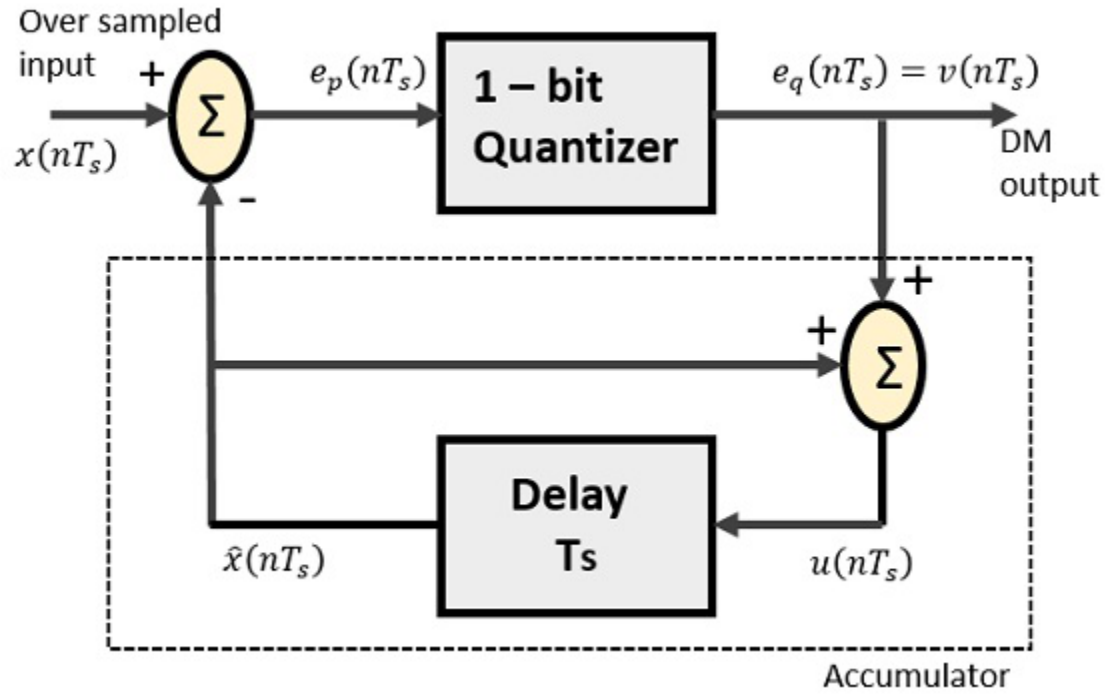
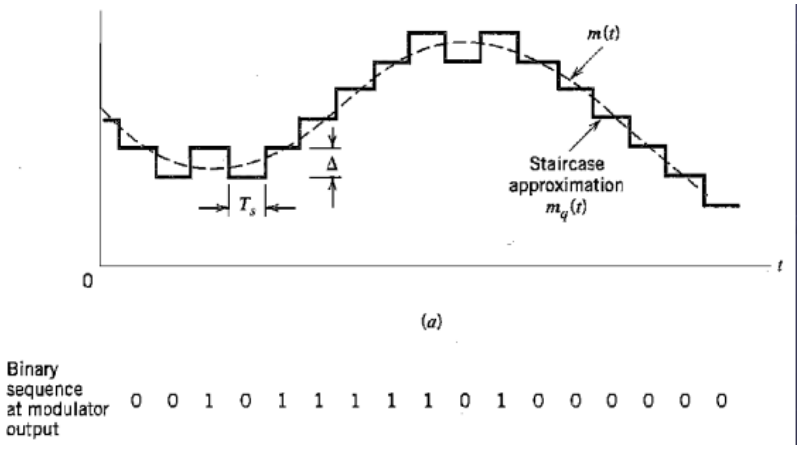
Delta modulation DM

