Exercise (SS 2022)
Comunication Systems and Protocols

Institut fuer Technik der Informationsverarbeitung
Dr. Jens Becker, Matthias Stammler M. Sc.

Task 1: Line Codes

/7

1.1 Draw the digital signals for the bit string 101 100 000 011 using each of the NRZ, Manchester, and differential Manchester digital encoding schemes. Use Figure 1.1. /3

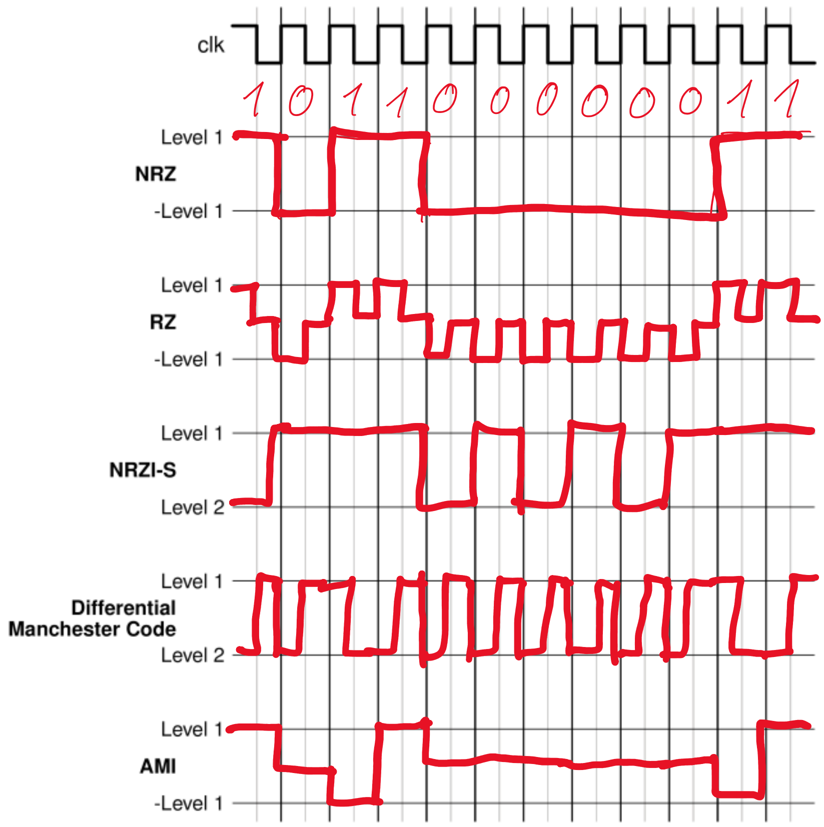

Figure 1.1: Line codes

1.2 Encode the following bit string using the 4B/5B code: /1

101000001111111000010111

1 2 3 4 5 6

1.3 What is the longest sequence of "0" if the 4B/5B code is used? /1

1.4 What is the longest sequence of "1" if the 4B/5B code is used? /1

Task 1.2: 10110, 11110, 11101, 11100, 01001, 01111

10110	11110	11101	11100	01001	01111
1	2	3	4	5	6

Task 1.3: The longest sequence of „0" is 3 e.g. 10100 01010

Task 1.4: The longest sequence of „1" is 8 e.g. 01111 11110

1.5 Figure 1.2 shows the signal sequence for a Manchester II coded signal. Determine the associated bit string.

/1

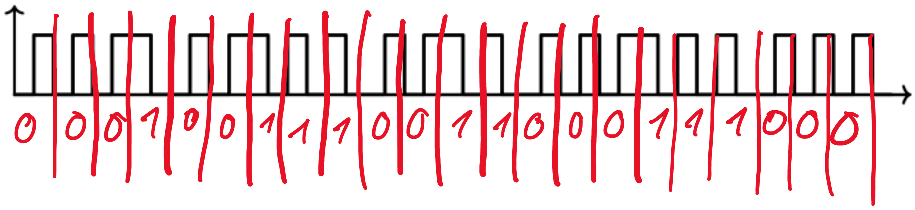

Figure 1.2: Manchester coded bit string

Task 2: Sampling

/4

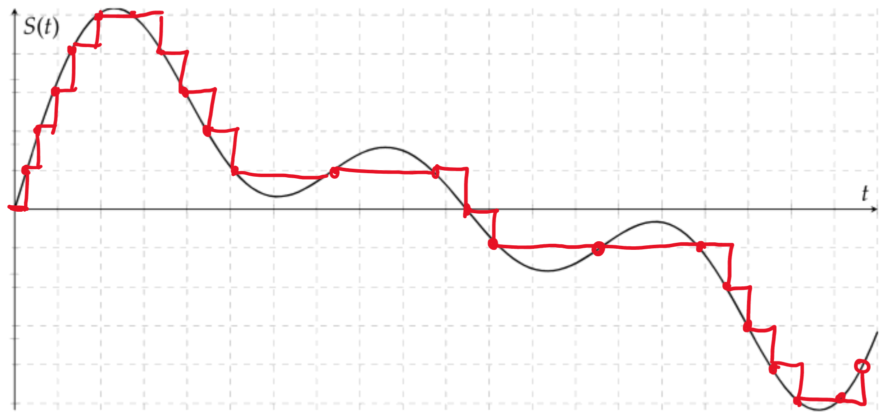

Figure 2.1: signal class:

2.1 The signal in Figure 2.1 is given as the original analog signal. Transform this signal into a amplitude quantized signal. Use the diagram in Figure 2.1 with the given sampling points. /4

Hold current value until analog signal crosses boundary

Task 3: Channel Capacity

/3

/3

3.1 A digital transmission system with a bandwidth of $B = 1,5 * 10^6 Hz$ has a channel capacity of $C = 5Mbit/s$ (according to Shannon). What is the minimum for the signal to noise ratio (SNR) in dB?

