

Dr.-Ing. Jens Becker (jens.becker@kit.edu) M. Sc. Matthias Stammner (stammner@kit.edu)

Communication Systems and Protocols

Exercise 2

Old exams

- Old exams of the years 2019 onwards are available on ILIAS

Examination

▶ EXAMINATION REGISTRATION

▶ EXAMINATION RULES

▼ OLD EXAMINATIONS

Ordner



Old exams



▶ SCHEDULE TO ARRIVE AT THE EXAM LOCATION

▶ EXAM GRADE DISTRIBUTION (NOTENVERTEILUNG)

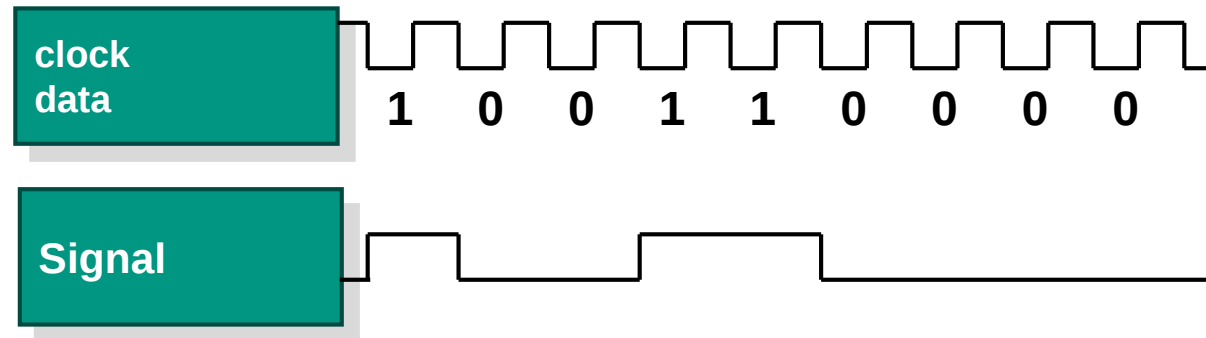
Old exams

 SS2019_Exam_questions  pdf 1,2 MB 13. Mai 2022, 15:52 Anzahl Seiten: 35
 SS2019_Exam_solutions  pdf 1,4 MB 13. Mai 2022, 15:52 Anzahl Seiten: 37
 SS2020_Exam_questions  pdf 480,0 KB 13. Mai 2022, 15:52 Anzahl Seiten: 28
 SS2020_Exam_solutions  pdf 591,2 KB 13. Mai 2022, 15:52 Anzahl Seiten: 28
 SS2021_Exam_questions  pdf 492,4 KB 13. Mai 2022, 15:52 Anzahl Seiten: 35
 SS2021_Exam_solutions  pdf 719,6 KB 13. Mai 2022, 15:52 Anzahl Seiten: 36
 WS1819_Exam_questions  pdf 697,7 KB 13. Mai 2022, 15:52 Anzahl Seiten: 39
 WS1819_Exam_solutions 

Baseband Representation

■ Baseband Representation

- Signals contain no modulation, in general it contains $f=0$.
Baseband signal = sequence of (square-)pulses



- Intuitive representation of data
- Requires theoretically unlimited bandwidth (due to square-pulses)
- Capacitive or inductive coupling of nodes infeasible

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

Important properties of Line Codes I

- Number of collectively coded bits
 - In a single value more than one bit can be encoded
- Direct Current Component
 - Sum VDC of voltages on a wire over a longer period of time
 - $VDC = 0 \rightarrow$ DC balanced (or: zero-DC, zero-bias, DC equalized)
 - $VDC \neq 0 \rightarrow$ a DC current is transported over the line
- Problem, if not DC balanced:
 - When transmitting data and power supply voltage over the same line, the supply voltage is affected
 - When using transducers as couplers, varying DC affects data interpretation on receiver's end
- In practice, DC balancing is only achievable in the statistic average of long transmission sequences.

Important properties of Line Codes II

■ Error detection

- Signal errors shall be detectable on the signal level itself.

■ Required Bandwidth

- How many signal changes are required to encode one bit?
- Is correlated to attenuation
- Higher frequencies are attenuated more than lower frequencies

■ Clock Recovery

- From received signals the value and clock of the send data can be recovered.
- Clock recovery is needed if no separate clock line is available.
- The clock portion shall not be correlated to the data content of the transmission.

