Calculator not needed. Composed by M.Valkama.

1. (a) Explain briefly what is meant by mutual information in communications system context. How is that linked to channel capacity and what does channel capacity mean? What's the role of the channel capacity theorem for system designers?

   (b) Discuss the role, importance, and mutual relation of signal power and transmission bandwidth from the communication system performance point of view. Consider this from both the theoretical as well as practical point of views (e.g., PAM technique).

2. Lets consider a carrier modulated PAM/PSK/QAM transmission chain. Draw the block diagram for such transmission system (transmitter, channel, receiver) with all relevant blocks/modules included, and explain the essential operation of these different blocks. Explain also how bit rate is defined in the system and how does it depend on the available bandwidth and other possible key parameters.

3. Explain briefly the basic ideas of ML and MAP detection principles and the underlying decision philosophies. In case of single symbol detection in AWGN (additive white Gaussian noise) channel, illustrate the underlying probability densities and the resulting decision boundaries related to the previous detectors. Based on this, explain in detail how (*i*) the statistics of the data symbols and (*ii*) the statistics of the channel noise contribute to the previous detection principles.

4. There are two principal approaches to control intersymbol interference (ISI) in receivers in carrier modulated PAM/PSK/QAM systems, what are these approaches are how do they work? Explain the basic ideas and essential underlying signal models of these techniques, and especially how the ISI mitigation is achieved. Explain also the relative pros and cons of these two approaches.

5. (a) What kind of different levels of error control can be deployed in transmission systems? What is the fundamental idea behind all these error control coding methods? What is in general meant by hard- and soft decoding?

   (b) Consider a (6,3) linear block-code whose generator matrix is given below.

$$\mathbf{G} = \begin{bmatrix} 0 & 0 & 1 & 1 & 0 & 1 \\ 1 & 0 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 0 & 1 & 1 \end{bmatrix}$$

   Explain how the code works. Is the code systematic? Write down all the codewords and their Hamming weights. What's the minimum Hamming distance of this code? Explain. How many errors can be (*i*) corrected or (*ii*) detected with this code in hard decoding? Explain. What's the output of a hard decoder when the decoder input word is 1 1 1 1 1 1 ?