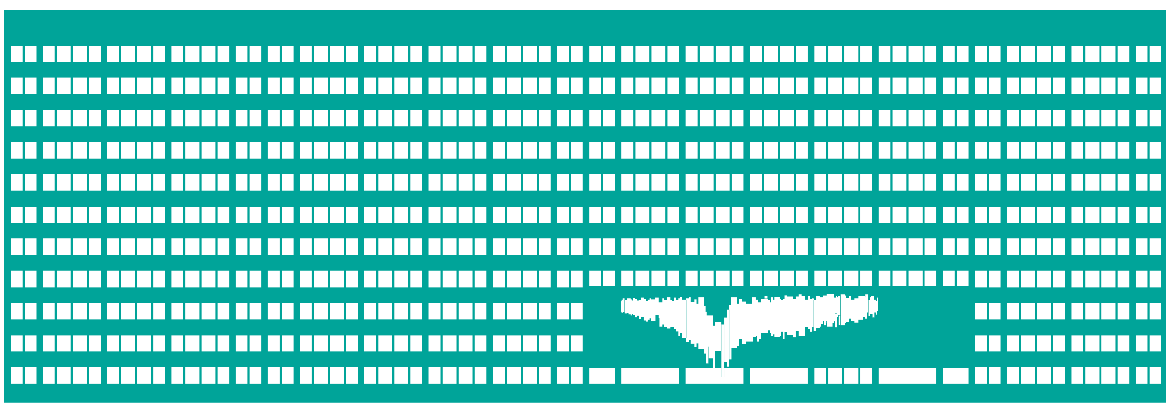
VSB TECHNICAL UNIVERSITY OF OSTRAVA | FACULTY OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE | DEPARTMENT OF COMPUTER SCIENCE

Basic Principles of Data Transfer



Computer Networks
Lecture 1

Classification of Data Transfers

Classification According to the Direction of the Communication

- Simplex – signal can flow in only one direction
  - Example: TV broadcasting
- Half duplex – communication is possible in both directions, but only one direction at a time (i.e. not simultaneously)
  - Examples: "walkie-talkie" 2-way radio, Ethernet stations connected by a hub
- Full duplex – allows communication in both directions simultaneously
  - Example: Switched Ethernet

Parallel and Serial Communication

- Parallel - multiple bits transmitted in parallel
- Serial – data are transmitted bit-by-bit
  - asynchronous
  - synchronous

In computer networks, the serial communication is mostly used

→ because of the cost of the cable plus the media interface circuitry and synchronization difficulties

Asynchronous Serial Communication (1)

- Data are transmitted character by character (characters may have either 8, 7,6 or 5 bits)
- Receiver and transmitter maintain their own (independent) clocks (of the same frequency)
- Before transmission of every single character, the phase of a receiver clock is synchronized (using the leading edge of the start bit)
  - as the difference between the transmitter and receiver clocks still increases, we may transfer just a few bits without a need of resynchronization

Asynchronous Serial Communication (2)

- The parity bit at the end of each character helps to detect (some types of) transmission errors
- A pause between characters is inevitable to give receiver a chance to process the character
    - A stop bit has to have an opposite polarity (1) than the start bit (0)
- The need of the synchronization before each character and inter-character pauses decrease the efficiency compared to synchronous communication
- Used for low-speed character-oriented communication
    - Terminals, industrial automation, PC COM ports

- Detailed explanation at http://en.wikipedia.org/wiki/Asynchronous_serial_communication

Synchronous Serial Communication (1)

- The receiver clock is derived from the received signal
  - the transmitter and receiver clocks always synchronized
- Data are transmitted in frames containing
  - Header
  - Payload
    - Variable-length (typically hundreds of bytes to a few kilobytes)
  - Frame checksum (FCS)
- Frames are delimited by flags in a transmitted bit stream

Synchronous Serial Communication (2)

- If there are no data to transmit, the transmitter transmits just the empty frames (repeating flags)
- No need for reoccurring synchronization before every character
    - lower overhead
- Used for high-speed data transfers and on isochronous links
    - In LANs, on WAN links
    - ISDN channels

Processes Involved in Data Transmission

How is the Transmitted Data Represented ?

The transmitted data are represented by changes of a suitable physical quantity, i.e. a signal s(t)