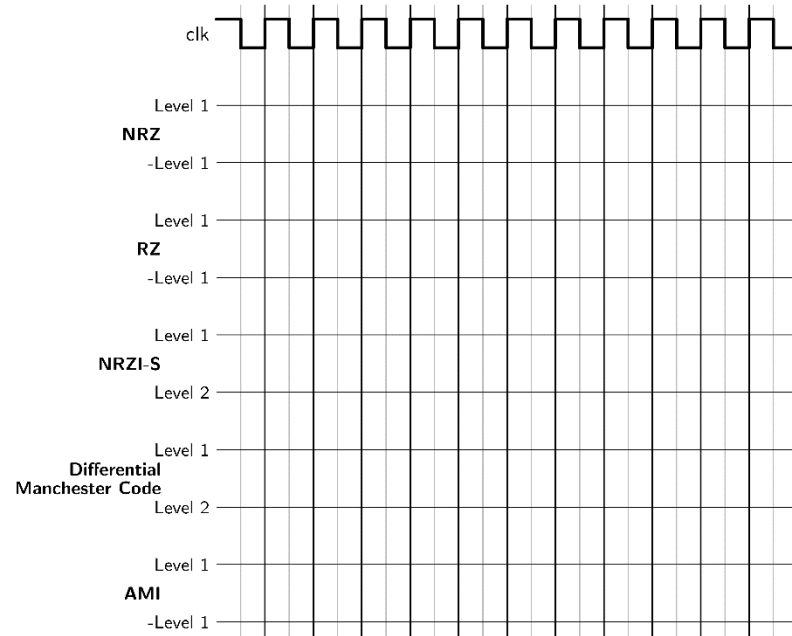
Block Codes

■ 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 1: Line Codes



101000001111111000010111



Time Allocated

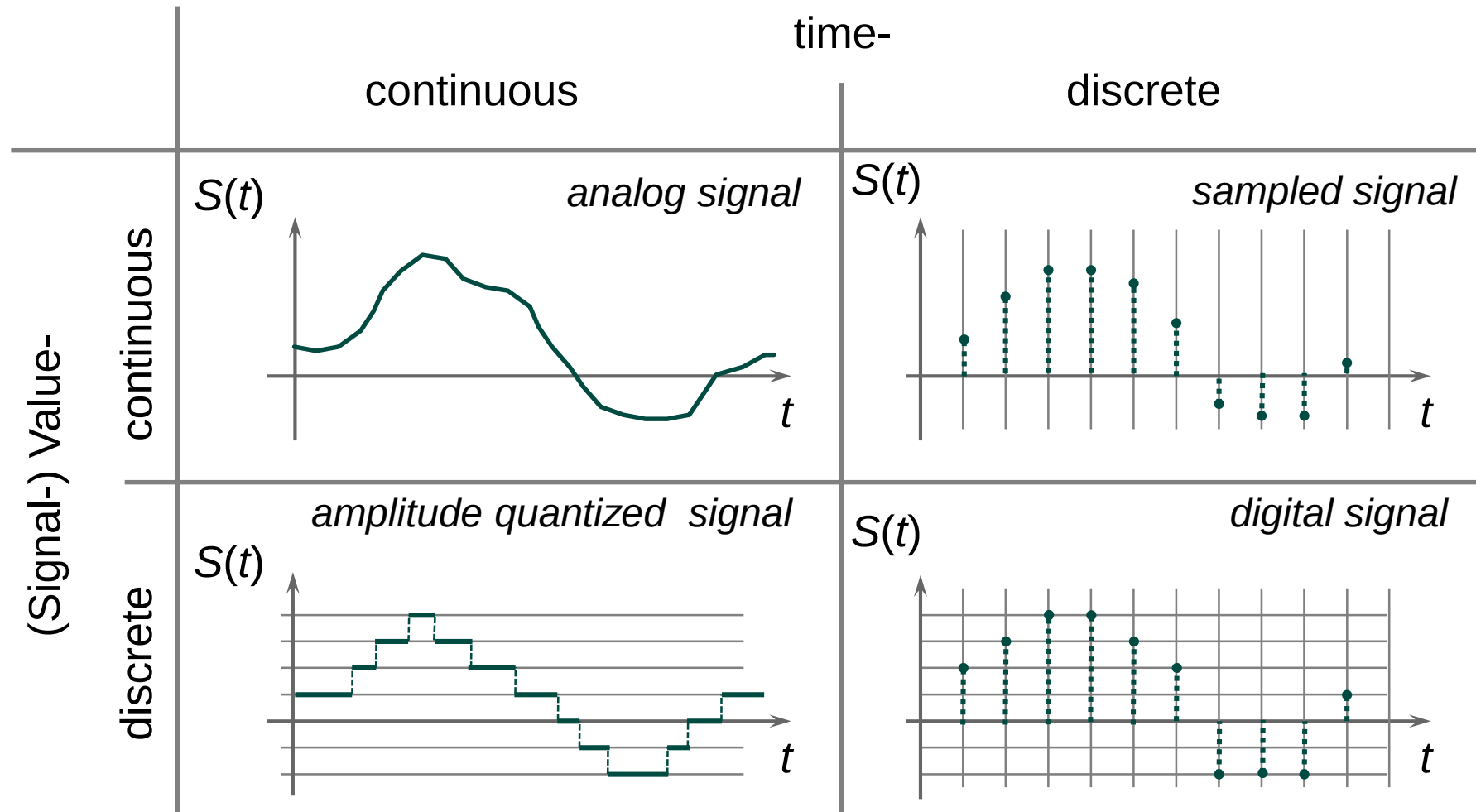
10 min

REMINDER: Homework

- Classify the Line Codes according to the properties (+, ++, -, --, O)

Line Code	DC Current	Required Bandwidth	Clock Recovery
