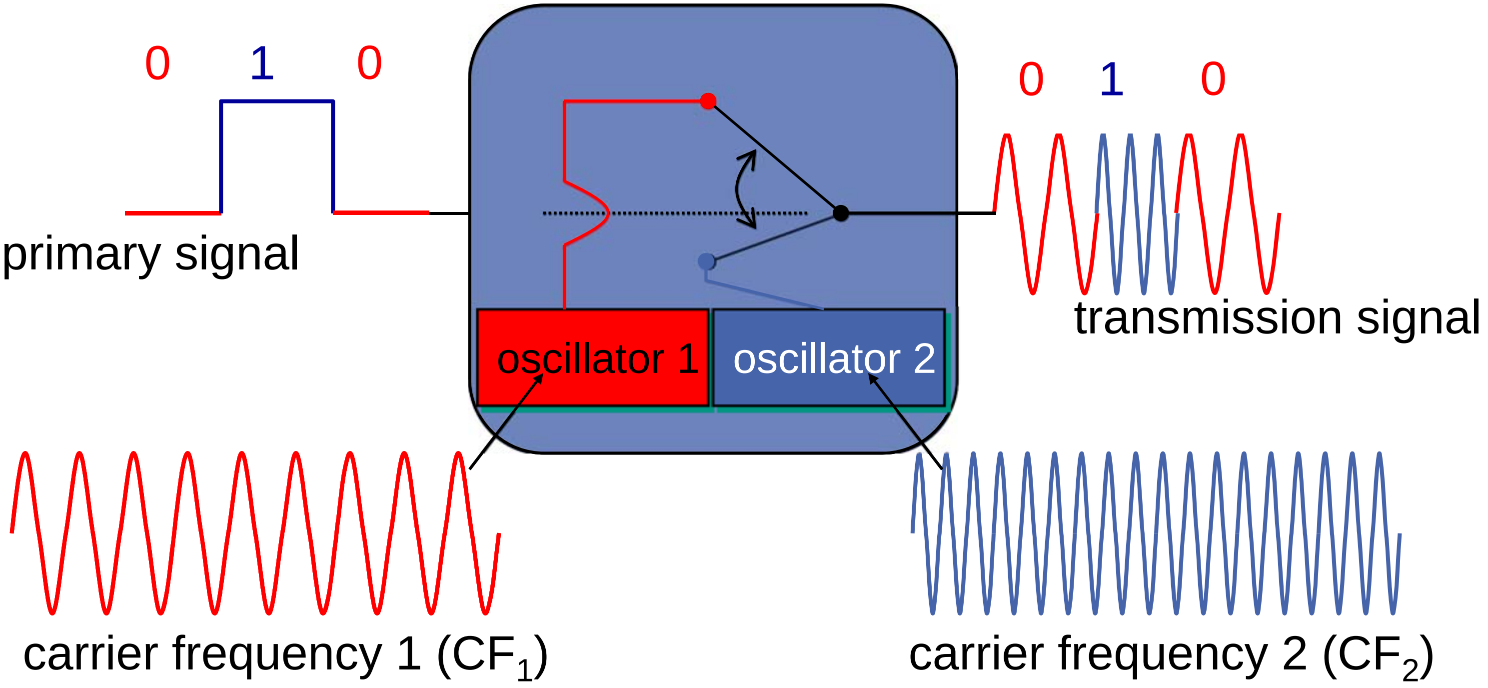
- Primary signal is modulated onto the carrier frequency by altering the amplitude.
- Amplitude modulation is highly susceptible.
- Example: Morse Code

