(*Suomenkieliset kysymykset paperin toisella puolella*)

1. (a) Explain briefly what is meant by (*i*) information and (*ii*) entropy. What kind of different interpretations can you give for entropy?

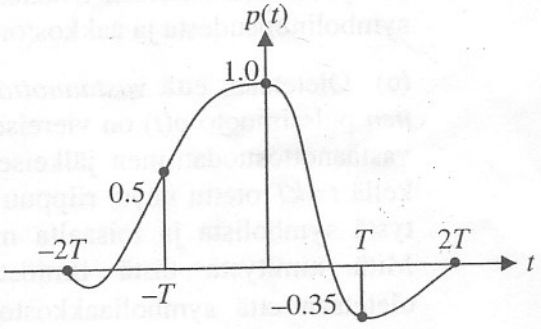
   (b) What is meant by channel capacity? In general, the average mutual information of random variables X and Y is usually defined as $I(X,Y) = H(X) - H(X|Y)$. Based on the entropy interpretations, explain what does this mean and how is it related to channel capacity (i.e., what do the random variables X and Y and their entropies represent in the channel capacity case?)

2. Consider a *baseband* transmission system based on digital linear modulation (PAM).

   (a) Explain the most important functions of transmit and receive filters.

   (b) How does the transmission bandwidth depend on the symbol rate? What is meant by the excess bandwidth in this context? How does the bit rate depend on the symbol rate and on the size of the alphabet?

   (c) Assume the pulse-shape $p(t)$ *after the receive filter* is depicted in the figure. How does the sample of the corresponding signal taken at $t=kT$ depend on the consecutive transmitted symbols? How is this phenomenon usually referred to as? Given that the symbol alphabet is $\{\pm 1\}$, how much the sample can differ from the transmitted symbol in the worst case?



3. (a) Explain briefly the basic idea of quadrature (I/Q) modulation used in *carrier modulated* PAM/PSK/QAM transmission systems. Sketch simple block-diagrams of the needed transmitter and receiver structures and illustrate the I/Q modulation principle by showing the spectra of the signals in different parts of these structures.

   (b) Assume the additive noise in a PAM/PSK/QAM transmission system is Gaussian. What's the leading principle in designing symbol alphabets to minimize the probability of *symbol* errors (assuming Maximum Likelihood (ML) detection)? How is this related to the physical transmit power? Given that the alphabet and *symbol* error probability are fixed, how (and why) does the so called Gray-code help minimize the *bit* error probability?

4. What is meant by spectral efficiency? Given that the target spectral efficiency in a *carrier modulated* PAM/PSK/QAM system is (*i*) 2 bits/s/Hz or (*ii*) 4 bits/s/Hz, how large symbol alphabet is needed in theory? What about in practice? If the symbol error probability and the bandwidth are fixed, how does increasing the spectral efficiency affect the needed transmit power? Explain.

5. Explain the basic principle of FSK. What are the main design aspects when designing such a system?