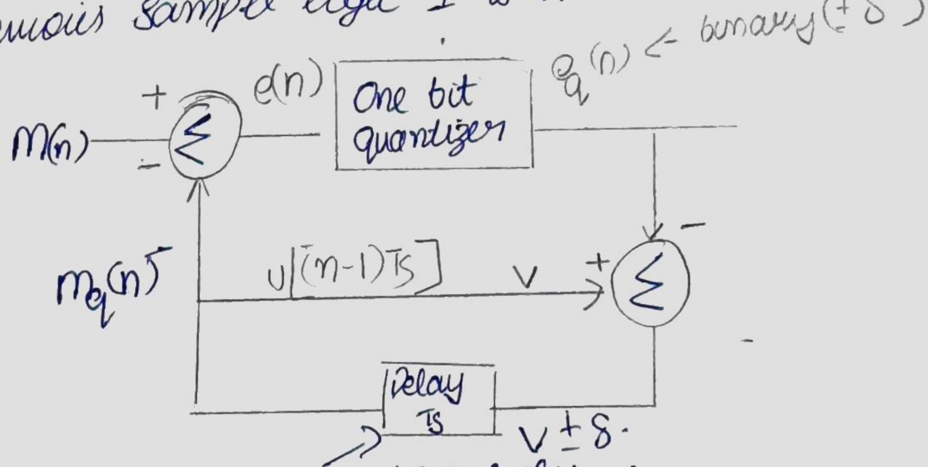
Experiment-3.

Aim:- To study Delta Modulation (DM) and Study Probability of Error Using Matlab / Octave.

Software Used:- GNU Octave

Theory:- Delta Modulation uses a single bit PCM code to achieve digital transmission of analog signal. With conventional PCM, each code is a binary representative of both the sign & magnitude of particular sample. The alogrithm of delta modulation is simple if the current sample is smaller than the previous sample a '0' is transmitted. If the current sample is larger than the previous sample logic '1' is transmitted.



Estimation cycle.

$$e[n] = m[n] - m_q[n] \leftarrow \text{quantized Estimate}$$

$$m_q[n] = m_q[n-1] + e_q[n-1]$$
$$= m[n-1] - (e[n-1] - e_q[n-1])$$

$$e_q[n] = Q(e[n]) = \begin{cases} +\delta & ; e(n) > 0 \\ -\delta & e(n) < 0 \end{cases} = \pm\delta$$

For calculation 'δ' (step size).

$$\boxed{\frac{\delta}{T_s} \geq \left|\frac{d\,(m(t))}{dt}\right|_{max}}$$

For compensating for slope overloading & granular noise reduction.

Also for capturing details, equality should hold true.

In case of sinusoidal signal:

$$\boxed{\delta = \frac{2\pi A_m f_m}{f_s}}$$

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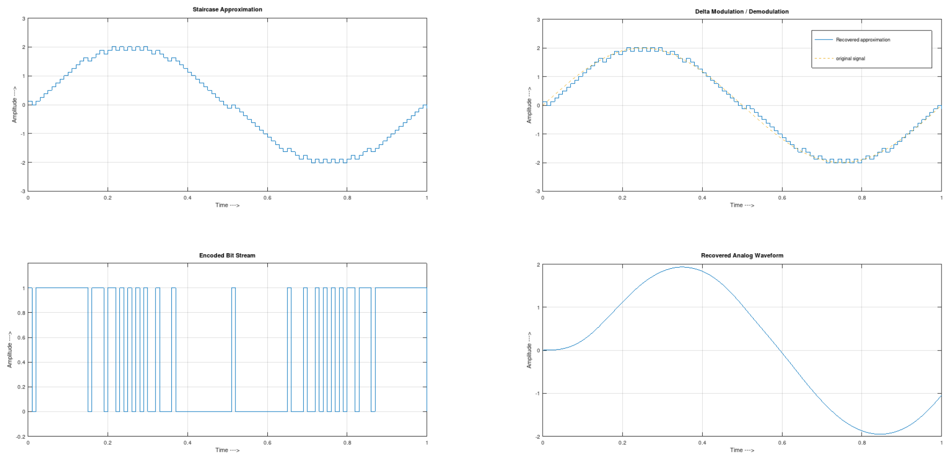
Code

