

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 slope overload and improve signal to noise ratio. If there is $2\times$ increase in sampling frequency will lead to $4\times$ 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 Quantizers. But unlike DPCM n-bit quantizers, 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 '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 step size 'S' 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 uniform distribution Quantization noise b/w $+\delta$ & $-\delta$.

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

$$\begin{aligned} \text{Noise power} = \overline{e_q^2} &= \frac{1}{\Delta} \int_{-\Delta/2}^{\Delta/2} q^2 dq \\ &= \frac{1}{\Delta} \left[\frac{q^3}{3} \right]_{-\Delta/2}^{\Delta/2} \\ &= \frac{1}{\Delta} \times \frac{2\delta^3}{3 \times 8} = \frac{1}{12} \Delta^2 \end{aligned}$$

$$\Rightarrow \overline{e_q^2} = \frac{1}{12} \times 48^2 = \frac{8^3}{3}$$

$$\overline{e_x^2} = P_s = \frac{A_m^2}{2}$$

$$SNR = \frac{\overline{e_x^2}}{\overline{e_q^2}} = \frac{A_m^2/2}{\delta^2/12} ; \text{ For optimal value of } \delta = \frac{2\pi A_m f_m}{f_s}$$

$$\boxed{SNR = \frac{3 f_s^2}{8\pi^2 f_m^2}} \text{ for Delta modulation}$$

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

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

III. $\delta = \frac{\pi}{100} \rightarrow \text{SNR} = \frac{P_s}{\delta^2/3} = 19.09 \times 10^3.$

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 terminals (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 SN performance of a PCM system with that of a Delta Modulator for the same step size.

$$\rightarrow \text{For PCM } (SNR)_{\text{PCM}} = \frac{12P_s}{\sigma^2}$$

$$\text{DM } (SNR)_{\text{DM}} = \frac{3P_s}{\sigma^2}$$

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

- 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.