Signal Processing Project (Monsoon 2025)

Part 1: Non-ideal sampling

We are familiar with Nyquist sampling criteria for band-limited signals and their reconstruction. In this problem you will be developing techniques to address complexities arising from non-ideal sampling conditions which may happen in practice. Let our signals of interest be band-limited and that sampling is performed above the Nyquist rate with sampling interval T_s. The continuous-time signal is denoted $x(t)$ and the sampled signal is denoted $x[n] = x(nT_s)$. Consider the following two non-ideal sampling scenarios:

a) The n-th sample is not always sampled at the time instant nT_s but there could be some error in the sampling instant giving rise to the samples $\hat{x}[n] = x(nT_s + k_n\Delta)$ where $\Delta = T_s/10$ and k_n is integer. The deviation $k_n\Delta$ in the n-th sampling instant is known but is random across the samples n. Specifically, k_n is equally likely to be any integer value in the interval $[-K, K]$ where $1 \leq K \leq 4$.

b) The n-th sample is not always available, i.e., with probability $p \in (0,1)$ it is missing. In this case the sampling instant has no error. Thus, the samples are $\tilde{x}[n] = x(nT_s)$ when they are available.

For each of the scenarios (a) and (b), develop a method to estimate $x[n]$ from $\hat{x}[n]$ and $\tilde{x}[n]$ respectively. Justify the methods with examples and analysis. Demonstrate results using at least three distinct band-limited signals.

For scenario (a), quantify the performance of your method as function of K.

For scenario (b), quantify the performance of your method as function of $p \in (0.01,0.1)$.

Part 2: Find the beats

You are given a few audio files which correspond to recordings of drum sounds – listen and verify. For each file, identify and output all the time instants corresponding to a drum hit. You should also measure approximately how long the sound of each hit lasts.

The drum sounds correspond to various instruments in the drum kit. Identify how many distinct instruments are being played in each file and group together the sounds/hits belonging to the same instrument.