The most commonly used physical quantities are

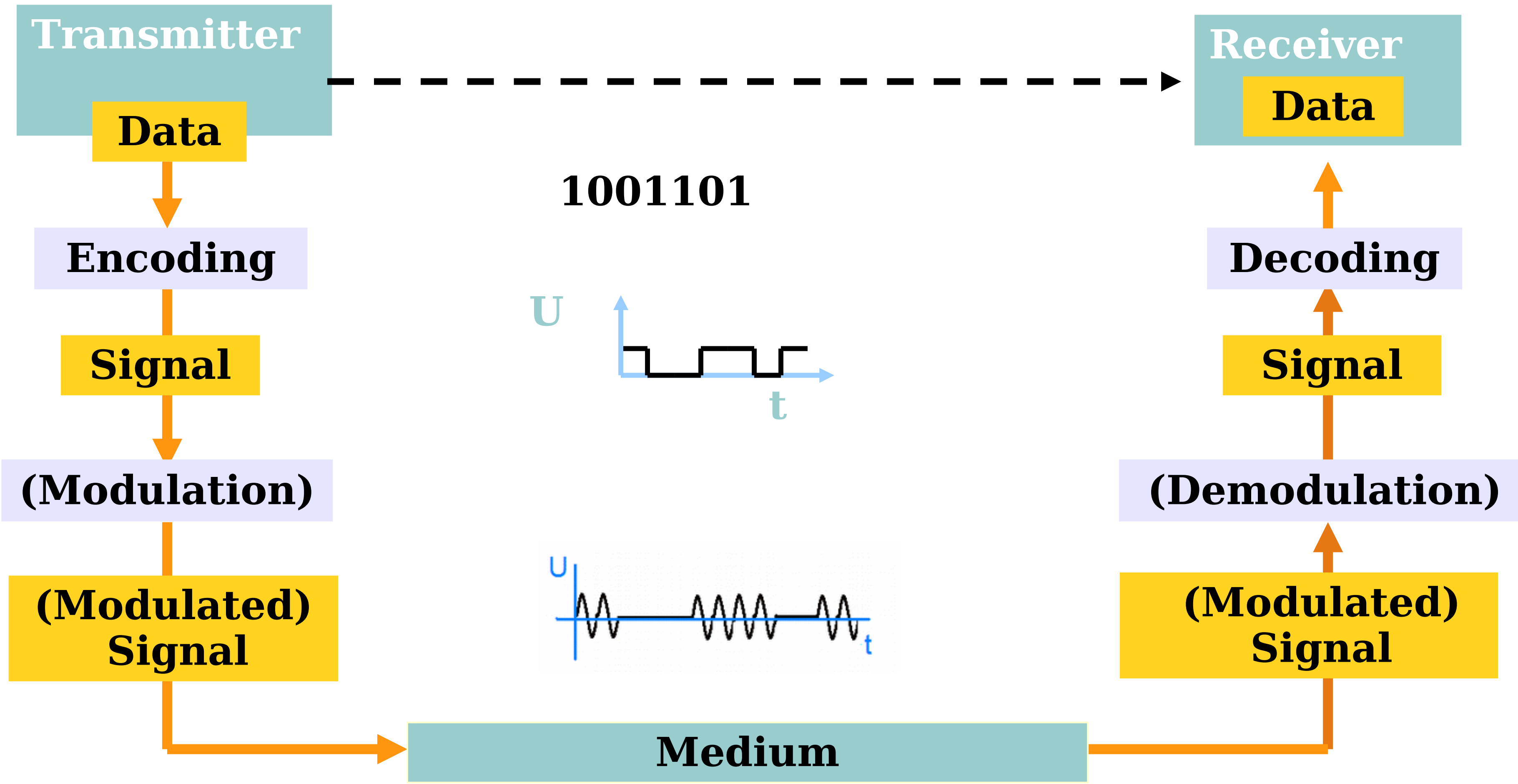
- Voltage (current)
- Intensity of the electromagnetic radiation (light)
- Sound pressure
- …

Transmission Media

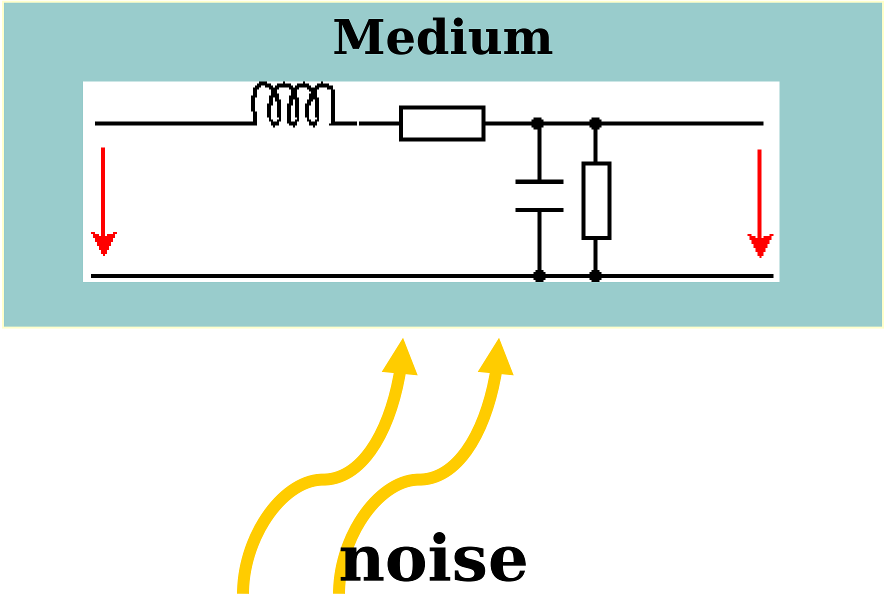
The signal travels along the medium (either guided or wireless)

- optical fiber
- twisted pair
- coaxial cable
- ...

The Processes Involved in the Data Transmission

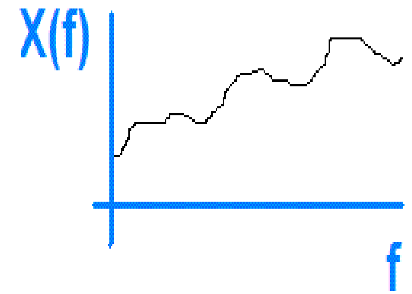


How does the Transmission Medium Influence the Signal ?