Amplitude Shift Keying II



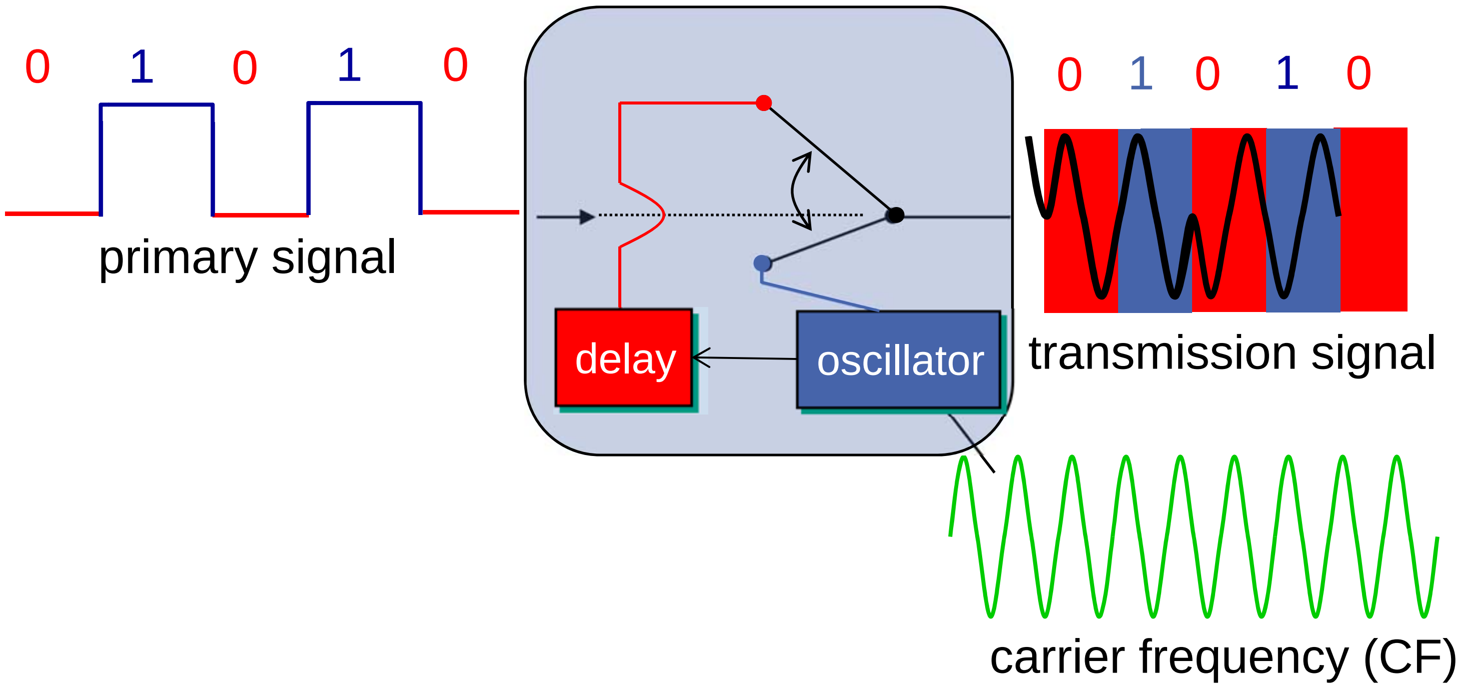
- Primary signal is modulated onto the carrier frequency by altering the amplitude.
- Amplitude modulation is highly susceptible.
- Detection of long runs of 1s requires stable clock generators

Frequency Shift Keying



- Primary signal is modulated via dedicated changes of the carrier frequency
- One of the uses of frequency modulation is the scheme used for VHF terrestrial radio

Phase Shift Keying

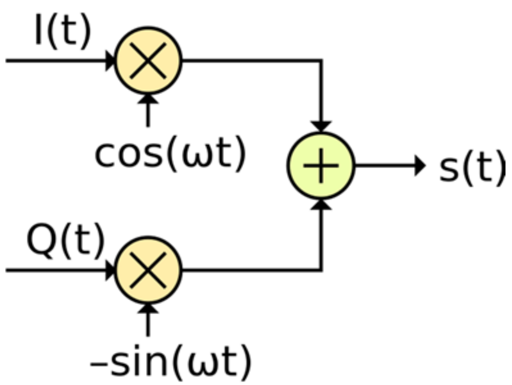


- primary signal is modulated using dedicated jumps in phase of the transmission signal
- Two methods possible
  - Absolute PSK: '0': no phase shift (in comparison to a reference phase)
    '1': phase shift (in comparison to a reference phase)
  - Relative PSK : '0': no phase shift (in comparison to phase of previous bit)
    '1': phase shift (in comparison to phase of previous bit)

