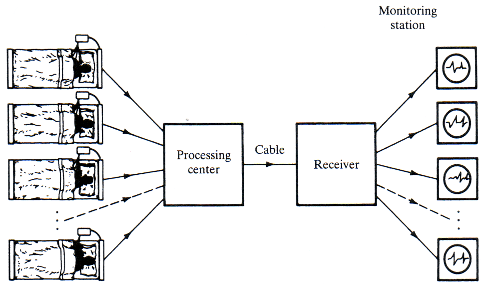
Aalto University
School of Electrical Engineering
Department of Communications and Networking

OPEN-BOOK EXAM
27.10.2011

S-72.1140 Transmission Methods in Comm. Systems



1. (6p.) It is desired to set up a central station for simultaneous monitoring of the electrocardiograms (ECGs) of 10 hospital patients. The data from the 10 patients are brought to a processing center over wires and are sampled, quantized (using uniform quantization intervals), binary-coded, and time-division multiplexed. The multiplexed data are then transmitted to the monitoring station as shown above. The ECG signal bandwidth is 100 Hz, and you can assume that the ECG signal from a patient varies over some symmetric interval $[-m_p, m_p]$. The maximum acceptable error in sample amplitudes is 0.25% of the peak signal amplitude. The sampling rate must be at least twice the Nyquist rate. Determine the minimum cable bandwidth needed to transmit these data.

2. Consider a message signal $m(t) = 2\cos 100\pi t$.
   (a) (1p.) Write an expression for the corresponding PM wave $\varphi_{\mathrm{PM}}(t)$ if the amplitude A is 10, the carrier (angular) frequency ω_c is 10^6 rad/s, and $k_p = 1$.
   (b) (2p.) Find the instantaneous frequency $f_i(t)$ of $\varphi_{\mathrm{PM}}(t)$.
   (c) (3p.) Estimate the bandwidth of $\varphi_{\mathrm{PM}}(t)$.

3. (a) (4p.) Consider a (6,2) code generated by the matrix

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

   Find the codewords for all possible input data words. What is the minimum distance of this code? How many errors can it correct?
   (b) (2p.) The polynomial $g(x) = x^3 + x + 1$ can be used to generate a (7,4) cyclic code. In practice, systematic encoding is almost always used. Find the systematic codeword corresponding to the data word **1011**.

4. A quaternary signaling scheme uses four waveforms:

$$
\begin{aligned}
s_1(t) &= 4\varphi_1(t) \\
s_2(t) &= 2\varphi_1(t) + 2\varphi_2(t) \\
s_3(t) &= -2\varphi_1(t) - 2\varphi_2(t) \\
s_4(t) &= -4\varphi_2(t)
\end{aligned}
$$

where $\varphi_1(t)$ and $\varphi_2(t)$ are orthonormal basis signals. All the signals are equiprobable, and the channel noise is white Gaussian with PSD $S_n(f) = 10^{-4} = \mathcal{N}/2$.

(a) (3p.) Represent the signals in the signal space and find the optimum decision regions (graphical presentation is sufficient here).

(b) (3p.) Compute the error probability of the optimum receiver.

(c) (3p.) Find the minimum energy equivalent signal set.

(d) (3p.) Determine the amount of average energy reduction (as a percentage) if the minimum energy equivalent set is used instead of the original one.