Characteristics of Transmission Media

- attenuation, crosstalk, (ACR)
- velocity of the signal propagation
- return loss
- …



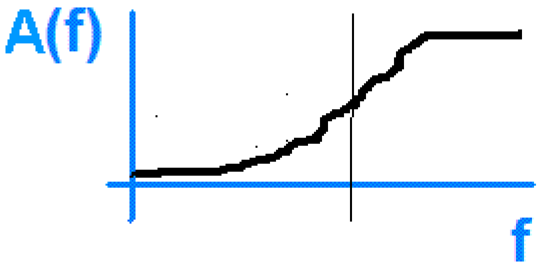
Media characteristics are frequency-dependent

⇒ We try to utilize as narrow frequency band as possible

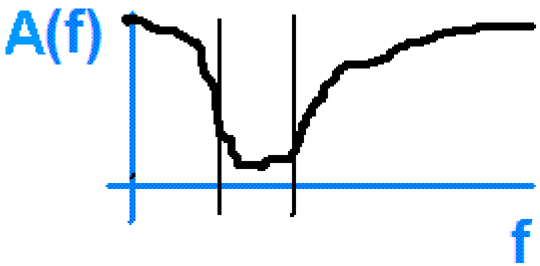
  - so that the media characteristics do not differ too much over the whole band

The Utilizable Frequency Band of the Medium

We use the medium in a frequency range where it has a desirable parameters



The medium behaves as a low-pass filter

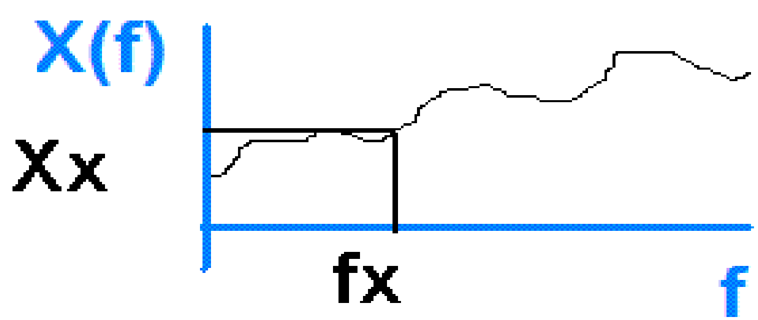


The medium behaves as a band-pass filter

There may also exist multiple utilizable frequency bands

How is the Signal Influenced by the Medium Itself ?

- Sine-wave signal
  - contains just the single frequency
  - we may obtain the value of the particular parameter from the measured medium characteristics

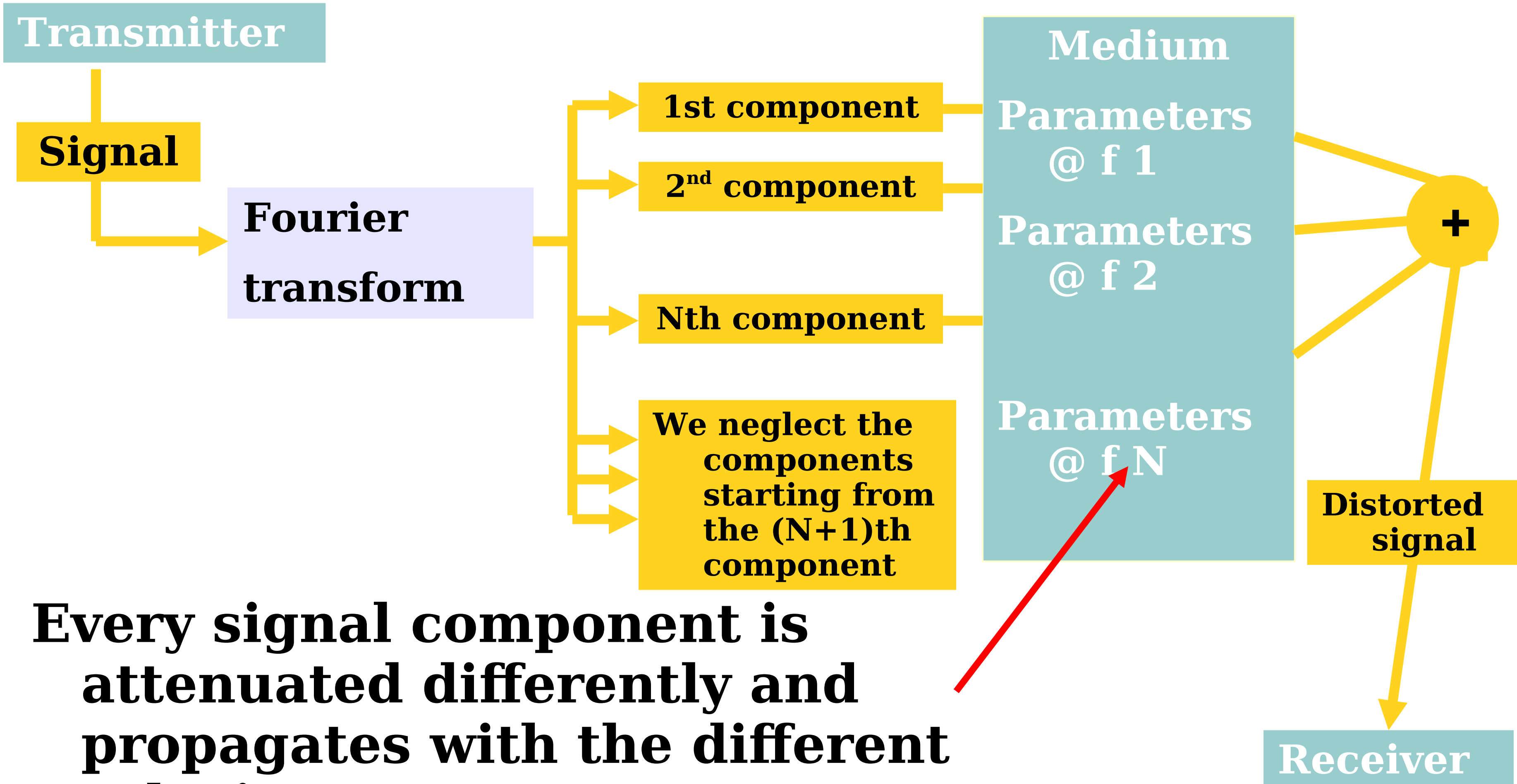


- What about general signal – ???

