8 Bandlimited baseband channels and ISI

Intersymbol interference

1. We will first visualize the effect of ISI using the channel model which has been developed in lab 6.
2. We had modelled the channel as a low pass filter. We will investigate what happens to a baseband waveform as it passes through a low pass or baseband channel.
3. Generate a baseband PAM signal corresponding to a random sequence of 100 bits for any choice of T_b.
4. Visualize the output of the channel with the low pass filter cutoff frequency f_c for the following cases: $f_c = \frac{2}{T_b}, \frac{1}{T_b}, \frac{1}{2T_b}$, and $\frac{1}{4T_b}$.
5. Find out what an eye diagram is and make a plot of the eye diagram for each of the cases above. What can you observe from the eye diagram for the cases above? Also plot the eye diagram of the baseband signal without passing through the channel and compare with the received signal's eye diagram.
6. Plot the eye diagram of the matched-filtered received signal. What differences do you observe?

Pulse shaping - introduction

1. Implement a MATLAB function to generate a rectangular pulse with amplitude A, a duration T_b.
2. Implement a MATLAB function to generate the following truncated sinc pulse
$$AT_b \frac{sin\left(\pi \frac{t}{T_b}\right)}{t}$$
3. Implement a MATLAB function to generate a raised-cosine pulse with amplitude A, i.e.,
$$AT_b \frac{sin\left(\pi \frac{t}{T_b}\right)}{t} \frac{cos\left(\pi \alpha \frac{t}{T_b}\right)}{\left(1 - \left(2\alpha \frac{t}{Tb}\right)^2\right)}.$$
4. Obtain the magnitude spectrums of the three pulses.
5. Simulate the output that would be obtained if rectangular, sinc, and raised-cosine pulses are passed through a continuous time filter with impulse response given by $h(t) = 0.1e^{-t}$.
6. Obtain the magnitude spectrum of the output pulse shapes.
7. Generate a random independent and identically distributed sequence of bits with equal probability of a bit being 0 or 1. The length of the sequence should be $N = 10$.
8. Generate the baseband PAM signal corresponding to the above bit sequence when using the rectangular, sinc, and raised cosine pulse shapes for $N = 10$. Let $T_b = 2$ for the baseband PAM signals.
9. Obtain the output of the filter when the baseband PAM signal obtained above is fed into it for the three pulse shapes. Obtain the output magnitude spectrums also. How do the magnitude spectrums change as a function of T_b? (try $T_b = 0.5, 1, 2.5, 4$).

10. If sampling is done perfectly, i.e., at the middle of the bit period what is the sampled output sequence?

11. How does timing jitter affect decoding of bits sent using sinc PAM? Using a simulation study, obtain the average fraction of bits decoded in error as a function of the timing jitter offset. Assume that the source puts out bits according to an IID process with uniform probability. Assume that $r_b = 1 bit/sec$ and the baseband channel bandwidth is $2r_b$.

12. How does timing jitter affect decoding of bits sent using raised cosine pulse shaping?

Pulse shaping - SRRC

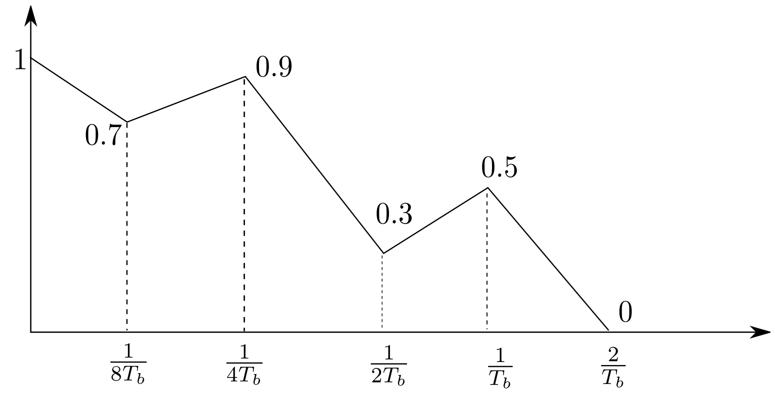
1. Find out what square root raised cosine pulse shaping is.

