Note Title 3/27/2020

Assignment #1 -- Oct.21, 2020

1. [5 marks] We consider raised cosine (RC) pulse shaped transmission. The impulse response of the pulse-shaping continuous time filter g(t) is given as follows:

$$g(t) = \mathrm{Sinc}(\pi t/T)\ \{\ \mathrm{Cos}(\pi\beta t/T)\ /\ (1-4\beta^2 t^2/T^2)\ \}$$

$t = nT_s,\ T_s = \frac{T}{J}$

where the excess bandwidth factor $0 \le \beta \le 1$ and T is the symbol duration and Sinc(x)=Sin(x)/x. We use a discrete-time filter g(nTs) = g(n) where the sampling rate Ts = T/J, where J is a positive integer. Also, the filter is truncated to 2LT symbol durations, i.e., LT symbol durations on each side of t=0, where L is a positive integer. The input bit (or symbol) stream I(kT) into this filter will be zero-interleaved with J zeros in order to create the output sequence x(kTs) which is then sent into a DAC.

Chose your own 16-bit random sequence where I(k)∈ {+1, -1} in order to create a BPSK signal. Assume all the bits before and after this 16-bit pattern are zeros. You are to plot the output sequence (samples) x(kTs) using both "symbol-plot" as well as join them using "line-plot" using Matlab.

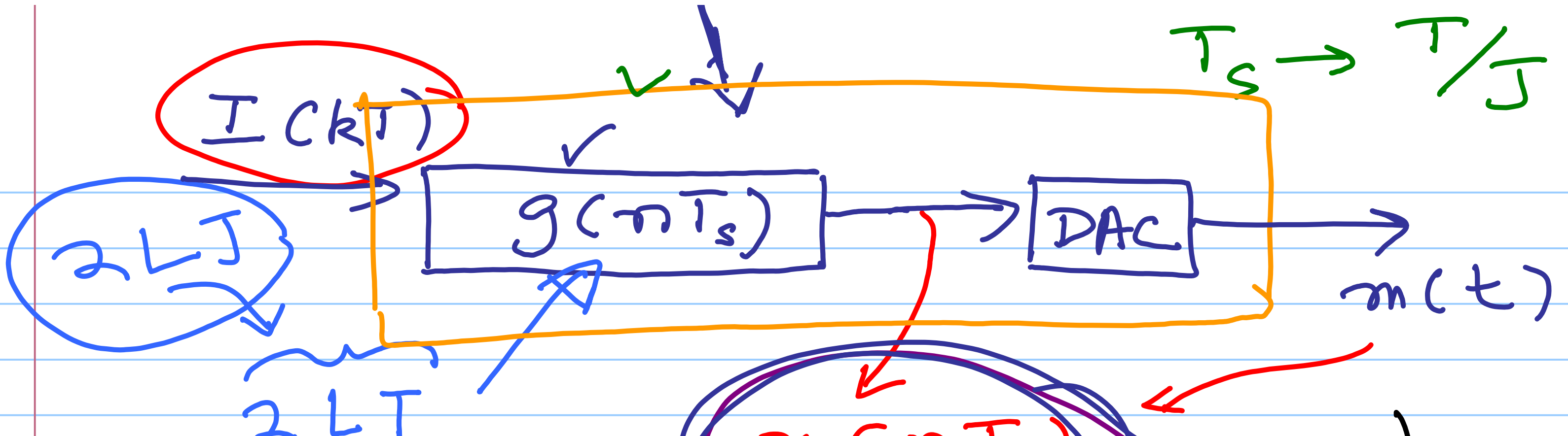
(a) Plot as Fig.1, x(kTs) for J=4, L=2, and β=0.
(b) Repeat (a) and include in Fig.1 another plot with the change L=4. L=4
(c) Plot as Fig.2, *three* different plots of x(kTs) where all of them have J=8, ~~L=2~~, but with *three* different excess bandwidth factors, namely, β=0, β=0.5, and β=1.
(d) Comment on your results in (b) and (c).

