**Introduction to Telecommunications**

Question 1

Let a signal sq_triangle(t) which is the square of the triangular periodic table. This signal has amplitude A = 4 V and frequency $f_m$ in kHz which $f_m$ is the sum of the last three digits of each student's Registration Number. If the sum exceeds 9 then the sum of the digits continues until a single digit number occurs. Figure 1 illustrates an example of a triangular periodic pulse series of amplitude A = 1 V and frequency 1 Hz.

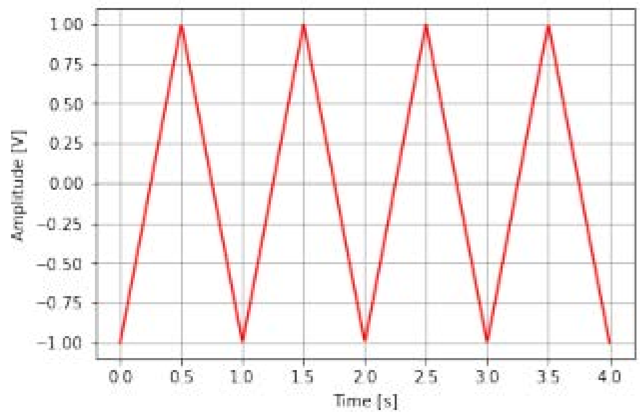


*Figure 1*

a) The above signal sq triangle (t) to be sampled with two different frequencies, first with $f_{s1} = 25f_m$ and then with $f_{s2} = 60f_m$. Present the following three graphs:
   i) Samples after sampling with frequency $f_{s1}$.
   ii) Samples after sampling with frequency $f_{s2}$.
   iii) The samples from questions (i) and (ii) in a common diagram.
b) What do you notice if the signal sq_triangle(t) is sampled with $f_s = 5f_m$? How would you find the minimum theoretical $f_s$ so that the exact signal under discussion can be accurately reconstructed? Approach it theoretically and numerically.
c) Let be a halftone $z(t) = A\sin(2\pi f_m t)$ of width A = 1 V and frequency $f_m$ in kHz. The frequency $f_m$ is the sum of the last three digits of the Registration Number of each student. If the sum exceeds 9 then the sum of the digits continues until it occurs a single digit number.
   i) Repeat questions (a) and (b) for signal z(t).
   ii) Repeat questions (a) and (b) for signal $q(t) = z(t)+A\sin(2\pi(f_m+\Lambda)t)$, where A = 1V and $\Lambda$=1kHz. What is the resultant signal? Explain briefly.

Note: In the diagrams the horizontal axis should express time (sec) and the samples should not be joined together. In the diagrams of queries a and c (i) to present four (4) periods while in c (ii) one (1) period.

Question 2

Consider as input to a uniform quantizer (mid riser) the signal y(t) of the 1st question after sampling frequency $f_{s1} = 45f_m$. If the frequency $f_m$ is even (based on the Registration Number) to be quantized with 4 bits, otherwise (if it is unnecessary) to be quantized with 5 bits.

a) Diagram the output of the quantum. The vertical axis will display the quantization levels (not as a decimal number but as a binary one, having coded Gray) and the horizontal axis the time (in sec).
b) Calculate the standard deviation of the quantization error
    i) for the first 10 samples
    ii) for the first 20 samples
    iii) Calculate the quantization SNR for cases (i) and (ii) as well as its theoretical value and explain any differences in the resulting values.

c) After the quantization, present in a diagram for a period the corresponding transmission flow from bits (bit stream) considering a line coding of BIPOLAR RZ with a bit duration of 1 msec. The amplitude (in Volts) is numerically equal to the frequency of the signal (eg for a frequency of 1 kHz, the amplitude is 1 V).

Question 3

Considering the sine signal z(t) of the 1st question with $f_{s2} = 130f_m$ as a carrier in AM configuration with modulation index 0.5 and information signal $m(t) = \sin(2\pi 35t)$:

a) Present the AM signal modulated signal for four (4) periods of the information signal m(t).
b) Implement a demodulator / ambient light and plot the signal after demodulation. The final signal at the demodulator output should coincide with the original pre-configuration information signal. It is recommended to use Python's SciPy library and more specifically the signal.firwin () and signal.lfilter () commands.