(*Suomenkieliset kysymykset paperin toisella puolella*)

1. (a) Explain briefly what is meant by (*i*) information, (*ii*) entropy, and (*iii*) channel capacity *in communications system context*. **[3p]**

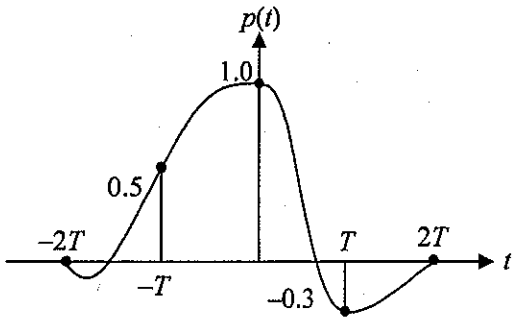
   (b) Discuss the role, importance, and mutual relation of signal power and transmission bandwidth from the communication system performance point of view. Consider this from both the theoretical (AWGN capacity law $C = W\log_2(1+S/N)$) as well as practical (e.g., PAM technique) points of view. **[3p]**

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

   (a) Explain the most important functions of transmit and receive filters in general. What is meant by Nyquist pulse-shaping? **[2p]**

   (b) How does the transmission bandwidth depend on the symbol rate? What is meant by the excess bandwidth in this context? How is the actual bit rate determined? **[2p]**

   (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? **[2p]**



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. What's the role of pulse-shaping in this context? How are the bit rate and transmission bandwidth now determined? **[4p]**

   (b) Assume the additive channel noise in a PAM/PSK/QAM transmission system is Gaussian. What's then the leading principle in designing symbol alphabets to minimize the probability of *symbol* errors (assuming minimum distance detection)? Why? 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? **[2p]**

4. What is meant by (*i*) spectral efficiency and (*ii*) energy efficiency of communications waveforms and corresponding transmission system? How is the spectral efficiency determined in a *carrier modulated* PAM/PSK/ QAM system and why? Give also some practical numerical example. If the target symbol error probability and the bandwidth are fixed, how does increasing the spectral efficiency affect the needed transmit power? Explain. **[6p]**

5. Suppose the receiver observation $Y = A + N$ where A is the transmit symbol and N is Gaussian noise variable. Assume further the case of binary symbol alphabet $\{-a,+a\}$ and symbol probabilities $P_A(+a) = 0.8$ and $P_A(-a) = 0.2$. Sketch the essential probability densities related to this setup, and stemming from these densities, explain how the Maximum Likelihood (ML) and Maximum A Posteriori (MAP) detectors work. **[6p]**

Note: The course project work is soon available at the course web site … stay tuned!