Decomposition of the Signal into the Harmonic Components

- Any (periodic) signal may be treated as a sum of (an infinite number of) the sine-wave signals of various frequencies
  - multiples of the basic frequency
    - Individual signal components differ in amplitude and phase shift
  - Calculated using a Fourier series
- We may investigate how the medium influences the individual signal components and sum up the results

Usage of Fourier Series to Investigate the Deformation of a General Signal



Every signal component is attenuated differently and propagates with the different velocity

How to Decompose a Signal to Harmonic Components?

$$g(t)=\sum_{n:1}^{\infty} A_n.\sin(n\omega t)+\sum_{n:1}^{\infty} B_n.\sin(n\omega t)+\frac{1}{2}c$$

$$\omega=\frac{2\pi}{T}$$

$$A_n=\frac{2}{T}\int_0^T g(t).\sin(n\omega t)\,dt$$

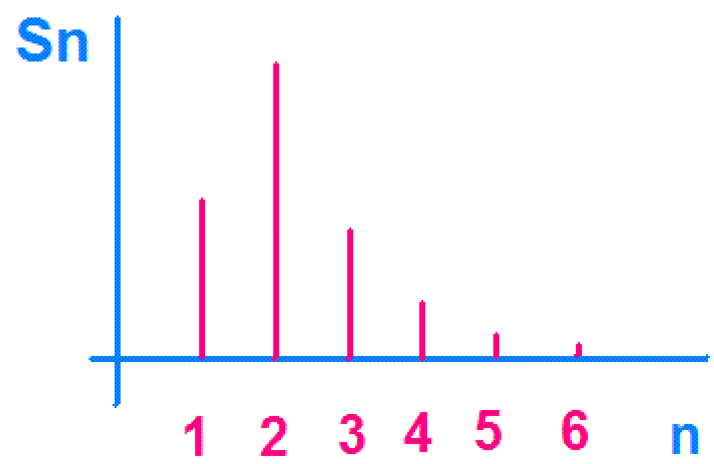
$$B_n=\frac{2}{T}\int_0^T g(t).\cos(n\omega t)\,dt$$

$$c=\frac{2}{T}\int_0^T g(t)\,dt$$

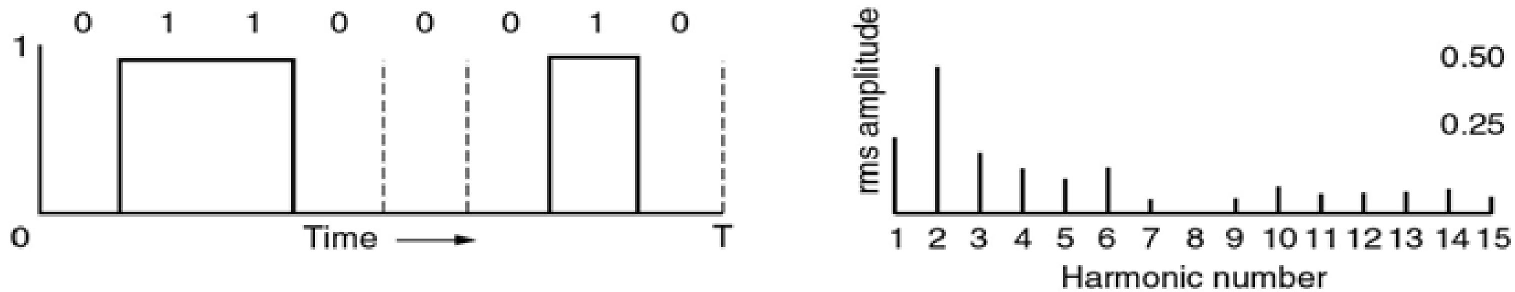
See http://en.wikipedia.org/wiki/Fourier_series for more detailed explanation

Frequency Spectrum of the Signal

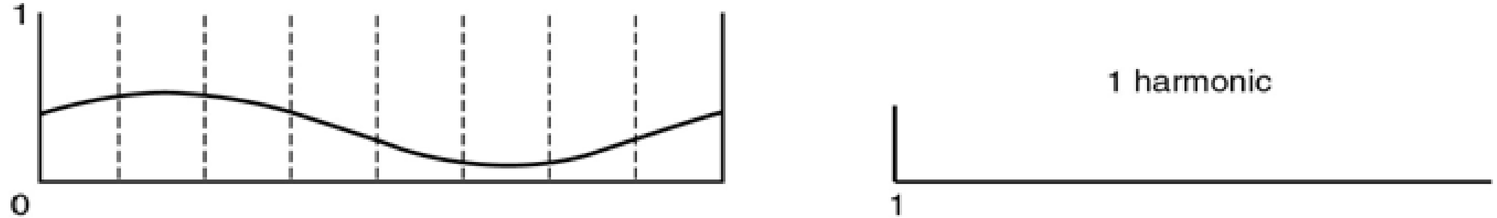
- Indicates how much power is carried by individual harmonic components
- Allows us to assess how much neglecting (filtering out) of some components influences the signal



