Department of Electrical and Computer Engineering
Digital Speech Processing
Problem Set No. 1

Problem 1

Consider the sequence of values described by the difference equation:

$$y[n] = 2y[n-1] - 0.5y[n-2]$$

with initial conditions:

$$\begin{aligned} y[-1] &= 0 \\ y[-2] &= -2 \end{aligned} \tag{1}$$

(a) Solve for $y[0], y[1], y[2], y[3]$
(b) Determine an analytic solution for $y[n]$ for all n
(c) If the limit of sequential terms is given by the factor G, i.e.,

$$\lim_{n\to\infty} \left(\frac{y[n]}{y[n-1]} \right) = G$$

determine G.

Problem 2

An input signal, $x[n]$, defined over the region $-\infty < n < \infty$, is passed through a cubic non-linearity yielding the output signal

$$y[n] = (x[n])^3$$

(a) If the input to the system is of the form

$$x_1[n] = \cos(\omega_0 n), \quad -\infty < n < \infty$$

determine the output spectrum, $Y_1(e^{j\omega})$, and plot the magnitude of $Y_1(e^{j\omega})$ (assuming $\omega_0 << \omega_S$, the radian sampling frequency of the digital system).
Hint: recall the trigonometric relationships

$$\begin{aligned} \cos^2(x) &= \frac{1}{2} + \frac{\cos(2x)}{2} \\ \cos^3(x) &= \frac{\cos(3x)}{4} + \frac{3\cos(x)}{4} \end{aligned}$$

(b) If the input to the system is the signal

$$x_2[n] = r^n \cos(\omega_0 n) u[n], \quad |r| < 1$$

plot the magnitude of $Y_2(e^{j\omega})$ (again assuming $\omega_0 << \omega_S$) and assuming a value of $\omega_0 = 2\pi \cdot 500$, $r = 0.9$ and $F_S = 10000$ Hz.

Problem 3

Consider the first order system:

$$y[n] = \alpha y[n-1] + x[n]$$

(a) Find the system function, $H(z)$, for this system.
(b) Find the causal impulse response of this system.
(c) For what values of α will the system be stable?
(d) Assume that the input is obtained by sampling with period T. Find the value of α such that

$$h[n] < e^{-1} \quad \text{for} \quad nT > 2 \text{ msec}$$

i.e., find the value of α that gives a time constant of 2 msec.

Problem 4

(a) An analog signal, $x_a(t) = A\cos(2\pi 200t)$, is sampled at a rate of $F_S = 10,000$ Hz, giving the digital signal $x_1[n]$. Sketch the resulting digital frequency response, $X_1(e^{j\omega})$.

(b) A second analog signal, $x_b(t) = B\cos(2\pi 201t)$ is also sampled at a rate of $F_S = 10,000$ Hz, giving the digital signal $x_2[n]$. Again sketch the resulting digital frequency response, $X_2(e^{j\omega})$.

(c) Are either (or both) digital signals, $x_1[n]$ or $x_2[n]$, periodic digital signals, and if so, what are their periods?

Problem 5 – Write a MATLAB program to do the following:

1. accept an arbitrary speech filename and load the file (filename.wav) using the loadwav command given on the webpage, or the native MATLAB wavload command.

2. listen to the speech file using the MATLAB sound command. (Pay attention to the required scaling for the speech file). Write down the sentence that you heard.

3. plot the sample values of the speech at N msec/line, 4 lines/page, where N is specified at run time.

Use the file s3.wav (from the website) as your test, with N equivalent to 250 msec of speech per line.