NRZ			
RZ			
NRZI			
AMI			
Manchester			

Classes of Signals

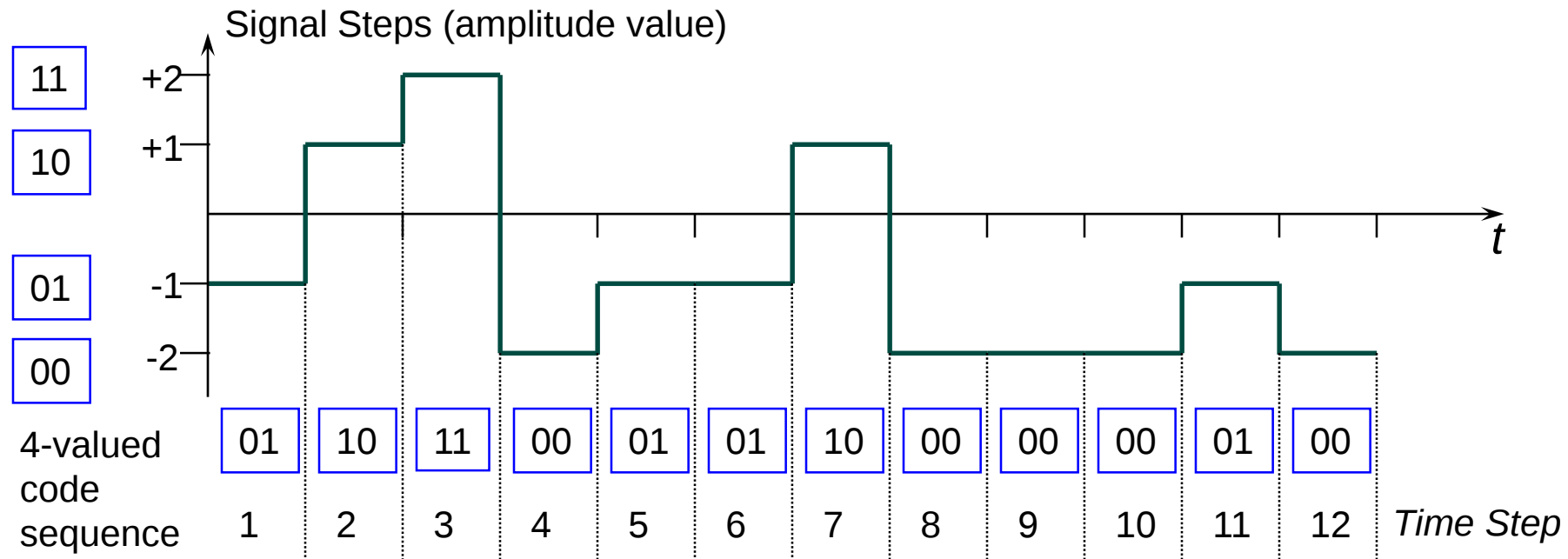


Transmission Capacity of a real channel

- 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
 - $S_{\text{norm}}=-10\text{dB}$, $N_{\text{norm}}=-34\text{dB}$, $W=3000\text{Hz}$
 - $\rightarrow 24,000\text{bit/s}$