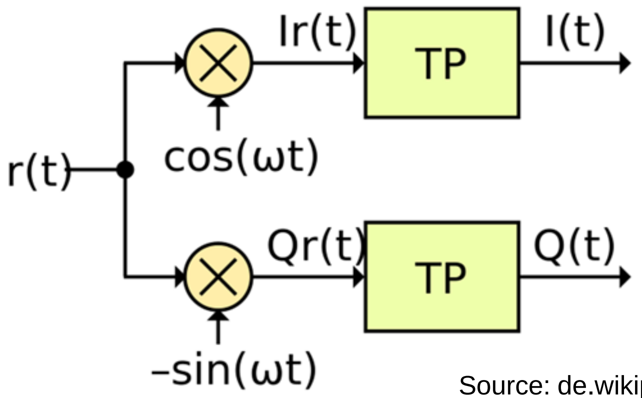
Quadrature Amplitude Modulation (QAM)

- Usage of two sine carrier signals that are shifted 90° to each other
  → Signals do not interfere with each other
  - One signal is called *In-phase component (I)*
  - Other signal is called *Quadrature Component (Q)*
- These two signals are added up to form the sender signal *(IQ-Modulation)*
- Demodulation requires same phase in sender and receiver → additional measures required

QAM-Modulation



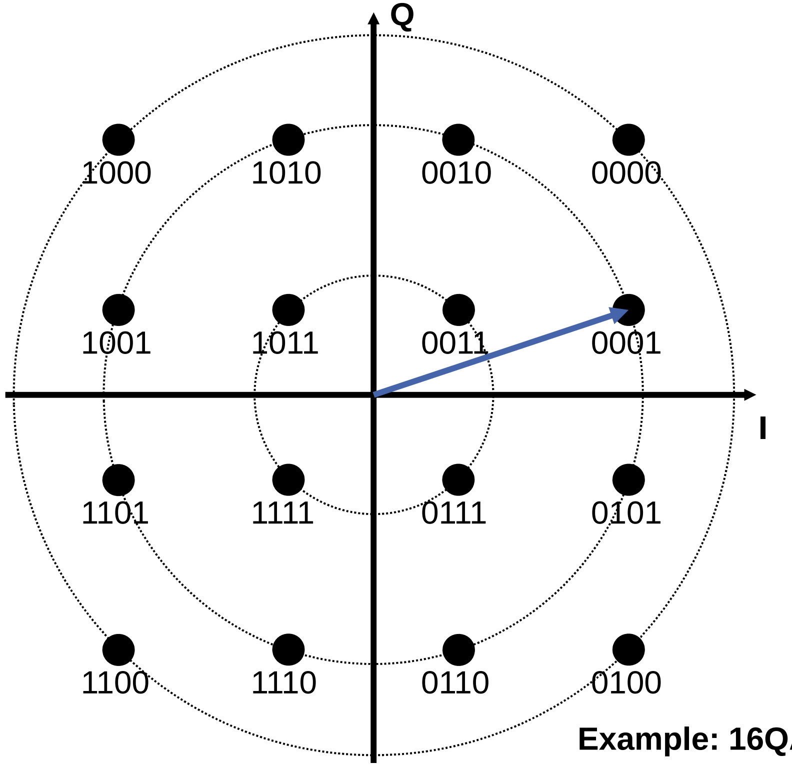
QAM-Demodulation



Source: de.wikipedia.org

Quantizied QAM: Constellation diagram

- The two QAM carriers can be represented in a two-dimensional diagram → **constellation diagram**
- When using discrete and independent signals, each point in the constellation diagram can represent more then one bit



