Soft Computing Lab (EC-674)

Channel Equalization with single neuron (perceptron)

Experiment 3:

Design a channel equalizer for 2 level PAM/ PSK signal. The transmitter transmits +1/-1 (logical 1/0). The samples pass through a linear time invariant channel. The channel additionally adds noise to the signal. The channel model can be considered as under.

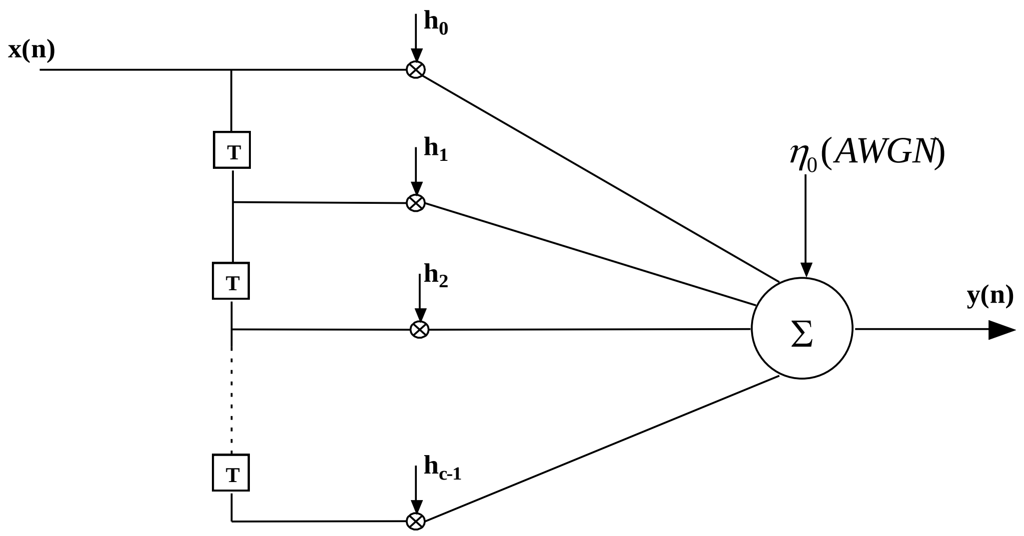

Figure 1: Model of a discrete channel

$y(n)$ constitute the observed signal from the channel. The channel transfer function is given by

$$H(z) = h_0 + h_1 z^{-1} + h_2 z^{-2} \dots \dots \dots .. h_{c-1} z^{-(c-1)}$$

c is termed as channel order. The channel also adds noise to the signal. The job of the equalizer is to recover the transmitted signal by processing the received signal $y(n)$. Normally a delay is provided at the receiver side. With this the received signal can be represented as $\hat{x}(n-d)$. Where, d is the delay samples from the observed signal $y(n)$. The equalizer can be presented as below

Following points may be considered as guideline:-

1. Transmit a set of inputs through the channel as training signal. Observe the channel output.
2. Use the observed signal as input to the equalizer. Train the equalizer parameters. Typically 1000 samples should be enough for training. Complete the training process and store the final arrived weights for further simulation of decision boundary and BER

plot. To compute the MSE after every step of training average the MSE result with 50 sets of training data. Each of the 50 training sets start with same set of starting weights. The sequence of input used in each experiment are independent. The weights arrived at, after each of 1000 iterations (over 50 experiments) should be averages and stored as final set of weights.

3. On completion of the training process decision capacity (finding the decision boundary) should be done. BER are computation should also be done. Both exercises are independent of each other. Decision boundary is made with only 2 inputs to the equaliser (input dimension).
4. Use random weights for initialization of perceptron.
5. **Channel Models:** Consider the following channel models.

   a) $y(n) = x(n) + \eta(n)$
   b) $y(n) = x(n) + 0.5x(n-1) + \eta(n)$
   c) $y(n) = 0.5x(n) + x(n-1) + \eta(n)$
   d) $y(n) = 0.364x(n) + 0.86x(n-1) + 0.364x(n-2)$