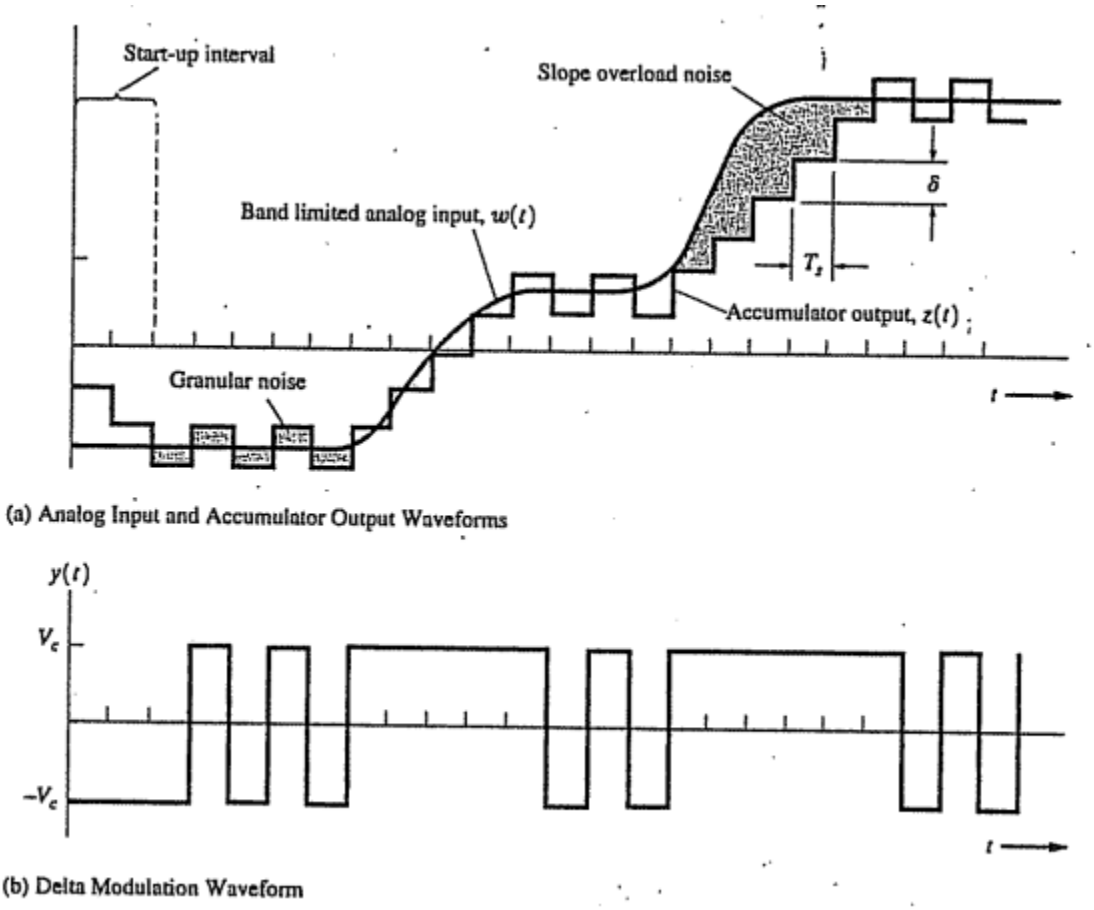
DM is a simple modulation scheme used to transmit one bit per sampling frequency.

The type of modulation, where the sampling rate is much higher and in which the stepsize after quantization is of a smaller value Δ, such a modulation is termed as **delta modulation**.



In its basic form, DM provides a stair case approximation to the oversampled version of the message signal as shown:





DM system waveforms.

- The difference between the input signal sample and the stair case approximation is quantized into only to two levels $\pm \Delta$.
- If the current sample is greater than the previous sample then the DM modulator generates $+\Delta$
- If the current sample falls below the previous sample, then the modulator generates $-\Delta$

Main advantage of DM

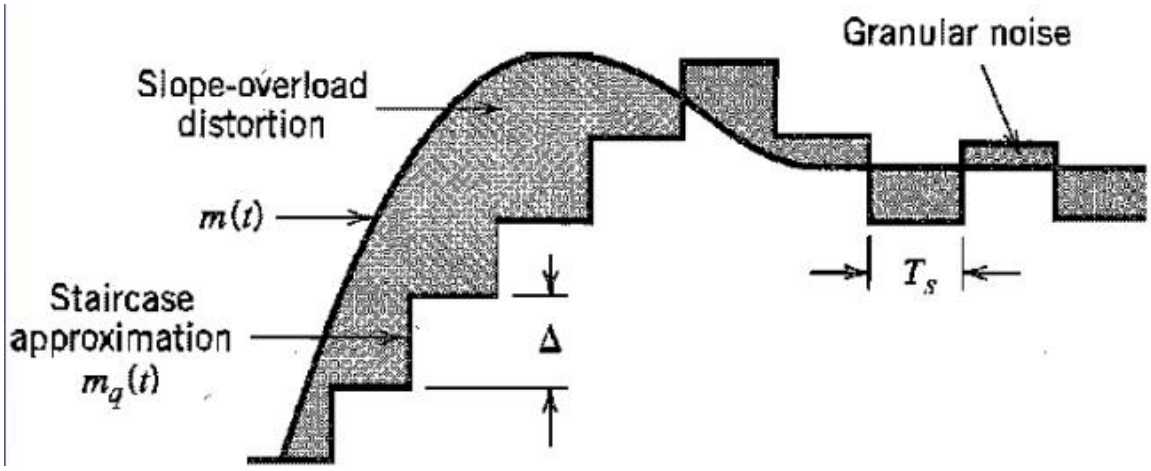
The main advantage of DM is its simplicity.