2. Implement SRRC at the transmitter and its corresponding matched filter at the receiver.

3. Visualize the eye-diagrams after matched filtering.

Channel inversion

1. Modify the channel function that you have written in the previous lab experiment to model a baseband channel which has the following frequency response with linear phase response in the pass-band (upto $\frac{2}{T_b}$).



2. Generate a baseband PAM signal corresponding to a random sequence of 100 bits for any choice of T_b.

3. Visualize the output of the above channel with when the PAM signal is transmitted through it.

4. Also visualize the output of the above channel using an eye diagram assuming that synchronization has been achieved.

5. In order to undo the effect of the channel, whose response $H(f)$ is known to us, we can use a equalizer which undoes the effect of the channel by channel inversion, i.e., the equalizer is a receive/transmit filter which has a response $G(f)$ such that $H(f)G(f) = 1$ over the effective bandwidth of the signal. Design a equalizer using channel inversion.

6. Modify your receiver to process the received signal out of the channel using the equalizer.

7. Visualize the output from the equalizer using an eye diagram. What do you observe?

Duobinary signalling

1. Read/review duobinary signalling from the textbook - Communication Systems.
2. In the above task, we had designed an equalizer with response $G(f)$ such that $H(f)G(f) = 1$ over the effective bandwidth of the signal. Designing such a response might be difficult (with the sharp rolloffs or transitions that are required). In duobinary signalling, we design an equalizer with response $G(f)$ such that $G(f)H(f) = H_d(f)$ where

$$H_d(f) \quad = \quad \begin{cases} 2cos(\pi f T_b) e^{-j\pi f T_b}, \text{ for } |f| \leq \frac{1}{2T_b}, \\ 0, \text{ otherwise.} \end{cases}$$

   Design an equalizer which satisfies the above condition. Visualize the frequency response of the combination.
3. Generate a baseband PAM signal corresponding to a random sequence of 1000 bits for any choice of T_b and transmit it through the channel $H(f)$ and the receiver filter $G(f)$.
4. Assuming that symbol synchronization is achieved, sample the received signal at the middle of each bit time and use the decision feedback rule in order to obtain the transmitted bits - under the assumption that the first bit is known at the receiver (use the first bit from the random sequence at the receiver in order to simulate this).
5. Check how many bits are received in error - note that error here is not due to noise, and would be caused due to any deterministic imperfections in the filter design.
6. Read about the precoding method for duobinary signalling from the textbook. Implement the precoding method and the modified decoding method.

Linear equalizer - Tapped delay line

1. Read/review linear equalization from the textbook - Communication Systems.
2. Assume that the baseband communication channel has a response $H(f)$ as in the above tasks. Let $h(t)$ be the corresponding time domain impulse response.
3. We note that the effect of ISI just needs to reduced at the sampling instants.
4. We assume that the output of this communication channel is fed into an equalizer with impulse response $q(t)$, so that the effective pulse shape from the input to the channel to the output is $p(t) = h(t) \star q(t)$ (here $\star$ denotes convolution).
5. Assume that in order to reduce the effect of ISI at sampling instants we require that

$$\begin{aligned} p(0) &= 1, \\ p(nT_b) &= 0, \text{ for } n = \pm 1, \pm 2, \pm N; \end{aligned}$$

   where T_b is the sampling period (or bit duration).
6. Design the equalizer impulse response $q(t)$ assuming that $q(t)$ is a tapped delay line filter (with delays of magnitude T_b). Note that the design should therefore specify the values of the tap weights of the filter. Do this design for $N = 2, 5, 10, 50$.
7. Visualize the output of the equalizer using an eye diagram for different values of N.