Standard formulas: $C = B \cdot \log_2(1+\frac{S}{N})$

Rearranged: $S/N = 2^{C/B} - 1$

$SNR = 10 \cdot \lg(S/N)$

$C = B \cdot \log_2(1+\frac{S}{N}) \quad | : B$

$\frac{C}{B} = \log_2(1+\frac{S}{N}) \quad | 2^{(\ )}$

$2^{C(/B)} = 1 + \frac{S}{N} \quad | -1$

$2^{C(/B)} - 1 = \frac{S}{N}$

$2^{\left(\frac{5 MBit/s}{1.5 \cdot 10^6 1/s}\right)} - 1 = 9,079$

$SNR = 10 \cdot \lg(9.079)$

$= \underline{9,58 dB}$

Matr. №: ID:

Task 4: Code Division Multiple Access (CDMA)

/11

4.1 The transmission scheme "Code Division Multiple Access" uses so called spreading codes to separate different transmissions. One group of functions that can be used for this purpose, are the Walsh functions. The CDMA scheme shall be used for simultaneous transmission of eight different messages. Derive the required Walsh functions. /2

4.2 Consider now that there are 100 messages to be sent. Here again CDMA scheme shall be used and Walsh table will be used to obtain the spreading codes. What is the number of elements in the spreading code? /1

4.3 For the simultaneous transmission of three messages, the Walsh function calculated in this task shall be used. The eight bit given in Table 4.1 shall be encoded each using one of the Walsh functions mentioned in Task 4A. They are the transmitted simultaneously. The Walsh function is to be inverted when a '0' is to be transmitted and remains unchanged for a '1' to be send. Give the resulting signal on the media. Make use of the given scheme. /3

Node	Data	Signal								
0	"1"	+1	+1	+1	+1	+1	+1	+1	+1	f_0
3	"0"	-1	+1	+1	-1	-1	+1	+1	-1	f_3
6	"1"	+1	+1	-1	-1	-1	-1	+1	+1	f_6
Signal on media		1	3	1	-1	-1	+1	3	+1	

Table 4.1: transmission with CDMA

The following Signal has been received from a transmission using the Walsh functions from this task.

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

As corruptions might happen during transmission, the receiver has a tolerance band for the detection of "1" and "0". All values differing up to ±0.5 from the ideal value will still be accepted as "1" and "0".

4.4 Calculate the bit value based on what the receiver listening to node 1 and 5 detects on the channel. /2

4.5 Is it possible to send only two different values (+1,-1) instead of the analog signal? /3

Creating Walsh functions: 1.) Place element below as well

Creating Walsh functions: 1.) Place element below as well as to the right as is.

2.) Element diagonally under is placed multiplied with (-1)

Start in: black
1. Step in: purple
2. step in: green
3. step in: blue

(negative marked red)

+1	+1	+1	+1	+1	+1	+1	+1	f_0
+1	-1	+1	-1	+1	-1	+1	-1	f_1
+1	+1	-1	-1	+1	+1	-1	-1	f_2
+1	-1	-1	+1	+1	-1	-1	+1	f_3
+1	+1	+1	+1	-1	-1	-1	-1	f_4
+1	-1	+1	-1	-1	+1	-1	+1	f_5
+1	+1	-1	-1	-1	-1	+1	+1	f_6
+1	-1	-1	+1	-1	+1	+1	-1	f_7

Task 4.2 100 spreading codes needed
Because walsh functions are created in powers of 2, we create 128 elements

Task 4.3 Take walsh function f_x for node number x.
-> See table.

Task 4.4 Received: +2.1 +1.9 +1.4 +2.0 -1.7 +5.3 -2.1 -1.9
Node 1: f_1 : +1 -1 +1 -1 +1 -1 +1 -1
inner product: 2.1 - 1.9 + 1.4 - 2.0 - 1.7 - 5.3 - 2.1 + 1.9 = -7.6

in range [-8.5, -7.5] so bit value „0" received!

Received: +2.1 +1.9 +1.4 +2.0 -1.7 +5.3 -2.1 -1.9
Node 5: f_5 : +1 -1 +1 -1 -1 +1 -1 +1
inner product: 2.1 - 1.9 + 1.4 - 2.0 + 1.7 + 5.3 + 2.1 - 1.9 = 6.8

neither in [-8.5, -7.5] nor in [7.5, 8.5], so error in transmission

Task 4.5: Information would be lost, if e.g. +3 would be shortend to +1.
Multiple different inputs may be shortend to the same bus values.

Example for signal distortion:

- Take value on bus from Task 4.3 receive node 3
- Distortion loss of 10% of power
- New values on bus:

Received: 0.9 2.7 0.9 -0.9 -0.9 0.9 2.7 0.9

f_3 : +1 -1 -1 +1 +1 -1 -1 +1

inner prod: 0.9 -2.7 -0.9 -0.9 -0.9 -0.9 -2.7 +0.9 = -7.2

-7.2 is outside of [-8.5, -7.5]