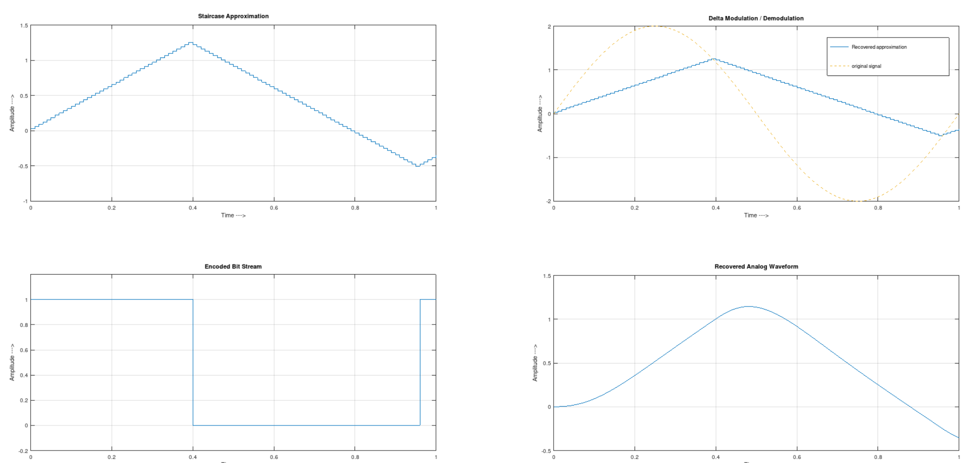
```
% octave pkg to load signal based utils
pkg load signal
pkg load communications

clc;
clear alll;
close all;

%Inputs
a = 2
t = 0:1/100:1;
x = a*sin(2*pi*t);
l = length(x)
delta = input('Required Step Size: ');

%Variation of this step size results in the
% problems of delta modulation like
%  granular noise and slope overloading
% leading to improper reconstruciton

xn = 0;

for i=1:l
    if x(i) >= xn(i)
        d(i) = 1;
        xn(i+1) = xn(i) + delta;
    else
        d(i) = 0;
        xn(i+1) = xn(i) - delta;
    end
end

% Plotting

subplot(2, 1, 1);
stairs(t, xn(2:end));
grid on;
title('Staircase Approximation');
xlabel('Time --->');
ylabel('Amplitude --->');
subplot(2, 1, 2);
stairs(t, d);
grid on;
title('Encoded Bit Stream');
xlabel('Time --->');
ylabel('Amplitude --->');
ylim([-0.2 1.2])

% Recovery

r = 0;
for i=1:length(d)
    if d(i) == 0
        r(i+1) = r(i) - delta;
    else
        r(i+1) = r(i) + delta;
    end
end

[p, q] = butter(2, 1/20);
rec = filter(p, q, r);

figure
subplot(2, 1, 1);
stairs(t, r(2:end));
hold on;
plot(t, x, '--');
legend('Recovered approximation', 'original signal');
grid on;
title('Delta Modulation / Demodulation');
xlabel('Time --->');
ylabel('Amplitude --->');

subplot(2, 1, 2);
plot(t, rec(2:end));
grid on;
title('Recovered Analog Waveform');
xlabel('Time --->');
ylabel('Amplitude --->');

pause
```

Outputs:

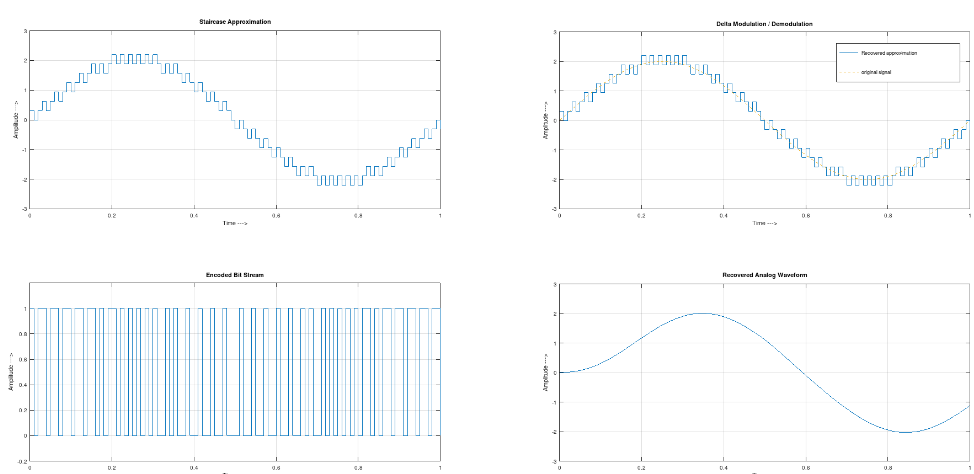
Case 1: Adequate Step Size $\delta = \pi/25$



Case 2: Large Step Size $\delta = \pi/100$



Case 3: Small Step Size $\delta = \pi/10$



Q1. What would be the effect of sampling frequency on the overall performance of the Delta Modulator for a given signal?