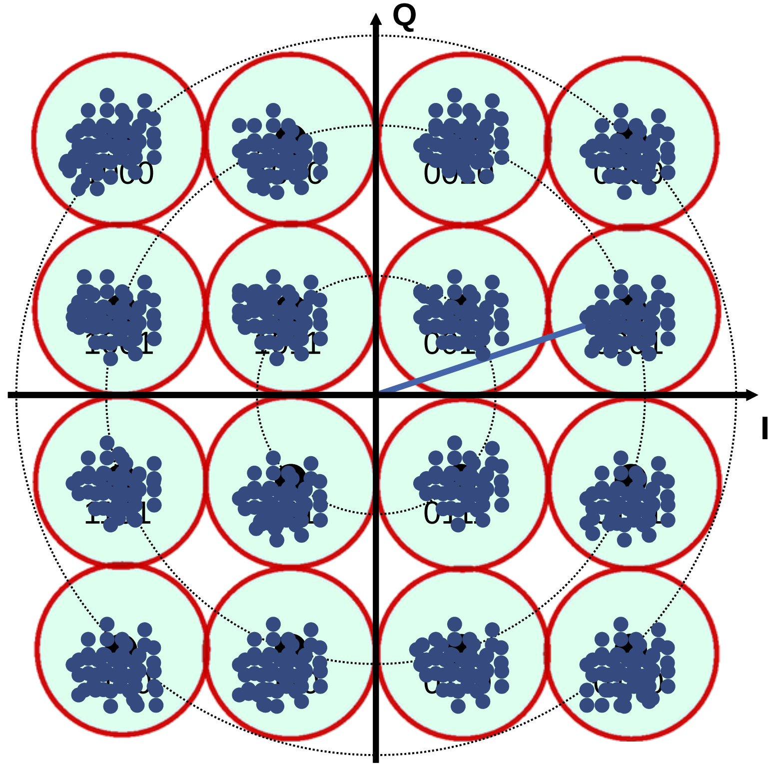
Example: 16QAM

QAM: placement of constellation points

- Signal is influenced by noise during transmission
  - Received signals are not at the ideal positions
  - Acceptance radius is required to define valid ranges for each point

Positioning of signal points:

- Maximize distance of points to avoid misinterpretation of a signal



In General:

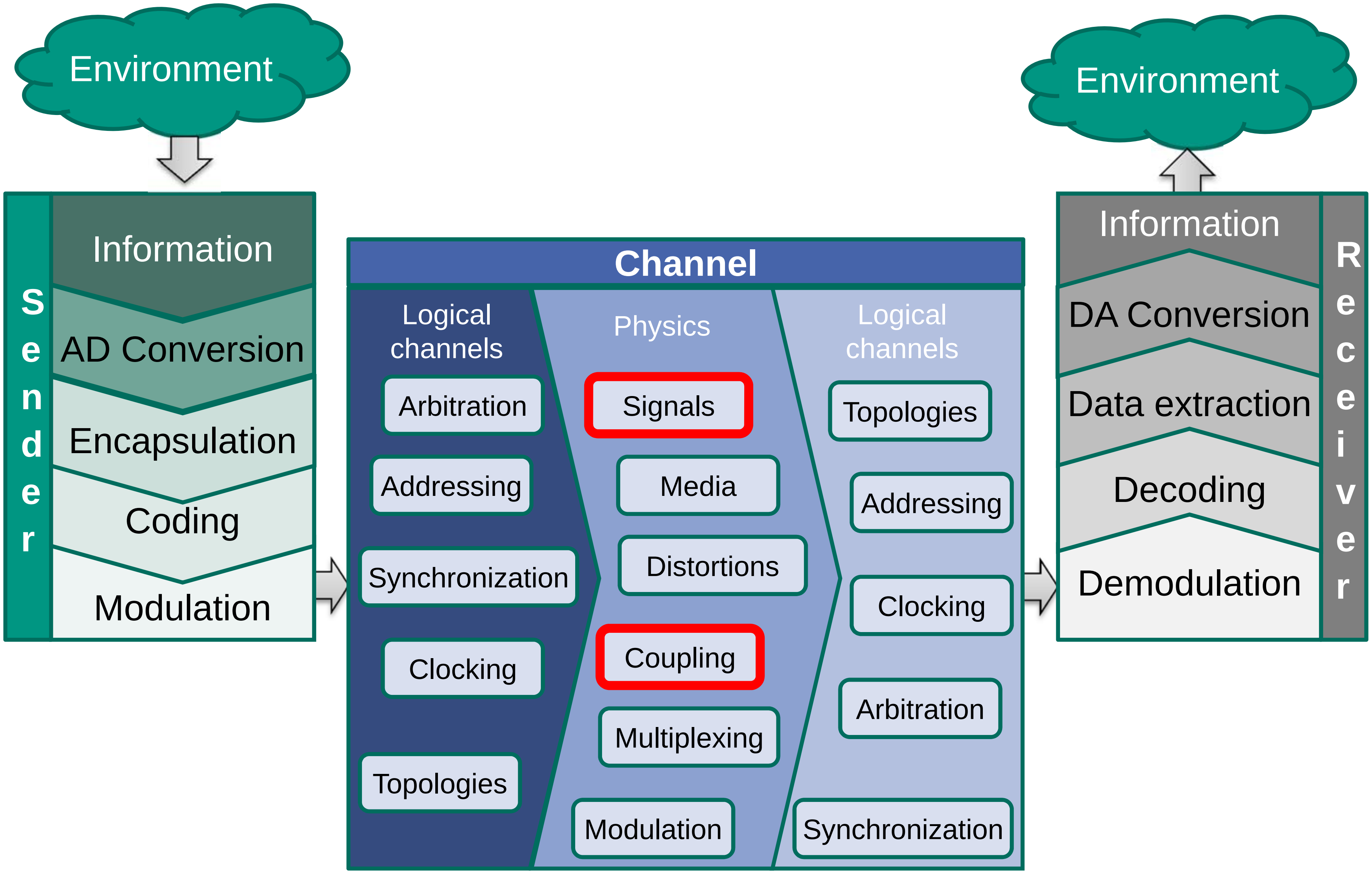
- More points allow more bits per signal (higher data rates) but require better signal-to-noise ratios

→ Trade-off required

Clicker Session: Modulation

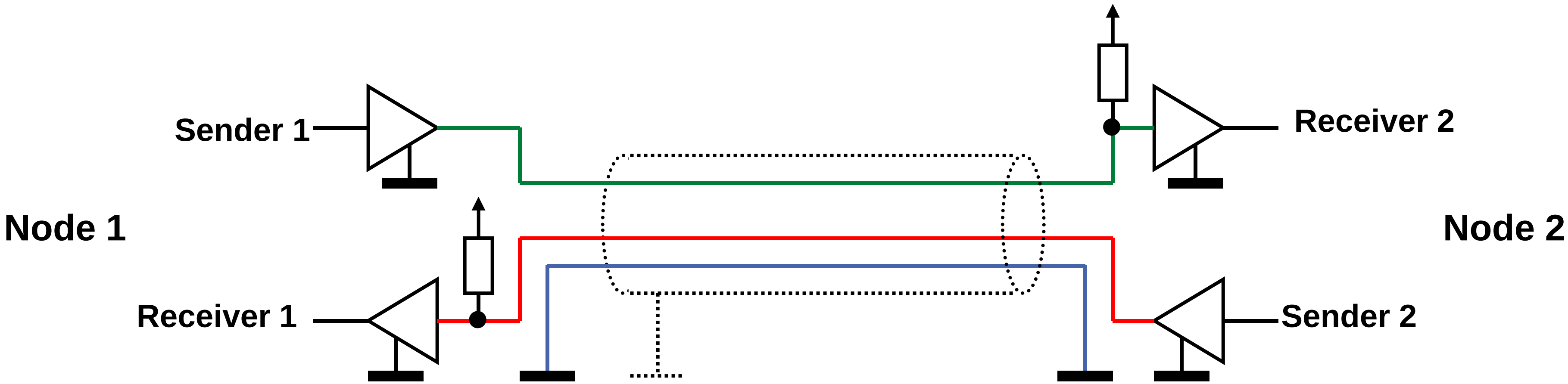
- https://arsnova.eu/mobile/#id/33969518