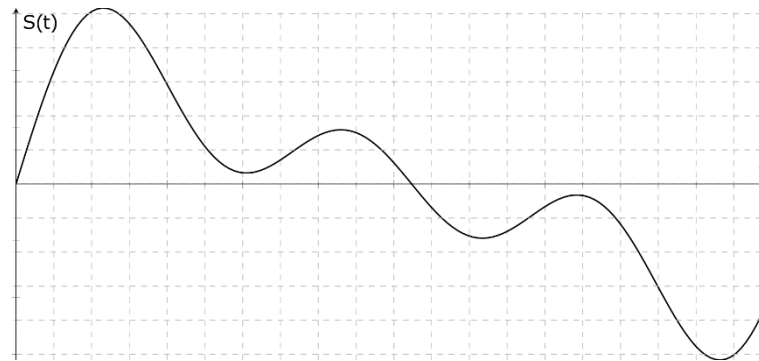
Example: Multi-Value digital Signal

- The (discrete) coordinate of a signal can have more than two values
 - Example: DIBIT: two bit per coordinate value (4-valued Signal)
- One Symbol encodes two bits



Task 2: Signal Classes

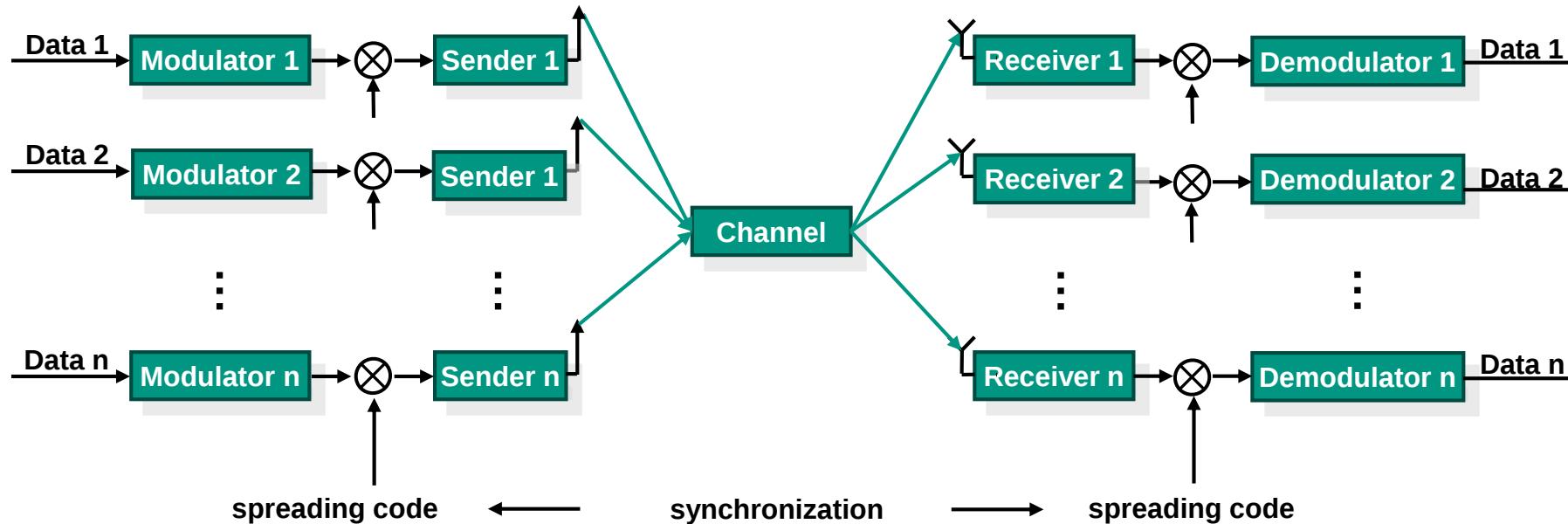
Task 3: Channel capacity and bandwidth



Time Allocated

5 min

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. The properties of orthogonal sequences are. (where N is the number of nodes).
- The inner product of two equal sequences is N
- The inner product of two different sequences is 0.

