CT303 **Digital Communication** **Autumn, 2018**

Lab. 4 **Sampling and Aliasing effect**

1. Consider an analog signal $x(t) = \cos(2\pi f_m t)$; $-\infty < t < \infty$. Sample it i.e., $t = nT_s = \frac{n}{f_s}$ at different frequencies $f_{s_1} = 400\ samples/sec$, $f_{s_2} = 800\ samples/sec$ and $f_{s_3} = 1600\ samples/sec$ choosing f_m= 50 Hz. Plot (n Vs amplitude) for 2 cycles in each case. Count number of samples in one cycle of each case.

2. Consider $x(t) = \cos(2\pi 50t)$. Sample it at $f_s = 400$ samples/sec .
   a. Take 8 point Discrete Fourier Transform (DFT) i.e., $X(k), k = 0,..,7\ (0,..,N-1)$ by considering one cycle of sampled signal.
      Which $X(k)$ values are non-zero and why? Note that $X(k), k = 0,..,7$ represent the (complex) amplitudes and frequency components (complex sinusoids) present in input $x(t)$.
   b. Verify that $X(k)$ is periodic and $x(n)$ is also periodic. Use the following expressions for N point DFT pair:

$$x(n) = \frac{1}{N}\sum_{k=0}^{N-1} X(k)\, e^{j\frac{2\pi}{N}.nk}, \text{ n=0, 1,.., N-1}$$

$$X(k) = \sum_{n=0}^{N-1} x(n)\, e^{-j\frac{2\pi}{N}.nk}, \mathrm{k} = 0,1,..,\mathrm{N}-1$$

3. Consider $x(t) = \cos(2\pi 50t) + \cos(2\pi 100t)$.
   a. Sample it at $f_s = 400$ samples/sec . Compute 8 point DFT by taking samples in one cycle of sampled $x(t) = x(nT_s) = x(n)$.
      i. How many and for which k, $X(k)$ values are non-zero and which frequency and amplitude they correspond to? Note that k represents frequency index for the amplitude $X(k)$.
      ii. Let us assume that you pass the above sampled signal through analog LPF (low pass filter) just above 100 Hz. Is there aliasing (distortion) in the reconstructed signal? Why? What happens if sampling is done at 200 Hz instead of 100 Hz. You may check it by computing FFT.

b. Now sample the same signal at $f_s = 175 \text{ samples/sec}$ and again take DFT on samples present in one cycle. How many $X(k)$ values are non-zero in this case. Is there aliasing present? If it is there which is the aliased frequency component? Can the analog signal be reconstructed back from the sampled signal in this case?

4. Take a speech wave file, Sample it at $f_s = 4000, 8000, 16000 \text{ samples/sec}$. Listen to the sound and comment on aliasing effect when the speech is sampled. Note that you will be listening to reconstructed analog version of sampled signal.