Transmission System – Electrical Drivers



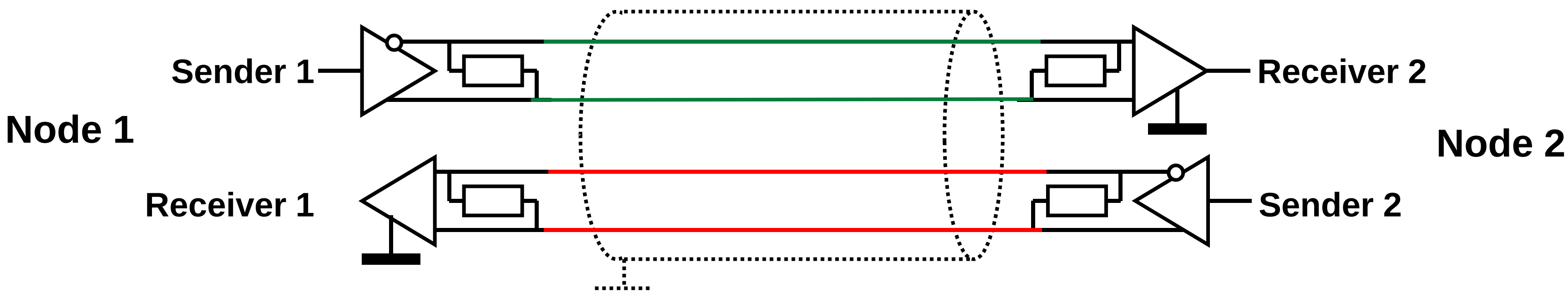
Unbalanced lines

- Unbalanced lines are transmissions lines whose conductors have unequal impedances with respect to ground
- One dedicated conductor per signal
- Second conductor is shared (or ground)
- Increased interference liability, e.g. cross talk
  - Additional shielding can minimize interference effects



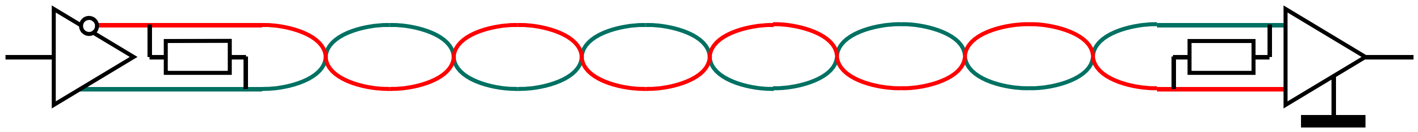
Balanced Lines

- Balanced lines have two conductors of the same type
  - Equal impedances along theirs lengths
  - Equal impedances to ground and other circuits
- Advantage:
  - Noise has the same effects on both conductors
  - External noise can be canceled out when using a differential amplifier as receiver

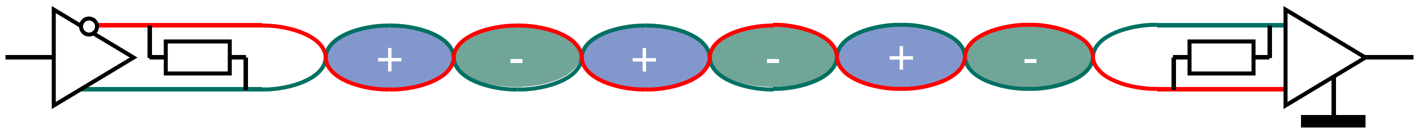


Balanced lines: Twisted-Pair-Cable

- Two conductors of a single circuit are twisted together



- Purpose: Protection against electromagnetic interference from external sources
- Principle: voltage induced in one conductor loop is canceled by induced voltage in next inverted loop

