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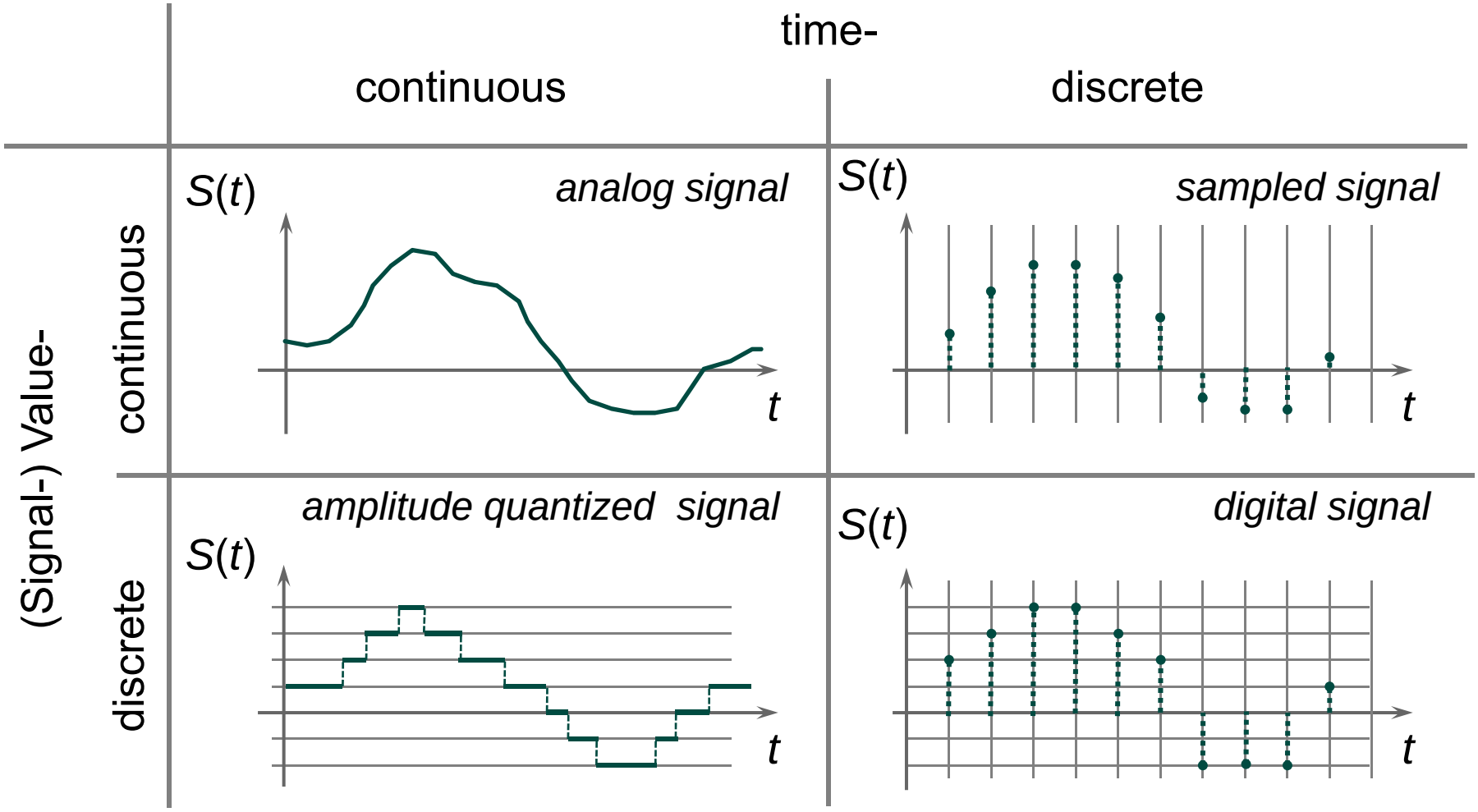
Communication Systems and Protocols

