6 Digital Signal Processing (MGK)

A zoologist wants to record the echo-location sounds emitted by a bat. The species of bat to be recorded emits only sounds in the frequency range 40 kHz to 80 kHz and the microphone used includes an analog filter with that passband.

(*a*) Explain for each of the following sampling techniques how it can be used to convert a continuous ultrasonic microphone signal $x(t)$ into a discrete-time sequence $\{x_n\}$ and state for each technique the lowest sampling frequency f_{s} that enables the exact reconstruction of $x(t)$ from $\{x_n\}$:

(*i*) Passband sampling [3 marks]

(*ii*) IQ downconversion [5 marks]

(*b*) Using a 32-bit floating-point data type, how many bytes per second are required to store each of the two resulting discrete sequences from part (*a*)? [2 marks]

(*c*) Compare your answers to part (*b*) with the memory required for storing $x(t)$ sampled at the Nyquist rate of 160 kHz and explain the difference in terms of redundancy in the acquired spectrum. [2 marks]

(*d*) If the sampling techniques from part (*a*) are applied to a test signal $x(t) = \cos(2\pi f t)$ with $f = 45$ kHz, what does the discrete-time Fourier transform of the resulting discrete sequence $\{x_n\}$ look like (over the normalized frequency range $-\pi < \dot{\omega} \leq \pi$) for each technique? [4 marks]

(*e*) For both sampling techniques described in part (*a*), briefly outline the steps needed to reconstruct the original continuous waveform from the discrete sequence. [4 marks]