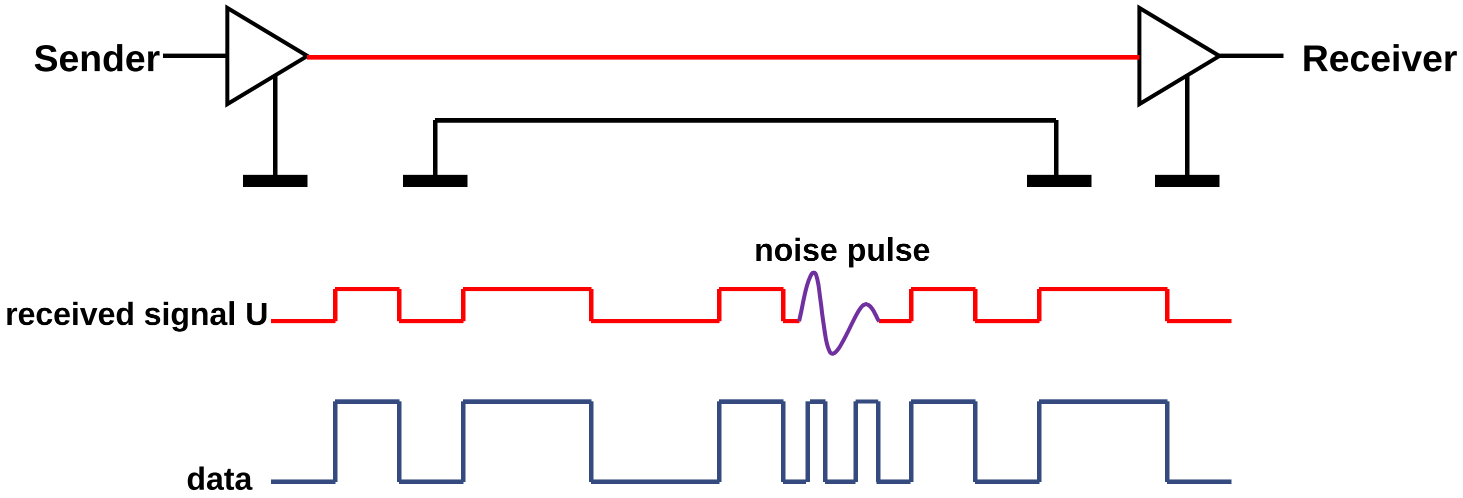


- Often used together with symmetric signaling

Single-ended signaling

- Sender generates a single voltage
- Receiver compares this signal with a fixed reference volatge
- Sender and receiver share the same ground

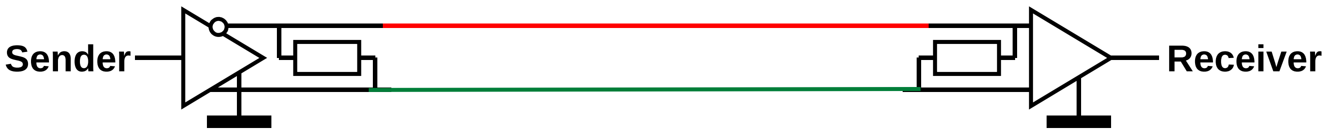
- Sensitive to noise
  - Floating ground
  - Interferences