■ Walsh code

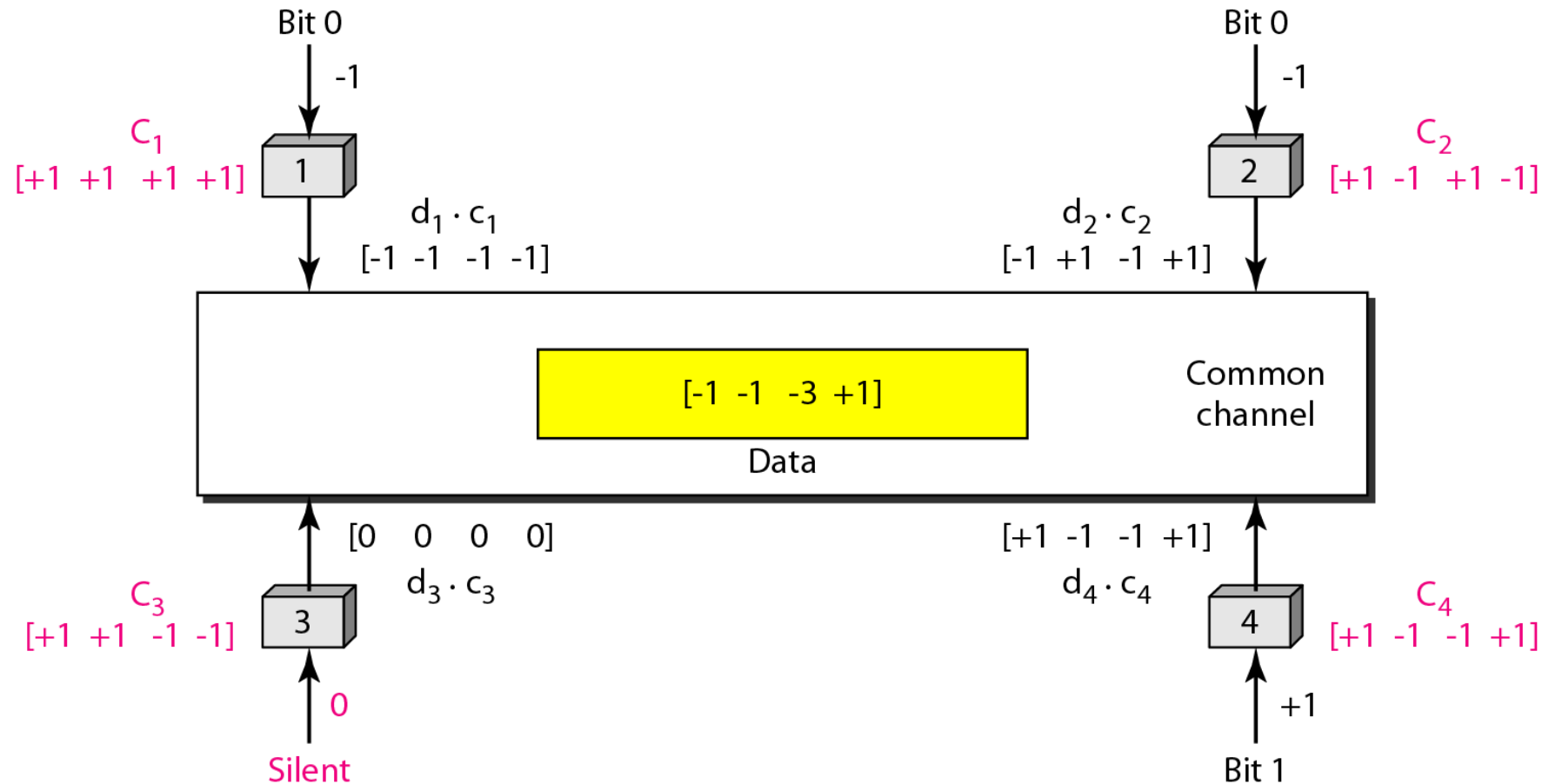
- Start with a logic “+1” as element a_{11} of a 2x2 matrix
- The element a_{11} is repeated at position a_{12} and a_{21}
- At position a_{22} the inverse of a_{11} is inserted

$$\begin{matrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{matrix} = \begin{matrix} a & a \\ a & \bar{a} \end{matrix} = \begin{matrix} +1 & +1 \\ +1 & -1 \end{matrix}$$