Exercise 2

Classes of Signals



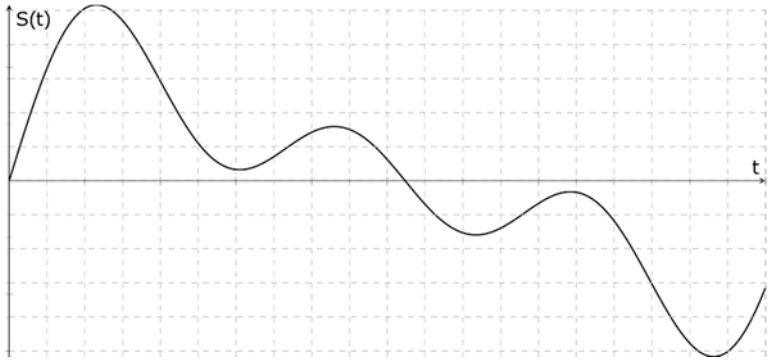
Transmission Capacity of a real channel

- C. Shannon, 1948:
  - Channel with random noise
  - How many different signal steps can be distinguished correctly?
- Signal/Noise ratio S/N limits the number of bits per symbol
- Number of transmittable bits per second:
  - Shannon Limit = $B \cdot \log_2(1 + S/N)\,[bit/s]$
    - S/N=0: no information (infinite amount of noise)
    - S/N=1: ~1 bit/s
    - S/N>1: multiple bits/s
- Example: analog telephone line
  - S_{norm}=-10dB, N_{norm}=-34dB, W=3000Hz

  → 24,000bit/s

Task 1: Signal Classes

Task 2: Channel capacity and bandwidth



Time remaining ‘5

Motivation: Line Codes

- Is baseband representation of bits sufficient?
- Value of bit can be encoded, but how about other features?
  - Clock recovery
  - Multi-valued signals
  - Simple signal reconstruction
  - Error detection
- There should be other encoding schemes besides baseband representation → Line codes

Classification of Line Codes

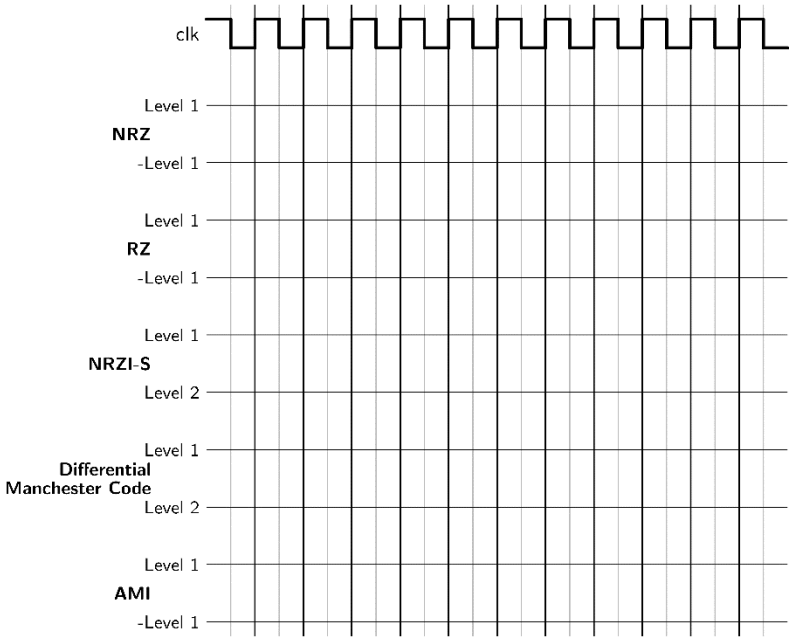
- Level orientated Line Codes
  - Symbols are represented by signal value
- Phase orientated Line Codes
  - Symbols are coded through phase jumps
- Unipolar Line Codes
  - only one active Signal level is used in addition to GND level
- Bipolar Line Codes
  - two different active Signal levels are use, GND is not used for coding
- Ternary Line Codes
  - Both symbol values 0 und 1 are encoded using three signal values (level 1, ground, level 2)
- Multi-valued Line Codes
  - Multiple bits are assembled within a single coding symbol

Block Codes

- 4B/5B Code
  - Avoiding the inefficiency of Manchester encoding
  - No long sequences of ‚0‘s or ‚1‘s
  - Addition of an extra bit to avoid such sequences
  - 4-Bit data is encoded in 5-Bit blocks
    - Not more than one leading ‚0‘s
    - Not more than two trailing ‚0‘s
  - Transmission is done using NRZ-I-Code
  - 80% efficiency

4-Bit Data	5-Bit Code
0000	11110
0001	01001
0010	10100
0011	10101
0100	01010
0101	01011
0110	01110
0111	01111
1000	10010
1001	10011
1010	10110
1011	10111
1100	11010
1101	11011
1110	11100
1111	11101