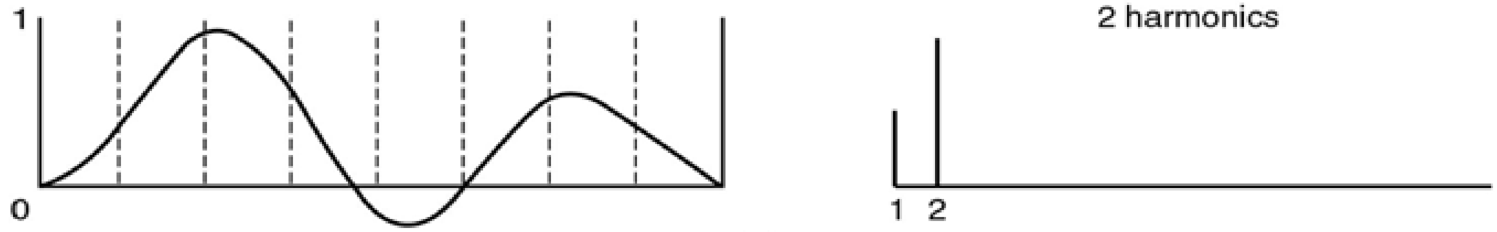
An Example (1)



(a)

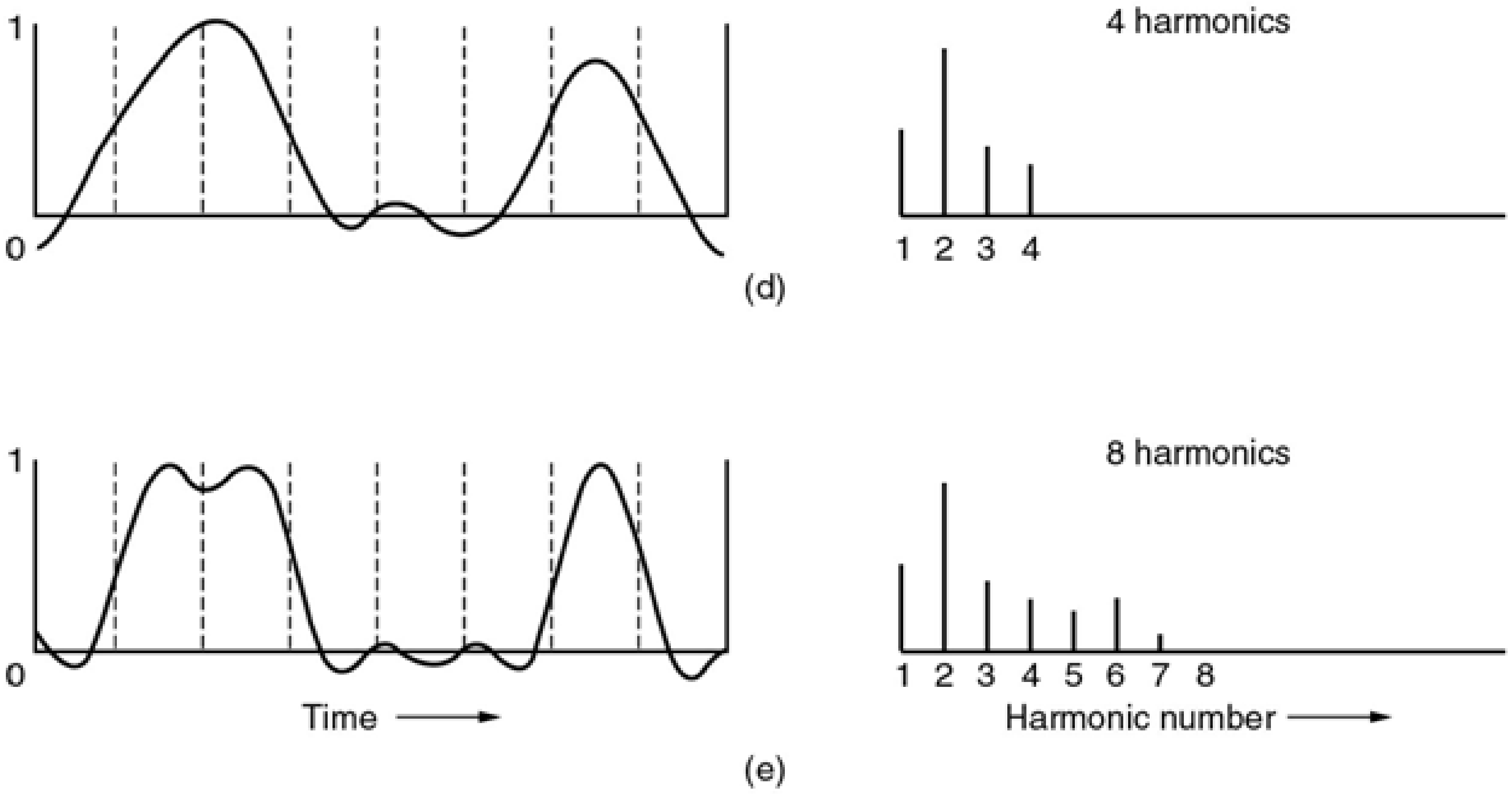


(b)



(c)

An Example (2)


1
0
(d)
4 harmonics
1 2 3 4
1
0
Time
(e)
8 harmonics
1 2 3 4 5 6 7 8
Harmonic number