Data transmission with CDMA

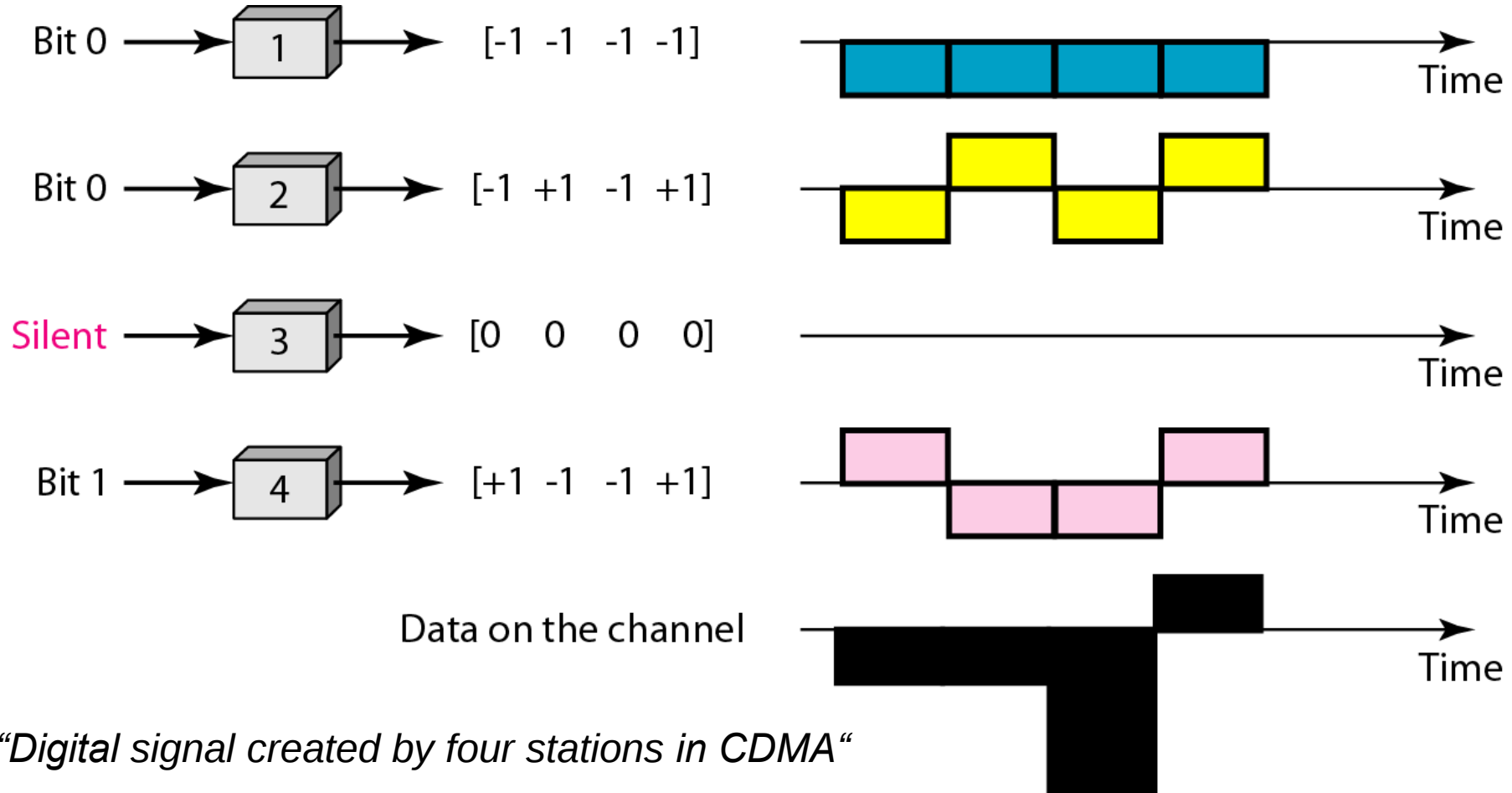
- Multiple nodes want to send data at the same time using the same frequency band
 - Every node has a unique spreading code assigned to it
- Every bit to be send is encoded with the spreading code assigned to the corresponding sender
 - Transmission of „1“: Spreading sequence is send as is
 - Transmission of „0“: 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!

