ESD5 – Fall 2024
Problem Set 6 – Solutions

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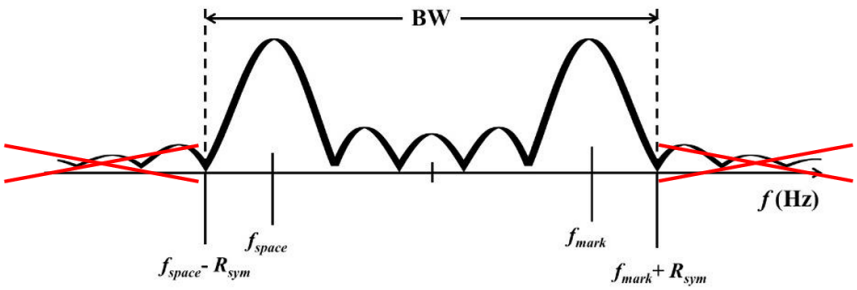
Problem 1 – Computing Rates

(a) Code rate: $R = \frac{\log_2(8)}{6} = 0.5$.



(b) The symbol rate is equal to the bit rate (10000 symbols/s).

$$\text{BW} = f_{mark} - f_{space} + 2R_{sym} = 220 \text{ [kHz]}.$$

Problem 2 – Digital Modulation

(a) 16 PSK

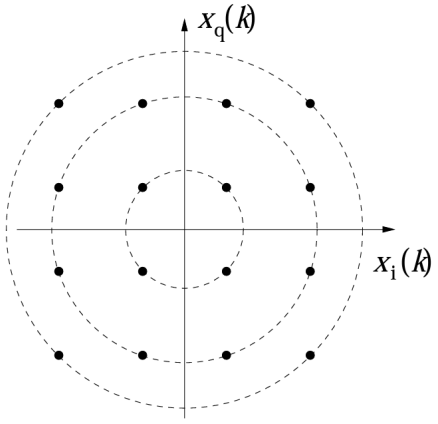
(b) 16

(c) $\log_2(16) = 4$ bits

(d) 10000 symbols/second * 4 bits/symbol = 40000 bits/second

Problem 3 – Yet Another Digital Modulation Technique

(a) 4 bits per symbol.



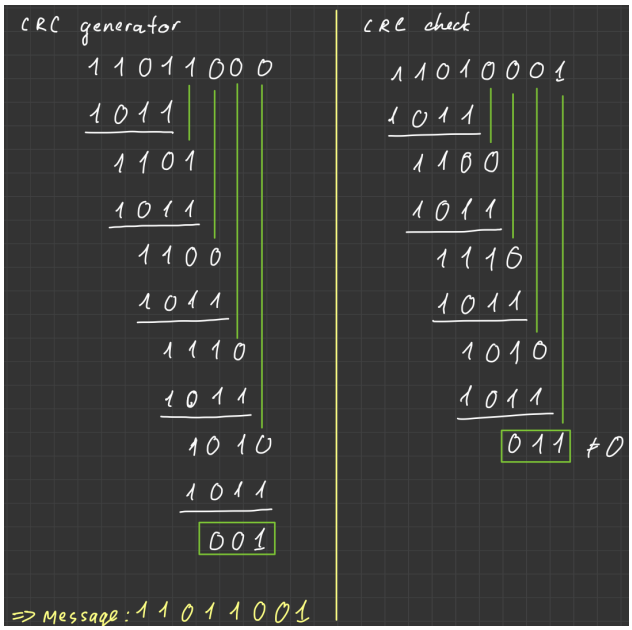
(b) Yes, the order in which the symbols are labeled matters. We can use for example Gray labeling. The idea is to reduce the quantity of errors and make them easier to be detected.

Problem 4 – An Error Detection Scheme

(a) 3 bits.

(b) Message: 11011001

(c) Yes, the receiver can detect the error.



Problem 5 – Maximum Ratio Combinining and Incremental Retransmission

1. Yoshi creates:

$$y_i = y_{i,1} + y_{i,2} = 2hs_i + n_{i,2} + n_{i,2}. \tag{1}$$

   If the noise samples are independent, then MRC makes the SNR of y_i double the original SNR under which the data is attempted to be decoded from the individual $y_{i,j}$. Assuming that the feedback from Yoshi is ideal and instantaneous, then double retransmissions will increase the overall transmission time of the packet two times, which decreases the nominal throughput two times.

2. This could be achieved by rich feedback instead of a simple NACK. After failing to decode the packet, Yoshi sends feedback to Xia, which contains information "I am missing b' bits of information to be able to decode". The key phrase is "in principle," as there is a major difficulty in finding coding/decoding methods that enable Yoshi to measure how much information he is missing to decode the packet correctly.

   The simplest way to use NACK for incremental redundancy is to retransmit only a subset of the symbols $\mathbf{S}_{1,1} = \mathbf{s}$ sent in the original transmission. For example, Xia retransmits s_1, s_2, s_3 only and during the retransmission, Yoshi receives $y_{i,2}$ for $i = 1, 2, 3$, as given by [eq. (1, 2), Prob. 1]. Then one option is that Yoshi replaces $y_{i,1}$ from the previously received packet with the respective $y_{i,2}$ for $i = 1, 2, 3$, while he reuses the remaining $y_{i,1}$ for $i > 3$ and attempts to decode the packet again.

Extra Problem – Hamming Code with Syndrome Decoding

The solution is in the file "`extra_hamming_code_solution.m`".