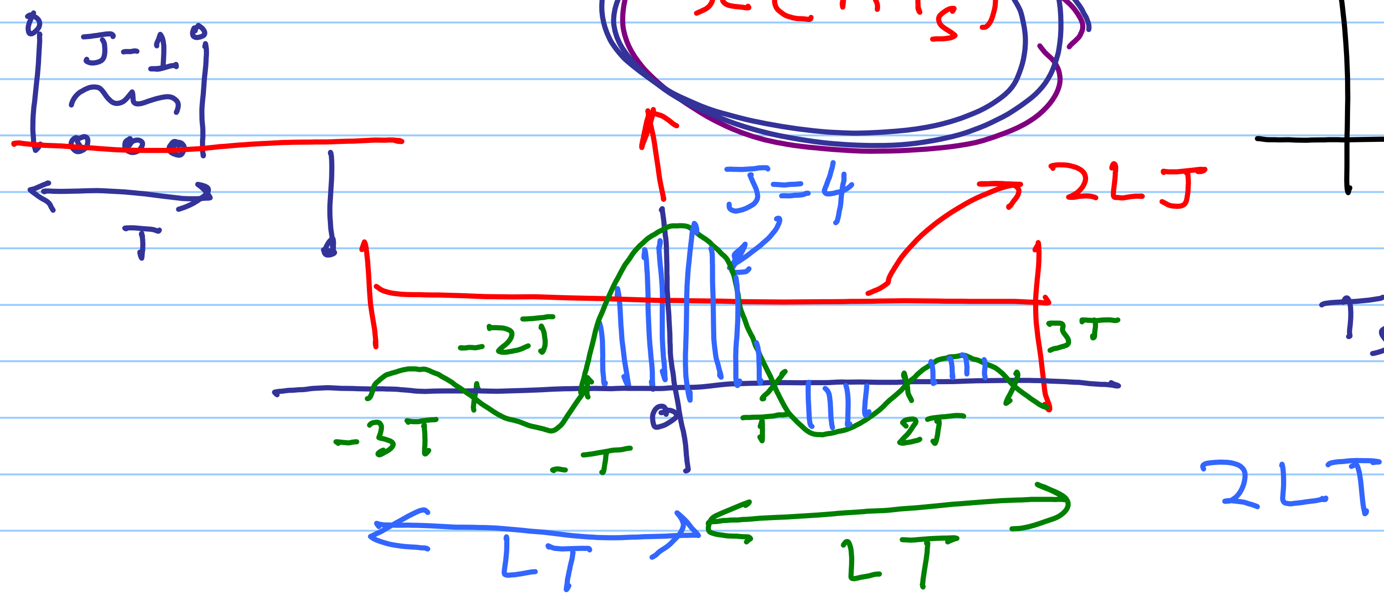
$m(t) = \sum I(k)\, g(t-kT)$

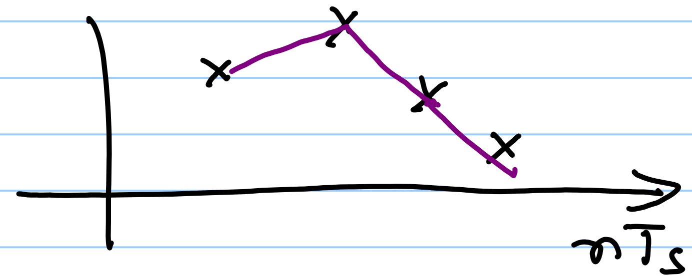
$\xrightarrow{I(kT)} \boxed{g(t)} \longrightarrow$

T → symbol Duration

$T_s \rightarrow T/J$, $J = 1, 2, 3 \ldots$







$T_s = T/J$

BER/SER

2. [15 marks] In this question, we compare the theoretical probability of symbol error P(e) = P_S ~~and/or probability~~ of bit error, P_B, with computer simulated symbol or bit error rate (SER or BER), for a few popular linear modulation schemes. The approximation on P_S using bounds will also be studied.

(a) For the same energy per bit, Eb, compute and plot on the same figure (Fig-1) the P_S of BPSK, QPSK, and 16-QAM signals. Assume the complex base-band AWGN measurement model r(k)=I(k)+v(k), where iid I(k) is uncorrelated with the white Gaussian noise v(k). For complex signals (QPSK and 16-QAM) the noise will be complex with variance $N_O/2$ per dimension. Vary the ratio $10\log_{10}(Eb/No)$ in 2dB steps from 0dB to 10dB, by changing the noise variance and plot against $\log_{10}(P_S)$, for all the 3 signals. Chose Eb=1 for all the signals. Note that the log of the error probability is plotted on the y-axis. The *Q*(.) function or the *erfc*(.) function can be evaluated using Matlab.

(b) Assuming Gray coding, plot $10\log_{10}(Eb/No)$ versus $\log_{10}(P_B)$ for the 3 signals. Add these curves also to Fig-1, and label neatly.

(c) For the QPSK signal set, compute using the following approximations to the symbol error probability. Plot each of these values of P_S for the range of SNRs from 0dB to 16dB in the same figure. Call it Fig-2.