   In the above channels it may be noted that Channe-1 is a simple AWGN channel. Channel 2 is simple channel with a zero inside unit circle. This type of channel is called a minimum phase channel. The third channel is called a maximum channel where all zeros are outside unit circle. The last channel is a mixed phase channel where some zeros are inside unit circle and some are outside unit circle.
6. **Decision Boundary:** Draw the decision boundary for 2^{nd} order equalizer with delay=0 for each case. In the same figure show the noise free signal points for each case, depending on +1/-1 being sent, plot the points using two different symbols (* and O) or ay symbols of your choice. When noise gets added to the received signal, the signal position starts to change. Show how the received samples overlap with each other in a 2-dimentional plane. The signal vector received changes around each of the points. Repeat this work 3 different noise conditions. 5dB, 10dB, 30dB SNR (In this part you will have to generate the received signal points constituting 3 figures for each SNR condition). Plot each of the 3 cases for all four channels. Looking at the noise free received signal vectors can u comment on whether a linear equalizer (LMS filter or single neuron equalizer) can equalize the Channel? Repeat the decision boundary plot for delay of 0 and 1. (2plots for each channel and 4 channel in all).
7. **Bit error simulation:** Consider 5^{th} order equalizers with 4 delay elements. For this equalizer draw the BER curve (BER vs. SNR). The plot should start with 1db SNR and continue till BER reaches 10^{-4}. Following should be considered while simulating the BER curve.
   - Train the equalizer once at 10dB SNR. Use the final set of weights to determine BER characteristic for all SNR conditions. The weights used for BER calculation should be the average set of weights arrived with 50 experiments (as discussed in earlier experiment).

   a) The BER simulation should use 10^6 sampled of data and calculated with accumulated minimum 100 errors. If the number of errors with 10^6 samples is less than 100, discard the result. First occurrence of this for a specific channel condition can be stopping criteria.
   b) For each channel following BER curves should be drawn in one graph:

a. BER with different delay (0/ 1/ 2/ 3/ 4) -4 curves
b. Repeat the above work for each channel being considered.

c) Analyse equaliser design for different channels. Which of the channels is difficult to equalize and find possible reason for the same.

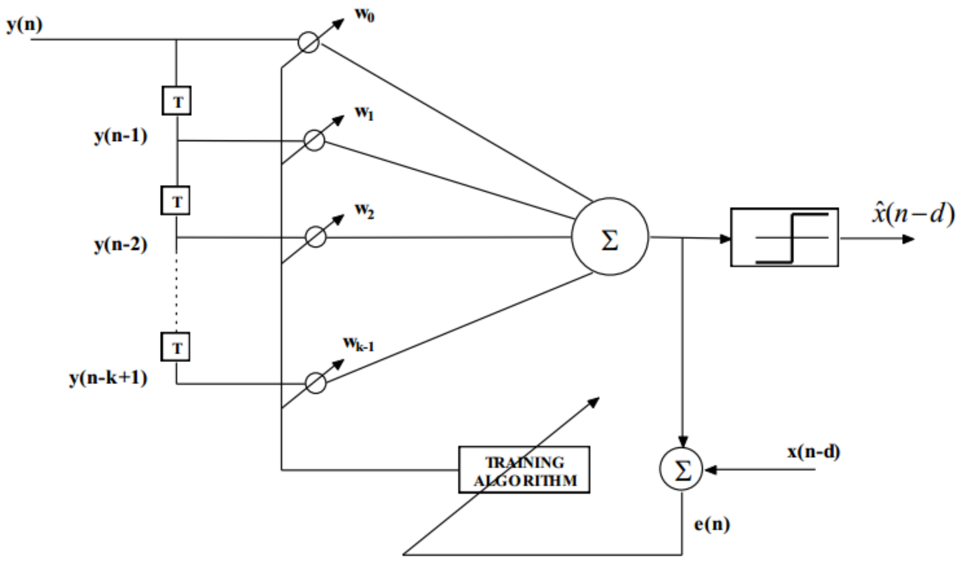

Figure 2:: Single neuron equalizer model

Sarat Kumar Patra

Department of Electronics and Communication Engineering