6 Communication over baseband channels

Baseband channel model

1. A baseband channel can be modelled as an LTI low-pass filter with a cutoff frequency of f_c. The channel can be modelled as introducing attenuation, noise, ISI, and unknown propagation delay leading to synchronization issues. Your task is to write a Matlab function which can model a baseband channel.
   a) Assume in the following tasks that signals are sampled at a frequency f_s.
   b) Write a Matlab *channel* function that takes as input a sampled signal $x[n]$ and produces an output $y[n]$ which is a delayed version of $x[n]$; the delay (in number of samples) should be an input
   c) Modify your channel function to introduce additive white Gaussian noise into $y[n]$. The variance of additive white noise should be an input into the function.
   d) Modify your channel function to also low-pass filter the input $x[n]$; the low pass filter should have a gain g in the passband as input, and a passband cutoff frequency of f_c.
2. As in the last lab, produce a random sequence of bits. Each bit should be converted into a sampled rectangular pulse of duration T_b (the sampling can be done at f_s). A bit 1 is mapped into a positive pulse and a bit 0 to a negative pulse. Obtain the pulse sequence or the baseband waveform obtained for the random sequence of bits that you have generated. This pulse sequence is called the baseband PAM signal.
3. Simulate the transmission of the baseband signal through the channel function.
4. Visualize the input and output waveforms in both time domain and frequency domain. Consider different values of g, noise-variance, f_c, T_b. Comment on your observations.

Detection and error performance

1. Modify your channel function to only introduce noise and the gain g (or choose the input parameters accordingly).
2. Simulate the transmission of the baseband signal corresponding to the random sequence of bits through the above channel.
3. Simulate the detection of the bits at the receiver. The bits are detected by sampling the received signal at the middle of each bit time T_b and applying the sample to a threshold detector, which decides whether a zero or one was transmitted.
4. Find out the bit error rate - which is the fraction of bits which are detected in error. The bit error rate should be obtained for the simulation of the transmission of a large number of bits, say 1000.
5. Plot the bit error rate as a function of the noise-variance. For making this plot, you have to consider different values of the noise variance. For each value of the noise variance, generate the bit error rate value for 1000 bits, 10 times. Take the average of the 10 bit error rates as the bit error rate for that noise variance. Repeat for all values of the noise variance.

Pulse shaping

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 $r_b = 1bit/sec$ and the baseband channel bandwidth is $2r_b$.
12. How does timing jitter affect decoding of bits sent using raised cosine pulse shaping?