Baseband and Broadband Transmission

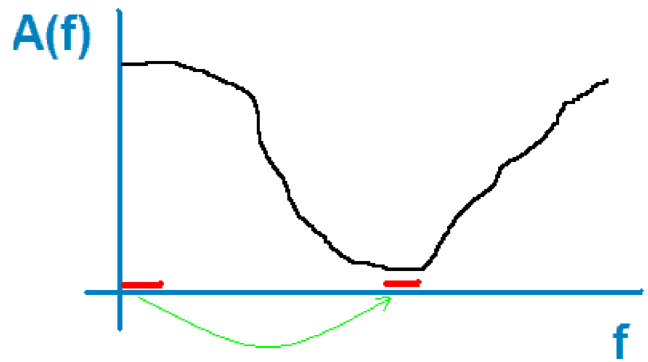
Baseband and Broadband Transmission Comparison

- Baseband
  - Utilizes the full bandwidth of the medium
  - The signal can include frequencies that are very near zero
- Broadband
  - Uses a specific part of the utilizable bandwidth of the medium
    - Multiple communications may share the medium at the same time
    - Avoids usage of subbands with unsuitable characteristics
      - Static or dynamic selection

Broadband Transmission

The Principle of the Broadband Transmission

- The signal have to be shifted to a frequency band suitable for transmission over a particular medium using the modulation



- Also solves the problems with channels that cannot pass the DC component

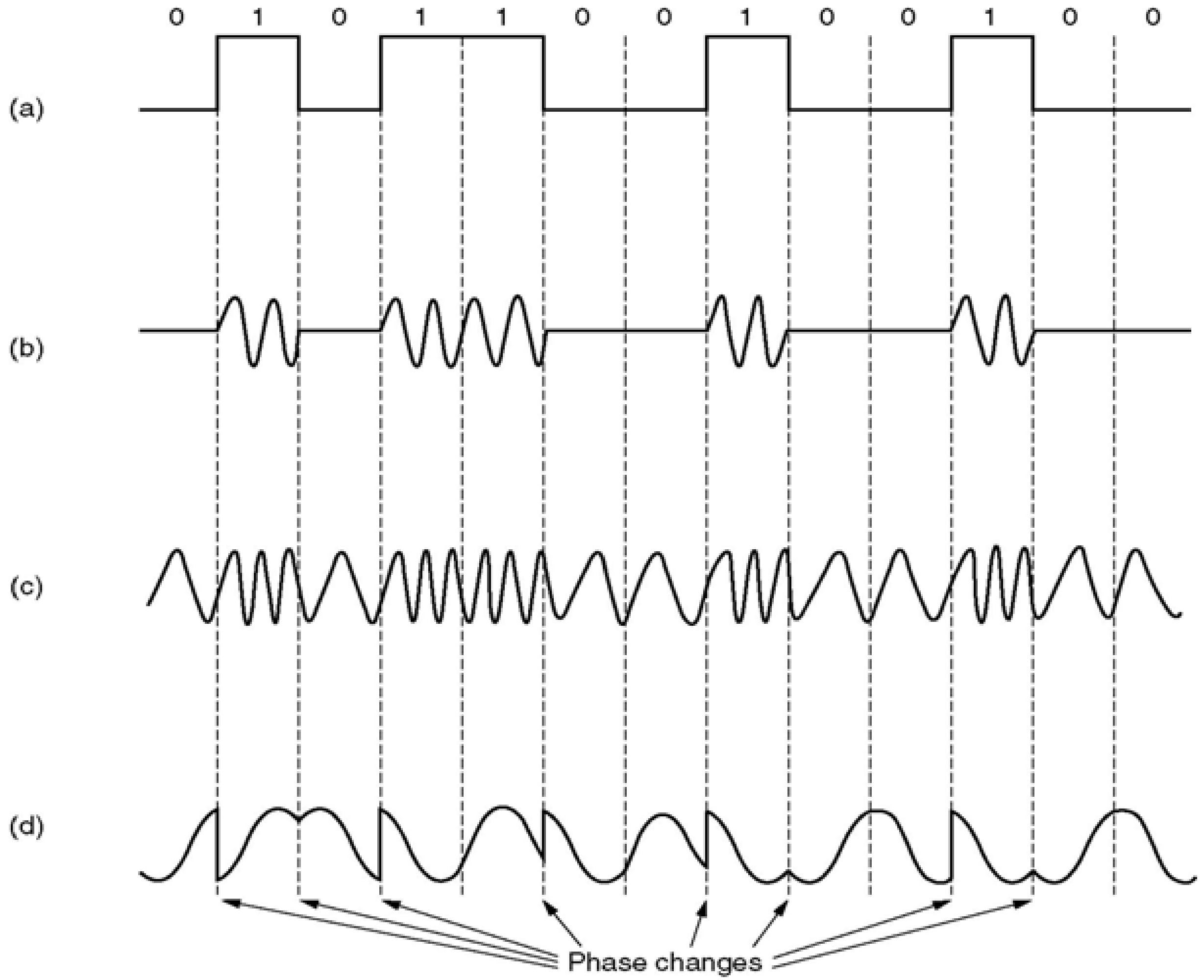
The Principle of the Modulation Process

We choose a sine-wave carrier signal with a frequency suitable for transmission over the given medium

$$s(t) = A.sin(\omega t + \phi)$$

- Then we change the carrier signal parameters to represent data bits being transmitted
  - amplitude
  - frequency
  - phase
  - combination of the above