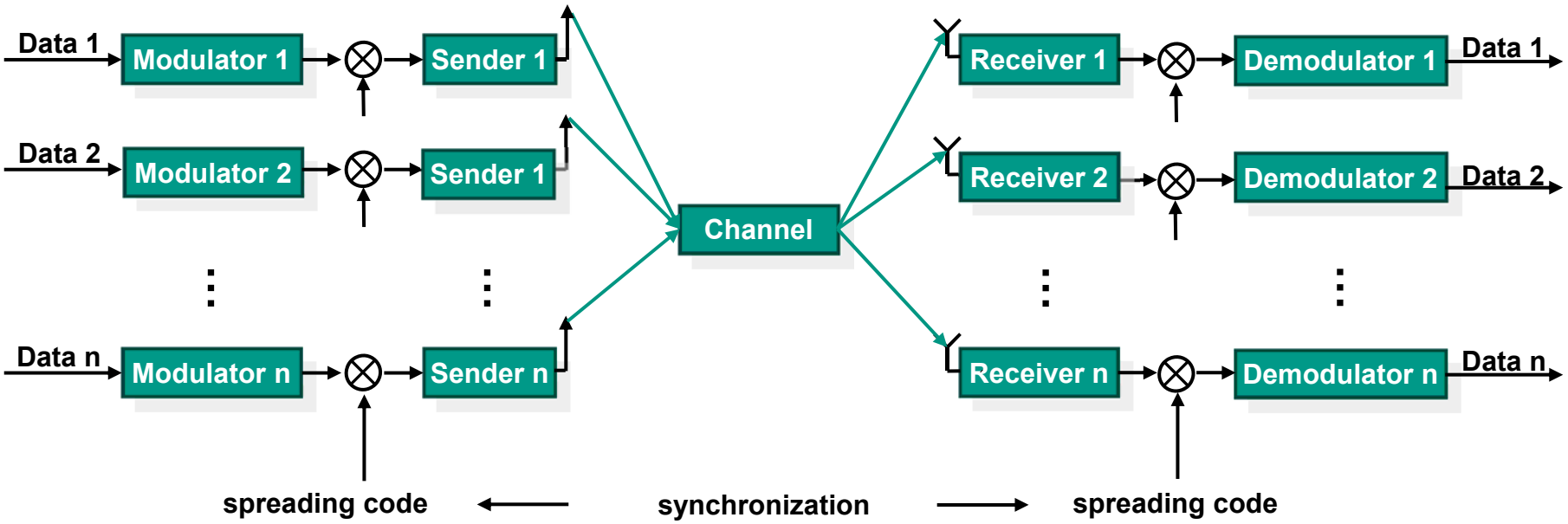
Task 3: Line Codes



10100000111111000010111

Time remaining ‘10

CDMA Transmission Path



- Data is transformed using a spreading sequence and decoded back into the original data by the receiver.
- Different nodes can be distinguished by their different spreading codes.
  - Logic combination with the correct spreading code will extract the original data
  - Transmissions of other nodes will appear similar to white noise and can be filtered out.

Spreading codes

- Spreading functions have to be orthogonal (orthogonal means that the inner product of two functions equals to 0)

- Walsh code
  - Start with a logic “0” as element a_{11} of a 2x2 matrix
  - The element a_{11} is repeated at position a_{12} and a_{21}
  - At position a_{22} the inverse of a_{11} is inserted

$$\begin{matrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{matrix}$$

- Walsh functions for sender nodes
  - Substitution in resulting matrix
  - Zeros with +1
  - Ones with -1

Data transmission with CDMA

- Multiple nodes want to send data at the same time using the same frequency band
  - Every node has a unique spreading code assigned to it
- Every bit to be send is encoded with the spreading code assigned to the corresponding sender
  - Transmission of „0“: Spreading sequence is send as is
  - Transmission of „1“: Spreading sequence is inverted
- Spreading sequences of all nodes are superimposed and form **one** signal on the media
  - Attention: The signal on the media is now multi-valued and not binary any more!

Reception with CDMA

- On receiver side the transmitted signal is correlated with the Walsh function that has been assigned to the node
- As the Walsh functions of the other nodes are orthogonal, only the signal that is meant for the receiver is filtered
  - If the result of the correlation is +8, a “0” has been send
  - If the result of the correlation is -8, a “1” has been send
- For real data transmission a decision based on the exact value is not possible any more because of interferences and other disturbances that distort the signal. Therefore the signal has to be within in a predefined interval to be interpreted as “1” or “0”.

Task 4: Code Division Multiple Access (CDMA)

Node	Data	Signal							
0	"0"								
3	"1"								
6	"0"								
Signal on media									

Node	Sender function							
0								
1								
2								
3								
4								
5								
6								
7								

data	+2.1	+1.9	+1.4	+2.0	-1.7	+5.3	-2.1	-1.9
Node								

Time remaining