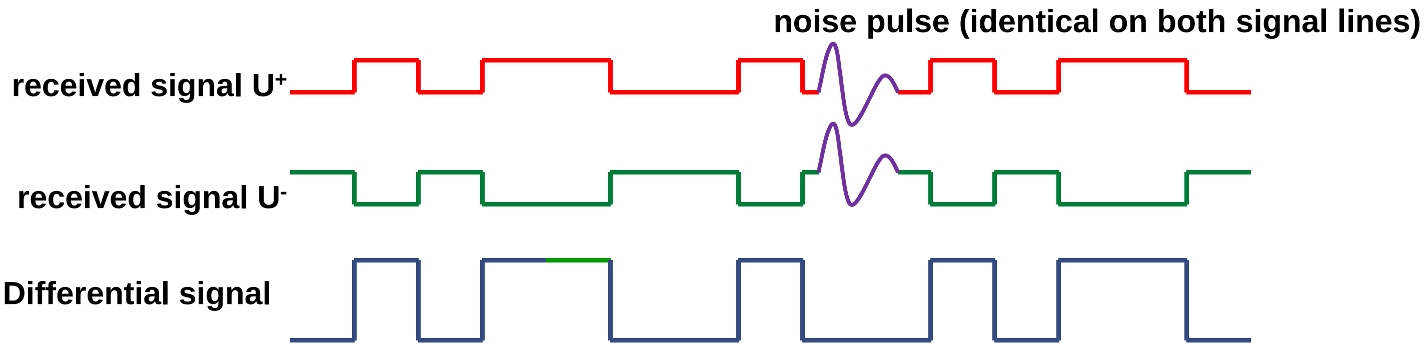


Differential signaling

- Transmission of each signal over dedicated signal paths using inverse signal voltages

- Electric potential between signal lines is doubled
  - Longer distances or smaller voltage levels possible
- Inherent compensation of disturbances





Motivation electrical drivers

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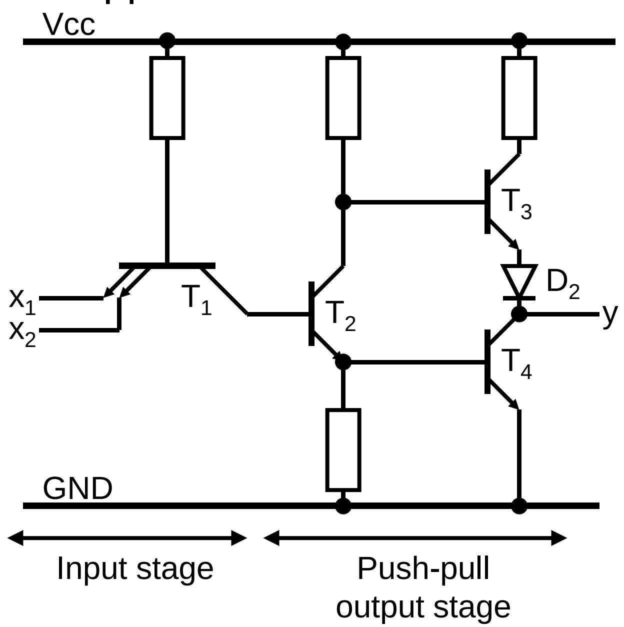
- Purpose of electrical drivers:
  - Different voltage levels for circuit and signal line
  - Higher currents needed for long signal lines
  - Adding additional noise resistance (e.g. differential signaling)

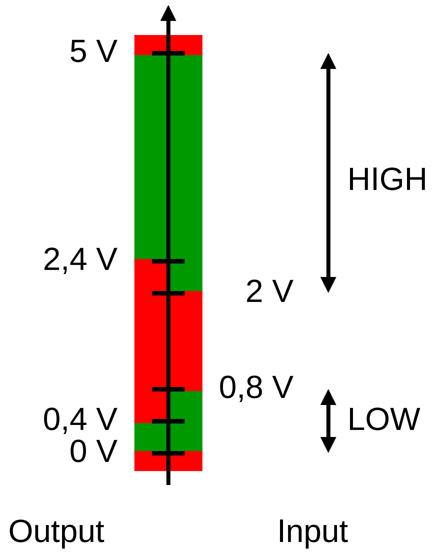
  - Busses require multiple senders and receivers to be coupled using one shared media

Electrical Output Driver

- Transistor-Transistor-Logic (TTL)
  - Earlier the most common used technology
  - Provides for a high current delivery
  - TTL level
    - Valid HIGH and LOW areas are wider at the input due to possible voltage drops on the lines
    - Asymmetric division since the HIGH level drops under load which does not happen to the LOW level



TTL basic gate (i.e. SN 7400)



TTL level

Outlook for next lexture

- Bus drivers
- Reflection on wires
- Distortions
- Signal classes