Amplitude, Frequency and Phase Modulation

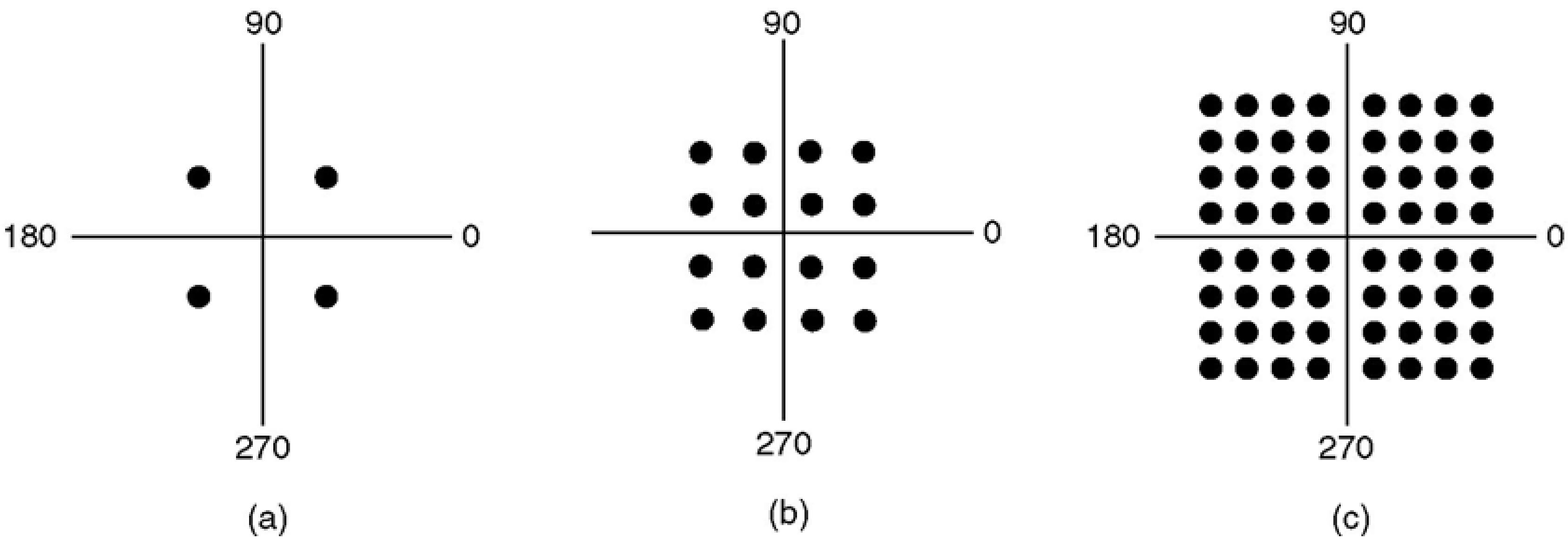


Phase Modulation (Phase-Shift Keying,PSK)

- If we have 2^n possible phase changes, we may encode n bits using one signal change
  - e.g. encode 2 simultaneously data bits by changing the signal by either 45, 135, 225 or 315 degrees (4 options)
- The number of possible signal change options is limited by capability of the receiver circuitry to differentiate between them

Quadrature Amplitude Modulation (QAM)

Combines together the amplitude and phase shifts



Transfer Rate vs. Modulation Rate

- Modulation Rate = number of changes of a signal during a time interval
  - Measured in bauds [Bd]
- Transfer Rate = number of bits transferred during a time interval
  - Measured in bits per seconds [bps]

The transfer rate can be higher than the modulation rate, as we may represent multiple bits by a single signal change

- provided that we have enough types of the signal changes

Baseband Transmission

Principle of the Baseband Transmission

- The encoded bit stream is transmitted in the original frequency band
  - modulation is not used
- Commonly used for metallic media in LANs and optical media in both LANs and WANs
  - the distance is limited due to unsuitable characteristics of the medium in some parts of the utilized frequency band
- If the modulation is not used, we need an another mechanism of the phase synchronization between transmitter and receiver => data encoding

Data Encoding for Baseband Transmission

- To give a receiver a chance to synchronize with a transmitter, we need to ensure enough changes of the signal
  - necessary for the phase synchronization and continuous adjustment of the receiver clock
  - but a signal with more changes during a time interval contains higher frequencies and thus requires wider frequency band
- Removes the DC component
  - If the coupling circuitry (such as a transformer) does not pass the DC component, we would not be able to differentiate between a sequence of 0's and a sequence of 1's

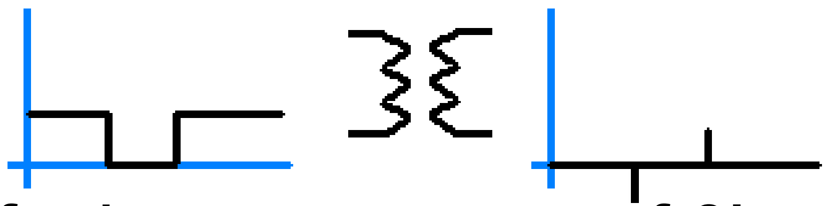
Do not confuse the data encoding with data encryption applied for security purposes

Non Return to Zero Encoding (NRZ)

- 0s and 1s are encoded directly by a low and high signal levels during the whole bit interval
  - binary 0: low signal level
  - binary 1: high signal level

Problems with NRZ Encoding

- If the DC component is not passed, we cannot differentiate a sequence of 0's and a sequence of 1's



- In case of a long sequence of 0's or 1's the receiver cannot maintain the time synchronization
  - „Did we receive 1000 or 1001 zeros”