Data transmission with CDMA : Example



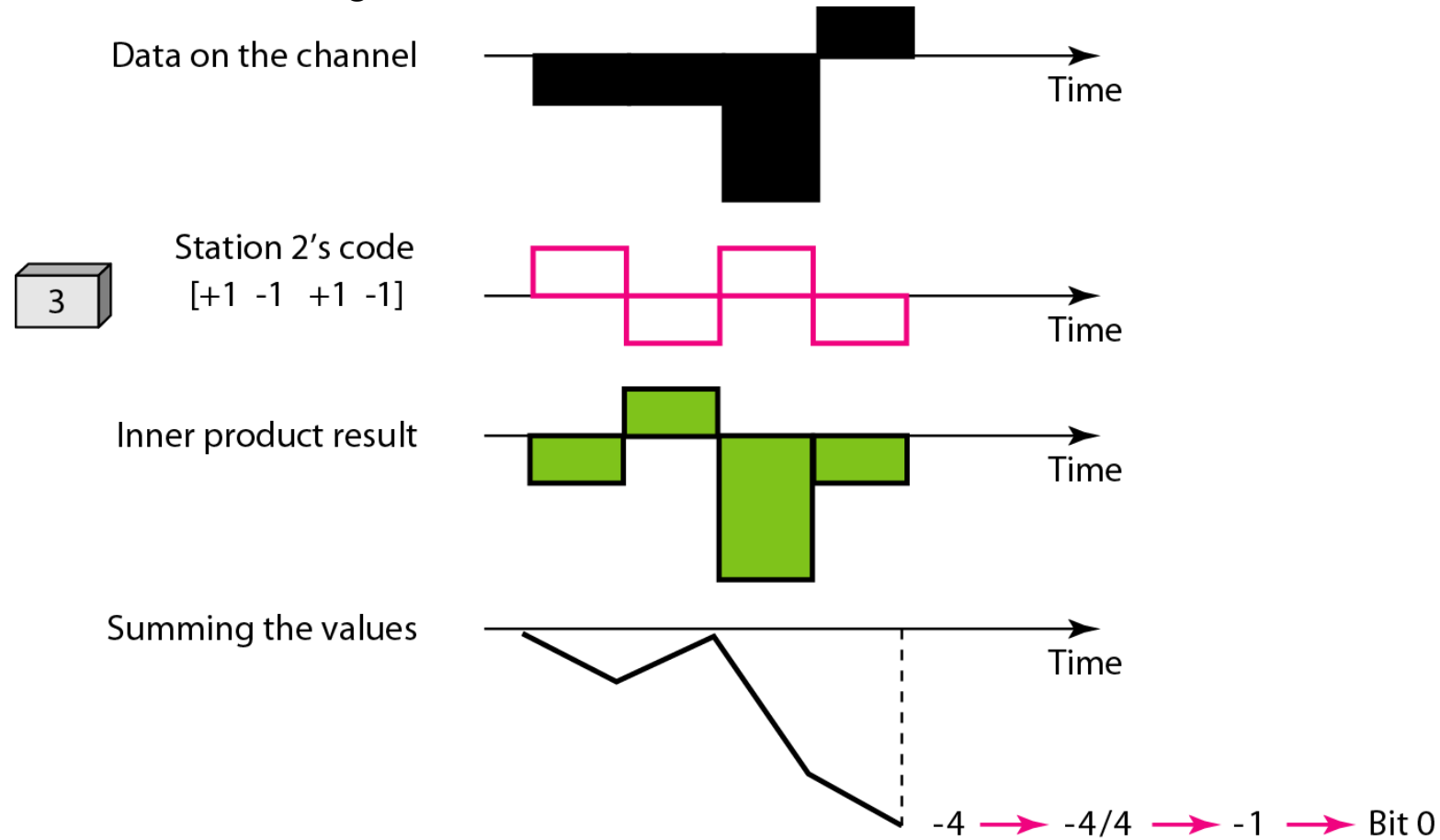
“Sharing channel in CDMA”

Data on the Channel



Reception with CDMA

- Station 3 is listening to Station 2



“Decoding of the composite signal for one in CDMA”

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 +4, a “1” has been send
 - If the result of the correlation is -4, a “0” 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	"1"								
3	"0"								
6	"1"								
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 Allocated

15 min