ELEC6021 (EZ619) Communications Assignment II

October 11, 2007

Baseband System Simulation

In this assignment, the following BPSK baseband communication system is simulated, where k indicates the symbol-spaced sampling quantity.

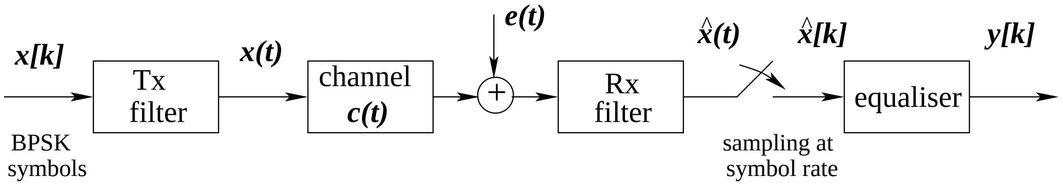

Figure 1: Basedband communication system.

You may assume a symbol rate, e.g. $f_{syb} = 10$ kHz (kSymbols/sec). The transmitted symbol sequence $x[n]$ is binary taking values from $\{\pm 1\}$. Simulation of analogue signal is performed using a sufficiently high sampling rate, e.g. 2 MHz (actually 400 kHz would be sufficient as this is a baseband system. But if you would like to reuse some of the results of Assignment I, such as pulse shaping filters, you may choose to use 2 MHz.). The transmit filter is a properly designed square root raised cosine filter, and the receive filter is identical to the transmit filter. See Assignment I. You need to consider the correct sampling instances.

Hint: Make sure the overall system gain from $x[k]$ to $\hat{x}(t)$ for the ideal channel is unity, and the gain from the noise $e(t)$ to the receiver output $\hat{x}(t)$ is unity.

1 Noise-Free System

Assume that $e(t)$ is absent.

a) Ideal Channel. The channel is ideal with an impulse response of $c(t) = \delta(t)$.

Plot the eye diagram of $\hat{x}(t)$, and show in graph the time waveforms of the transmitted symbol sequence $x[k]$ and the received sampled signal $\hat{x}[k]$.

b) Non-ideal Channel. The channel is non-ideal with an impulse response of $c(t) = \delta(t) + 0.5\delta(t - T_{syb})$, where $T_{syb} = \frac{1}{f_{syb}}$ is the symbol period.

Plot the eye diagram of $\hat{x}(t)$, and show in graph the time waveforms of the transmitted symbol sequence $x[k]$ and the received sampled signal $\hat{x}[k]$.

c) Equalisation. For the case of non-ideal channel in **b)**, implement an equaliser

$$y[k] = \hat{x}[k] - 0.5\hat{x}[k-1] + 0.25\hat{x}[k-2] - 0.125\hat{x}[k-3] + 0.0625\hat{x}[k-4] - 0.03125\hat{x}[k-5] + 0.015625\hat{x}[k-6]$$

Show in graph the time waveform of $y[k]$.

2 Noisy System

Assume that the Gaussian white noise $e(t)$ is present, which has a variance of 0.04.

a) Ideal Channel. The channel is ideal with an impulse response of $c(t) = \delta(t)$.
Plot the eye diagram of $\hat{x}(t)$, and show in graph the time waveforms of the transmitted symbol sequence $x[k]$ and the received sampled signal $\hat{x}[k]$.

b) Non-ideal Channel. The channel is non-ideal with an impulse response of $c(t) = \delta(t) + 0.5\delta(t - T_{syb})$.
Plot the eye diagram of $\hat{x}(t)$, and show in graph the time waveforms of the transmitted symbol sequence $x[k]$ and the received sampled signal $\hat{x}[k]$.

c) Equalisation. For the case of non-ideal channel in **b)**, implement an equaliser

$$y[k] = \hat{x}[k] - 0.5\hat{x}[k-1] + 0.25\hat{x}[k-2] - 0.125\hat{x}[k-3] + 0.0625\hat{x}[k-4] - 0.03125\hat{x}[k-5] + 0.015625\hat{x}[k-6]$$

Show in graph the time waveform of $y[k]$.

d) Bit Error Rate Plots. For the case of non-ideal channel in **b)**
Plot the bit error rate of this system without equaliser over an appropriate range of signal to noise ratio.
Plot the bit error rate of the five-tap equaliser for this system over an appropriate range of signal to noise ratio.

3 Adaptive Equalisation

The symbol-rate sampled channel output $\hat{x}[k]$ is given by

$$\hat{x}[k] = 0.5s[k] + 1.0s[k-1] + e[k]$$

where $s[k] \in \{-1, +1\}$ is the transmitted BPSK symbol, and the noise $e[k]$ has a variance of 0.25. A three-tap adaptive equaliser

$$y[k] = a_0\hat{x}[k] + a_1\hat{x}[k-1] + a_2\hat{x}[k-2]$$

is used to detect the transmitted symbol $s[k-1]$.
Compute the minimum mean square error solution of $\mathbf{a} = [a_0 \ a_1 \ a_2]^T$ that minimises the MSE cost function

$$J(\mathbf{a}) = E[(s[k-1] - y[k])^2]$$

Implement the LMS adaptive algorithm

$$a_i[k] = a_i[k-1] + \mu\,(s[k-1] - y[k])\,\hat{x}[k-i], \ 0 \le i \le 2$$

You should choose an appropriate small positive number for adaptive gain μ and you can use the initialisation $(0.0, 1.0, 0.0)$ for the equaliser's weights, $a_i[0]$, $0 \le i \le 2$.
Investigate convergence behaviour and steady-state MSE performance of this LMS algorithm.
(Think what are you going to plot carefully)