→ For any given signal, increasing the sampling frequency will lead to decrease in step size i.e reducing slop overload and improve Signal to Noise ratio. If there is 2x increase in sampling frequency will lead to 4x SNR improvement. But since the number of bits sent is also increased, hence bandwidth is also increased.

Q2. Delta Modulation is a special case of DPCM. Discuss.

→ Delta modulation has a similar construction to that of DPCM with the fact that it uses Differential Quantizer. But unlike DPCM nbit quantizer, only a single bit quantizer is used and there is no prediction circuit.

Q3. How do you identify just from the bit stream if the given data is facing slope overload or granular noises?

→ Slope Overloading :- Repeating sequences of '1's or Repeating sequences of '0's.

Granular Noise :- Repeating sequences of '10' '10' - - -

Q4. How does adaptive delta modulation help in reducing the effect of slope overload & granular noises?

→ Adaptive delta modulation is a control mechanism that changes the slope of the delta modulation sequence based on the incoming bit stream.

If the incoming bit stream has slope overloading i.e repeating '1's or repeating '0's, it increases the the step size 'δ' by factor k where K>1 but very small.

Similarly if incoming bit stream is a repeating sequence of '101010...' i.e granular noise, it will change the value of step size 'δ' by factor '$1/k$'.

Q5. Derive the expression for S/N ratio for the example used in the code & the value for the optimal choice of delta.

→ Assuming the Delta Modulation uniforming distributing Quantization noise b/w $+\delta$ & $-\delta$

$$\Rightarrow \Delta = 2\delta$$

$$\text{Noise power} = \sigma_Q^2 = \frac{1}{\Delta}\int_{-\Delta/2}^{\Delta/2} q^2\,dq$$

$$= \frac{1}{\Delta} \left.\frac{q^3}{3}\right|_{-\Delta/2}^{\Delta/2}$$

$$= \frac{1}{\Delta} \times \frac{2\Delta^3}{3\times 8} = \frac{1}{12}\cdot\Delta^2$$

$$\Rightarrow \sigma_Q^2 = \frac{1}{12} \times 4\delta^2 = \frac{\delta^3}{3}$$

$$\sigma_x^2 = P_s = \frac{Am^2}{2}$$

$$SNR = \frac{\sigma_x^2}{\sigma_Q^2} = \frac{Am^2/2}{\delta^2/3}$$; For optimal value of $\delta = \frac{2\pi Am fm}{fs}$

$$\boxed{SNR = \frac{3\,fs^2}{8\pi^2 fm^2}}$$ for Delta Modulation.

In the example, 'δ' used are $\frac{\pi}{5}, \frac{\pi}{25}, \frac{\pi}{100}$. Message signal is a sinusoid with $A_m = 2$

$\rightarrow P_S = 2$.

I. $\delta = \pi/5 \rightarrow SNR = \frac{P_S}{\delta^2/3} = 47.7$.

II. $\delta = \pi/25 \rightarrow SNR = \frac{P_S}{\delta^2/3} = 1.19 \times 10^3$

III) $\delta = \frac{\pi}{100} \rightarrow SNR = \frac{P_S}{\delta^3/3} = 19.09 \times 10^3$.

- Large step is poor SNR performance, where large step size has better SNR performance but increase bandwidth and slope overloading.

Q6. A possible method of implementation of 1 bit quantizer is using a Comparator Explain

$\rightarrow$ A comparator is a differential amplifier where input values given at input terminal (positive & negative) and the difference at output where if difference is positive $\rightarrow +V_{cc}$ and if negative $\rightarrow -V_{cc}$, which is essentially 1 bit quantizer. But a gain factor needs to be implemented to overcome large values of 'V_{cc}'.

Q7. Compare S/N performance of a PCM system with that of a Delta modulator for the same step size.

→ For PCM $SNR)_{PCM} = \frac{12 P_s}{\delta^2}$

DM $SNR)_{DM} = \frac{3 P_s}{\delta^2}$

For same step size PCM has better SNR performance compared to DM by a factor of 4.

To achieve similar SNR in delta modulation, the step size need to be reduced to half by increasing F_s, which is not very bandwidth effective.

Q8. Discuss some practical application of Delta Modulation

application

-> Delta modulation is mainly used for transmission where quality is not of primary importance.

-> Recreating legacy synthesizer waveforms.

-> Digital voice storage & voice information transmission over large distance.