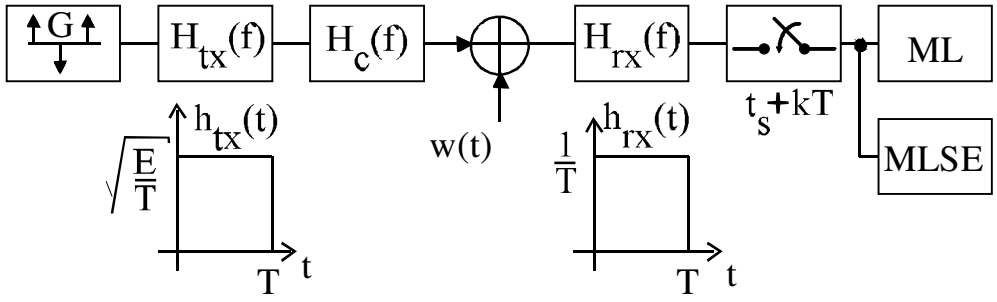
S-72.232 RADIO COMMUNICATION SYSTEMS
EXERCISE 3/2005
24.2.2005

11.



The figure shows a bipolar binary system, where either symbol by symbol ML decision or Viterbi-algorithm is used. Symbol timing recovery searches for the maximum eye opening.

a) Derive the sampler input signal expression and draw the corresponding pulse waveform, when the multipath channel impulse response is: $h_c(t) = 0,5\delta(t) + \delta(t - 0,5T) + 0,9\delta(t - 2T)$.

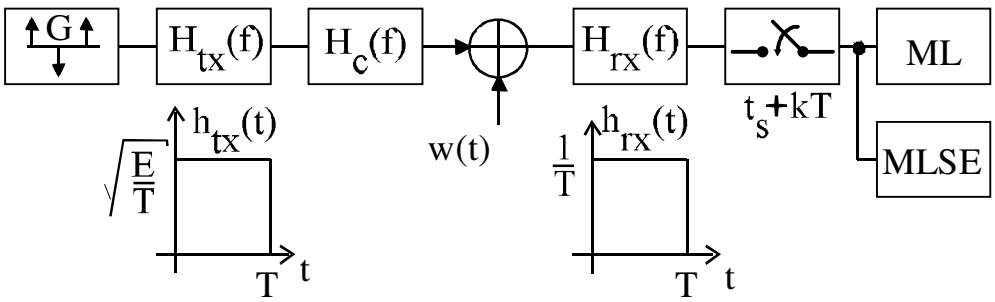
b) Determine the time instant for the maximum eye opening on the time interval (0,*T*). Then derive the expression of the signal samples x_k.

c) Calculate the noise sample power and the signal to noise ratio.

d) Derive the error probability expression of the symbol by symbol ML-receiver.

e) Calculate the performance degradation (dB) caused by the delayed multipath components.

12.



The figure shows a digital transmission system using a Viterbi-equalizer. The channel is the same as in Problem 11.

a) How many states there are in the trellis diagram and how many partial metrics should be calculated in each state transition, if the

transmitted signal is i) a bipolar binary signal, ii) 4QAM, or iii) 16QAM? The symbol rate is assumed constant.

b) Draw the trellis diagram, when the transmitted signal is a bipolar binary signal.

c) Calculate the signal values $q_j(a_k, s_k)$ corresponding to the possible state transitions.

13. The state path corresponding to the transmitted bit sequence is $S_{12} = \{8,8,8,8,8,8,8,8,8,8,8,8\}$, and the signal to noise ratio is $10\lg(2E_{tx}/N_o) = 15dB$.

a) Draw into the trellis diagram the error paths corresponding to 3, 4, 5, and 6 error states.

b) Calculate the Euclidian distance between the error paths and the correct path.

c) Identify the three most critical error paths and conclude from them exists there possibly a more critical error path which has a longer duration.

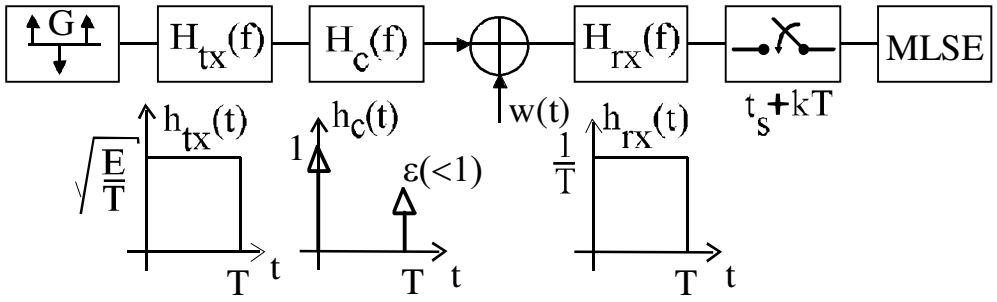
d) Calculate the occurrence probability of the three most critical error paths.

e) Present the binary sequence corresponding to the most critical error path and estimate based on that the bit error probability.

f) What is the SNR improvement of the Viterbi-equalizer compared to the ML-receiver?

14. In the Viterbi-algorithm summation and multiplication take 3 clock periods, comparison of two numbers 5 clock periods, and storage of one number 1 clock period. Estimate the highest possible bit rate on different symbol and ISI combinations. The clock frequency is 1 GHz.

HOMEWORK 3, return time 1 month, at latest before May 2005 exam



The figure shows a bipolar binary system using a Viterbi-equalizer.

a) Derive the impulse response of the complete filter chain, determine the decision sampling instant based on maximum eye pattern opening, draw the trellis diagram, and calculate the signal values $q_j(a_k, s_k)$ corresponding to the state transitions.

b) Estimate the bit error probability using the expressions below where the latter gives the squared Euclidian distance between the shortest error path and the correct path.

$$P_b(\varepsilon) = w_b P\{C_1\} P\{C_2\} Q\left(0{,}5\frac{\|\Delta Q\|}{\sigma_n}\right), \qquad \|\Delta Q\|^2 = \sum_{i=1}^{N} (q_i - \hat{q}_i)^2$$

$P\{C_1\} \cong 1$, $P\{C_2\} = \prod_{m=k}^{k+l-L-1} \frac{M - |\varepsilon_m|}{M}$, w_b is the fraction of error bits in the error path.

c) How large is the SNR improvement of the Viterbi-equalizer compared to i) the MAP-receiver in an ideal channel, ii) the single symbol MAP-receiver, when ε = 0.95?
(In the single symbol MAP receiver $P_s(E) = Q\left(\sqrt{2E_{rx}/N_o}\right)$, where E_{rx} is the energy of the received pulse waveform.)