(c1) Union bound using *all* the pairwise symbol errors
(c2) Union bound using only the *nearest neighbours*
(c3) In part (c2) replace the *erfc*() function with the Chernoff bound and add this also to Fig-2.

(d) Now, we wish to simulate the symbol error rate (SER) for QPSK. For generating the transmit symbols, use uniform random variable (rv) between (0,1). If the rv takes a value X between 0 and 0.5, it is mapped to say -d; else, it is mapped to +d, where 2d is the distance between the symbols. We will need 2 rvs, one of the real part and one for the imaginary part. Chose "d" to ensure Eb=1. Generate 10^5 symbols to measure the SER over the same range of SNRs as in part (c). Plot your results back in Fig-2. Comment.

(e) Repeat part (c) above for the 16-QAM signal set. Call this Fig-3.

(f) Repeat part (d) for the 16-QAM signal set. Chose the rv to symbol mapping appropriately and explain how you did it. Plot this result back in Fig-3.

(g) With Gray-coding done, compare the simulated bit error rate (BER) of QPSK and 16-QAM. (*Hint*: while you are measuring the SER in parts (e) and (f), you can also compute the BER for both the modulations). Plot these two results together in Fig-4, again for Eb=1 in both cases. Note that for computing BER, you will

10^{-3}

$100 \times (10^3)$

$= 10^5$

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.mls

Instructions: Submit only a single PDF file for the report. Name the file as "rollnumber-assignment1-report.pdf". Your working code, properly commented, **must be included** as Annexure-1 to the PDF file, and also separately sent by email to the TAs. Your working code can be named "rollnumber-assignment1-code.m". Please see other instructions, if any, in the WhatsApp group.

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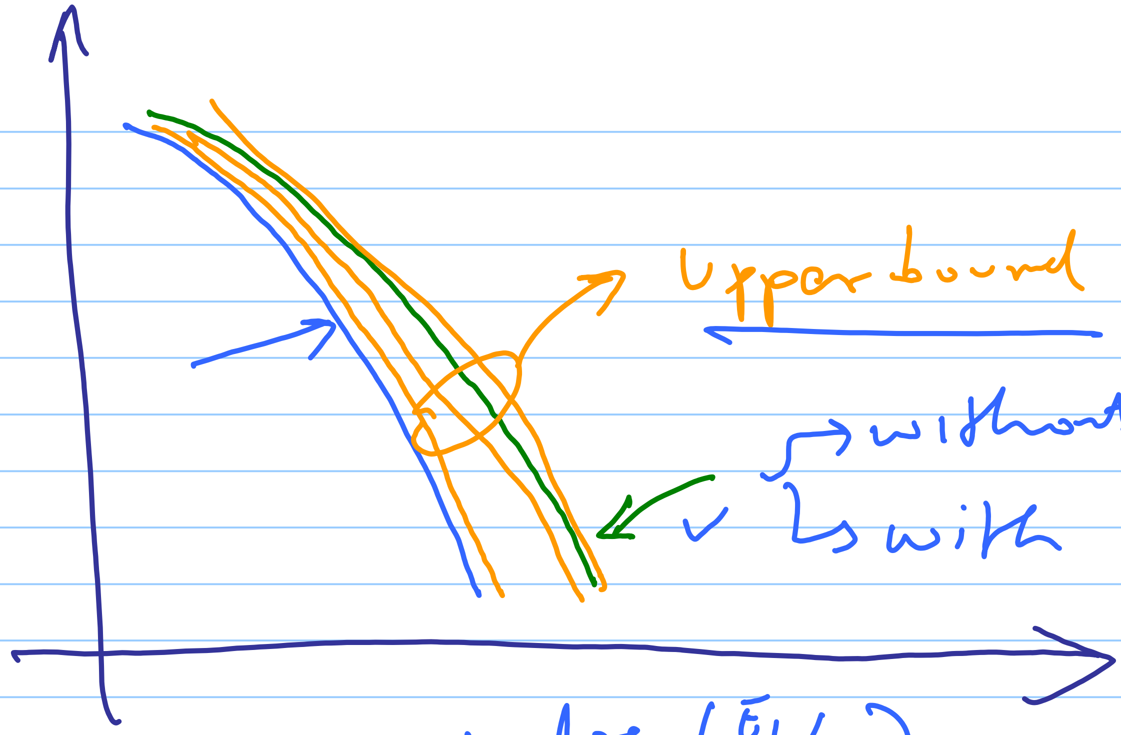
SER

$P_s = P(e)$

$\log_{10}(P_s)$



$10\log_{10}(E_b/N_0)$

upper bound

without GC

with GC

SER

BER