Advantages of DM

- 1-bit quantizer
- Very easy design of the modulator and the demodulator

However, there exists some noise in DM.

- Slope Over load distortion (when **Δ** is small)
- Granular noise (when **Δ** is large)



Slope overload distortion can be avoided if the step size Δ is selected according the following equation:

$$\frac{\Delta}{T_s} \geq \left| \frac{dm(t)}{dt} \right|$$

Example

A linear delta modulator is designed to operate on speech signals limited to 3.4 kHz. The specifications of the modulator are as follows:

- Sampling rate = $10 f_{\text{Nyquist}}$, where f_{Nyquist} is the Nyquist rate of the speech signal.
- Step size $\Delta = 100$ mV.

The modulator is tested with a 1-kHz sinusoidal signal. Determine the maximum amplitude of this test signal required to avoid slope overload.

Solution:

$f_s = 10 f_{\text{Nyquist}}$

$f_{\text{Nyquist}} = 6.8 \text{ kHz}$

$f_s = 10 \times 6.8 \times 10^3 = 6.8 \times 10^4 \text{ Hz}$

$$\frac{\Delta}{T_s} \geq \max\left|\frac{dm(t)}{dt}\right|$$

For the sinusoidal signal $m(t) = A_m \sin(2\pi f_m t)$, we have

$$\frac{dm(t)}{dt} = 2\pi f_m A_m \cos(2\pi f_m t)$$

Hence,

$$\left|\frac{dm(t)}{dt}\right|_{\max} = |2\pi f_m A_m|_{\max}$$

or, equivalently,

$$\frac{\Delta}{T_s} \geq |2\pi f_m A_m|_{\max}$$

Therefore,

$$|A_m|_{\max} = \frac{\Delta}{T_s \times 2\pi \times f_m}$$

$$= \frac{\Delta f_s}{2\pi f_m}$$

$$= \frac{0.1 \times 6.8 \times 10^4}{2\pi \times 10^3}$$

$$= 1.08 \text{V}$$

Example: Given a sine wave of frequency f_m and amplitude A_m applied to a delta modulator having step size Δ. Shows that the slope overload distortion will occur if $A_m > \frac{\Delta}{2\pi f_m T_s}$. Here T_s is the sampling period.

Solution: Let us consider that the sine wave is represented as,

$$x(t) = A_m \sin(2\pi f_m t)$$

It may be noted that the slope of x(t) will be maximum when the derivative of x(t) with respect to t will be maximum. The maximum slope of the delta modulator may be given as,

$$Maximum\ slope = \frac{Step\ size}{Sampling\ Period} = \frac{\Delta}{T_s}$$

We know that slope overload distortion will take place if the slope of the sine wave is greater than the slope of the delta modulator i.e.,

$$max\left|\frac{d}{dt}x(t)\right| > \frac{\Delta}{T_s}$$

$$\text{or, } max\left|\frac{d}{dt}A_m \sin(2\pi f_m t)\right| > \frac{\Delta}{T_s}$$

$$\text{or, } max\left|A_m 2\pi f_m \sin(2\pi f_m t)\right| > \frac{\Delta}{T_s}$$

$$\text{or, } A_m 2\pi f_m > \frac{\Delta}{T_s}$$

$$\text{or, } \boxed{A_m > \frac{\Delta}{2\pi f_m T_s}}\text{. Hence proved.}$$

1. **What is delta modulation and how does it work?**

Answer: Delta modulation process **compares the present sample value to the previous sample value**. Based upon the difference amplitude is going to be increased or decreased by step signal. If the amplitude is increased then step size increases by one step i.e., $+\Delta$ and bit 1 are generated.

2. **What is the use of a delta modulator?**

Answer: A delta modulation (DM or Δ-modulation) is an analog-to-digital and digital-to-analog signal conversion technique used for the **transmission of voice information where quality is not of primary importance**.

3. **What are the advantages of the delta modulator?**