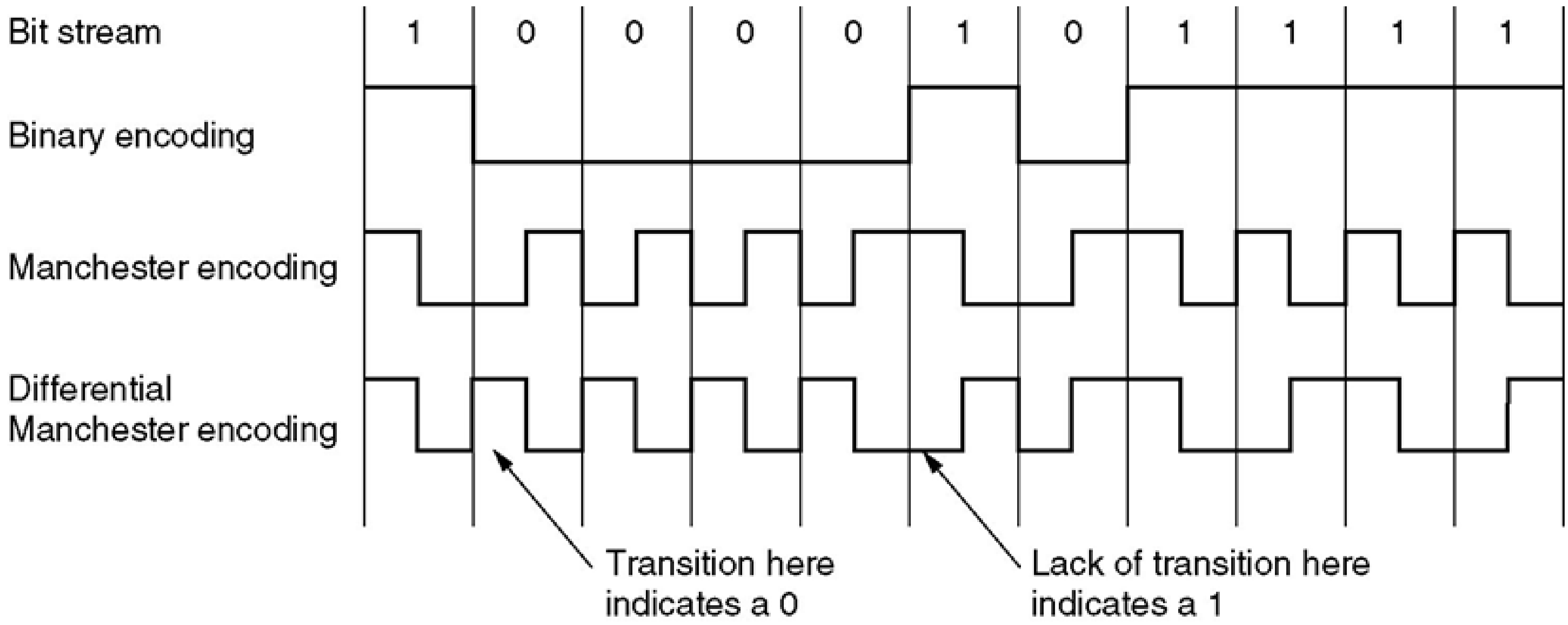
The Encodings Most Used in Baseband Transmission

See http://en.wikipedia.org/wiki/Line_code

Manchester, Differential Manchester

- Manchester
  - A 1 is expressed by a low-to-high transition at the middle of the period, a 0 by a high-to-low transition
  - Transitions at the start of a period are made as necessary and don't signify data
  - Used in 10Mbps Ethernet (on copper media)
- Differential Manchester
  - A 0 is expressed as a signal change at the beginning of a period, a 1 as an unchanged value
  - There is always a transition at the middle of the period (either low-to-high or high-to low as necessary to encode the subsequent bit)

Manchester and Differential Manchester - An Example



Return Zero (RZ)

- Three signal levels (0, -1, +1)
- The first half of the bit interval encodes the data bit value
  - +1 represents binary 1
  - -1 represents binary 0
- The signal is always on the level 0 in the second half of the bit interval

Non Return to Zero Inverted (NRZI)

- Two signal levels
- Change of the signal encodes binary 1
- To encode binary 0 the signals keeps the original level

Alternate Mark Inversion (AMI)

- 3 signal levels (0, +1, -1)
  - Binary 0: level 0
  - Binary 1: represented alternately by +1 a -1 levels
- By violation of polarity alternation rule, we may mark a significant event in the data stream
  - e.g. the beginning/end of a frame, as in ISDN BRI S/T interface
- There is still a problem to maintain receiver synchronization during long sequences of transmitted 0s

HDB3

- Modification of AMI
  - Solves the problem of loosing the synchronization during sequences of 0s
  - Inserts 1 after 3 consecutive 0s
  - The inserted 1 is identified by violation of polarity alternation rule
- Used on PCM E1-E3 links
  - Digital links between telephony COs

Code Mark Inversion (CMI)

- Used to transfer AMI/HDB3 over optical lines
  - Optical lines do not allow to use 3 levels (just „light/darkness“)
- The one of the original 3 signal levels is encoded as a combination of two bits
  - one combination remains unused

4B5B (5B6B, ...)

- Groups of 4 bits are mapped to (a chosen) 5-bit marks
  - Similarly, 5 bits may be mapped to (a chosen) 6-bit marks etc.
- Marks are chosen with regard to a reasonable number of changes and balancing of the resulting signal
  - i.e. all 0s, all 1s are excluded
- Some marks are used to represent significant states
  - frame beginning and end, idle link
- Usage example: Fast Ethernet

2B1Q

- 2 bits are represented as one of the 4 amplitude levels
- Usage example: U interface of ISDN BRI