Delta Modulation and Demodulation using Simulink®

Aim: To build and analyse Delta modulation scheme using Simulink ® software and demodulate the DM signal to get back the original message signal.

Software used: Simulink ®

Introduction: A delta modulation (DM or Δ-modulation) is an analog-to-digital and digital-to-analog signal conversion technique used for transmission of voice information where quality is not of primary importance. DM is the simplest form of differential pulse-code modulation (DPCM) where the difference between successive samples are encoded into n-bit data streams. In delta modulation, the transmitted data are reduced to a 1-bit data stream. Its main features are:

- The analog signal *x(t)* is approximated with a series of segments.
- Each segment of the approximated signal is compared to the preceding bits and the successive bits are determined by this comparison.
- Only the change of information is sent, that is, only an increase or decrease of the signal amplitude from the previous sample is sent whereas a no-change condition causes the modulated signal to remain at the same 0 or 1 state of the previous sample.

To achieve high signal-to-noise ratio, delta modulation must use oversampling techniques, that is, the analog signal is sampled at a rate several times higher than the Nyquist rate.

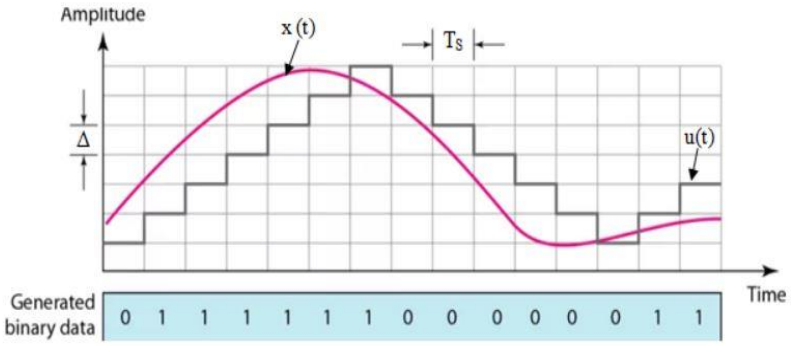

Figure 1: Delta modulation

x(t) represents the analog signal and $x_q(t)$ represents the staircase approximation. Following discrete relations explain the construcion of the staircase waveform which forms the basis of delta modulation.

$$e(nT_s) = x_q(nT_s) - x_q(nT_s - T_s)$$

$$e_q(nT_s) = \delta\, sgn[e_q(nT_s)]$$

$$x_q(nT_s) = x_q(nT_s - T_s) + e_q(nT_s)$$

Where T_s is the sampling instant, $e(nT_s)$ is the error signal and $e_q(nT_s)$ is the quantized version of error signal.

Block Diagram:

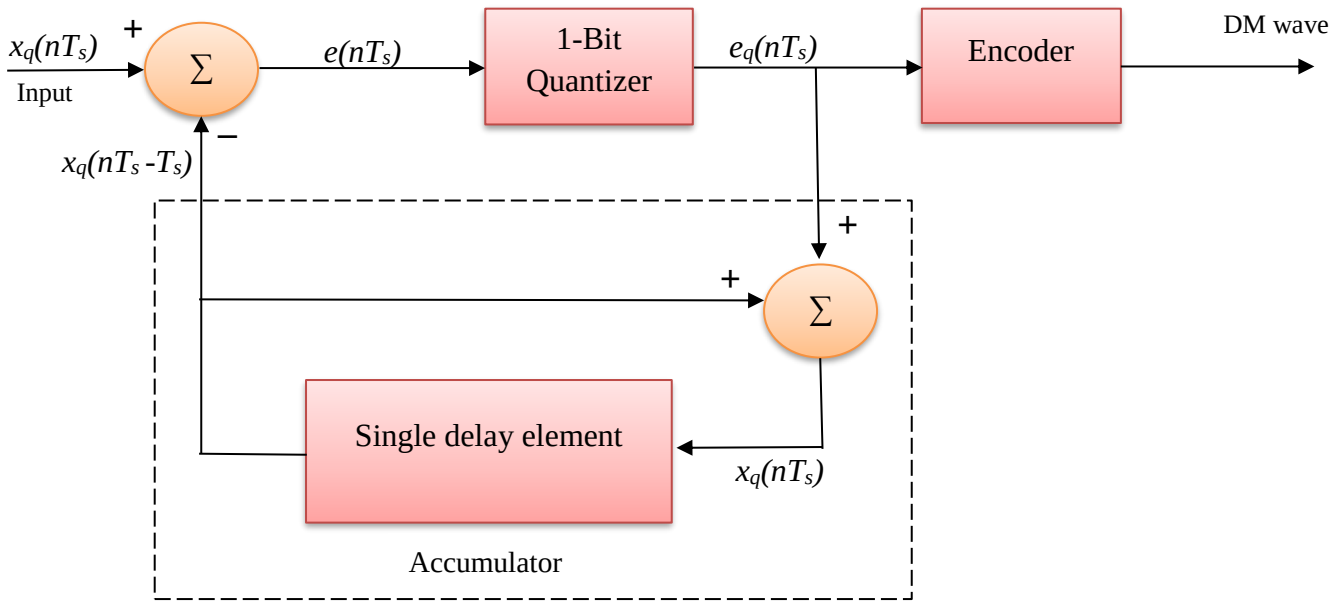

Figure 2: Block diagram of the DM transmitter

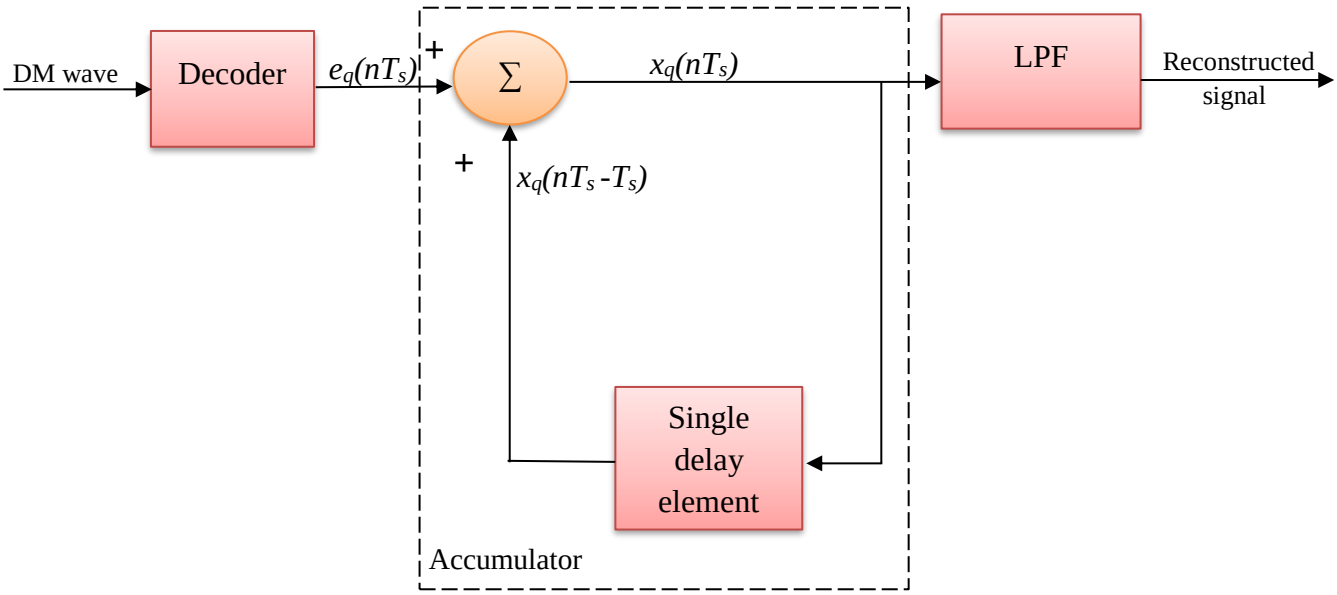

Figure 3: Block diagram of the DM receiver

Simulink model of Delta modulation:

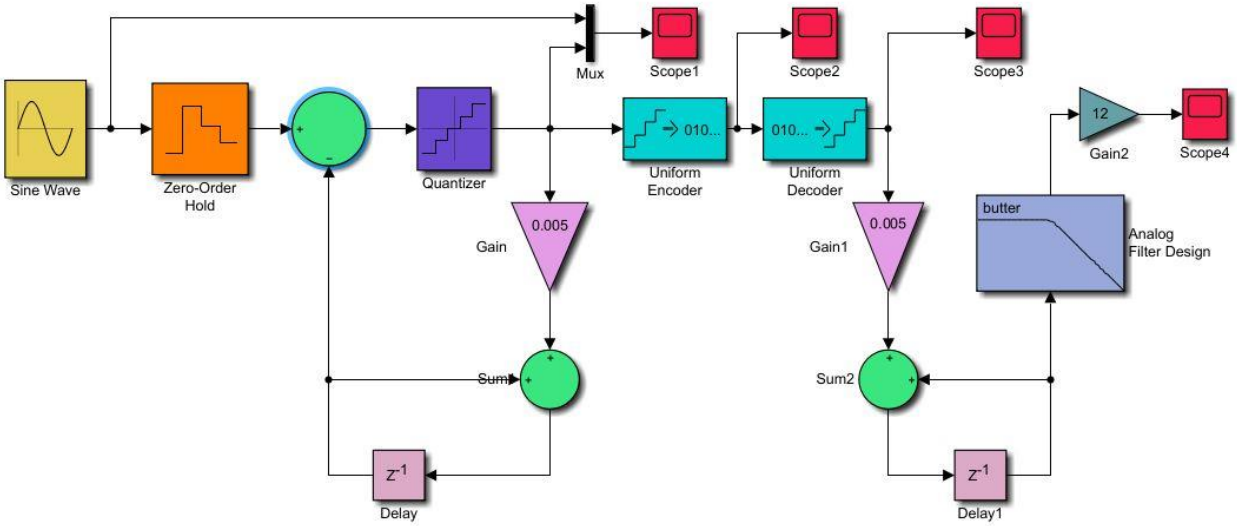

Figure 4: Simulink Model of delta modulation

Description:

- Initially an analog sine wave of frequency 80Hz is sampled at a frequency of 8000Hz using the block "Zero-Order Hold" as shown in Figure 4.
- The DM transmitter involves a comparator, a quantizer and an accumulator as shown in Figure-1 and the same is implemented in the model shown in Figure 4. The block "Gain" with the value 0.005 specifies the step size of quantization.
- The comparator gives difference between input signal and the delayed signal called error signal $e(nT_s)$.
- The output of the quantizer is one of the two levels depending on the output of the comparator.
- Output of the quantizer is applied to the accumulator and accumulator constructs staircase waveform that keeps track of input signal as close as possible.
- A uniform 8-bit encoder with peak value 2, is used to encode the quantized data. Similarly, an 8-bit decoder with peak value 2, is used to decode the encoded data at receiver side.
- In demodulator section, the staircase approximation is reconstructed by passing the error sequence of positive and negative pulses at the decoder output through an accumulator.
- An LPF (Low pass filter) is used to remove step variations and to get smooth reconstructed message signal. The LPF constructed is an analog Butterworth LPF of 8^{th} order.
- Also, the lowpass filter does a favor in rejecting the out of band quantizing noise in the high frequency staircase approximation.
- A variable gain block at the end of the receiver section is used to amplify the signal since the amplitude of the received signal is small compared to the message signal.

Output Waveforms:

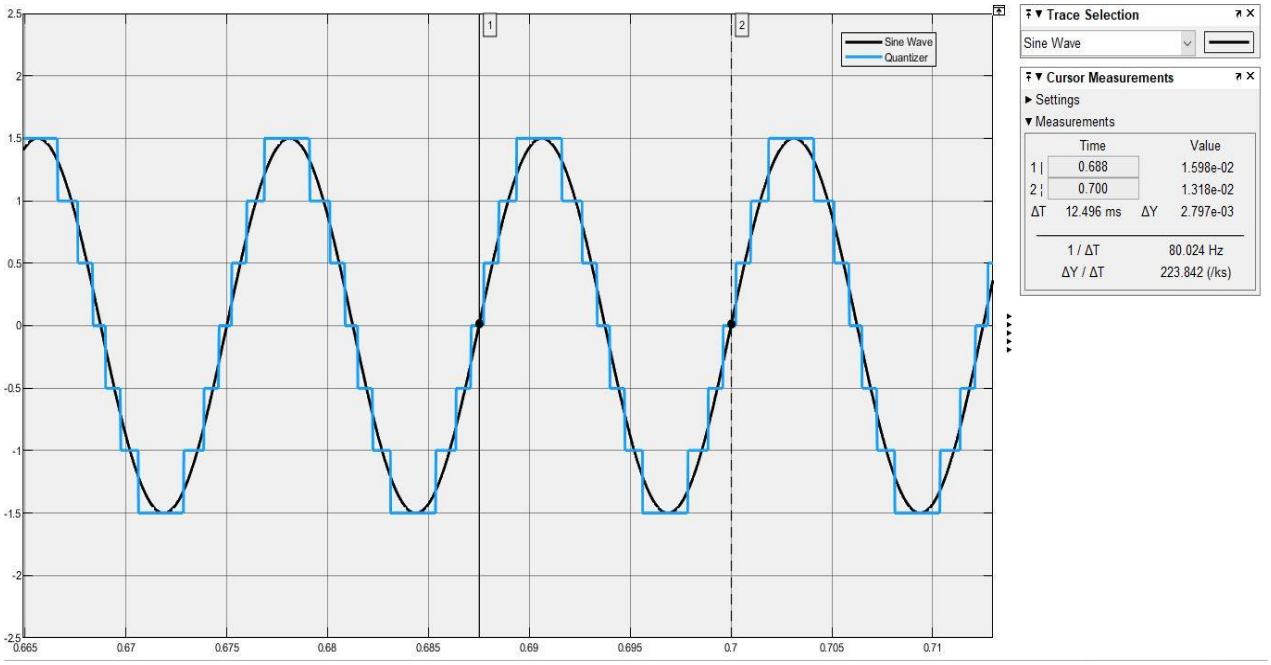

Figure 5: Waveform consisting of message signal and DM signal

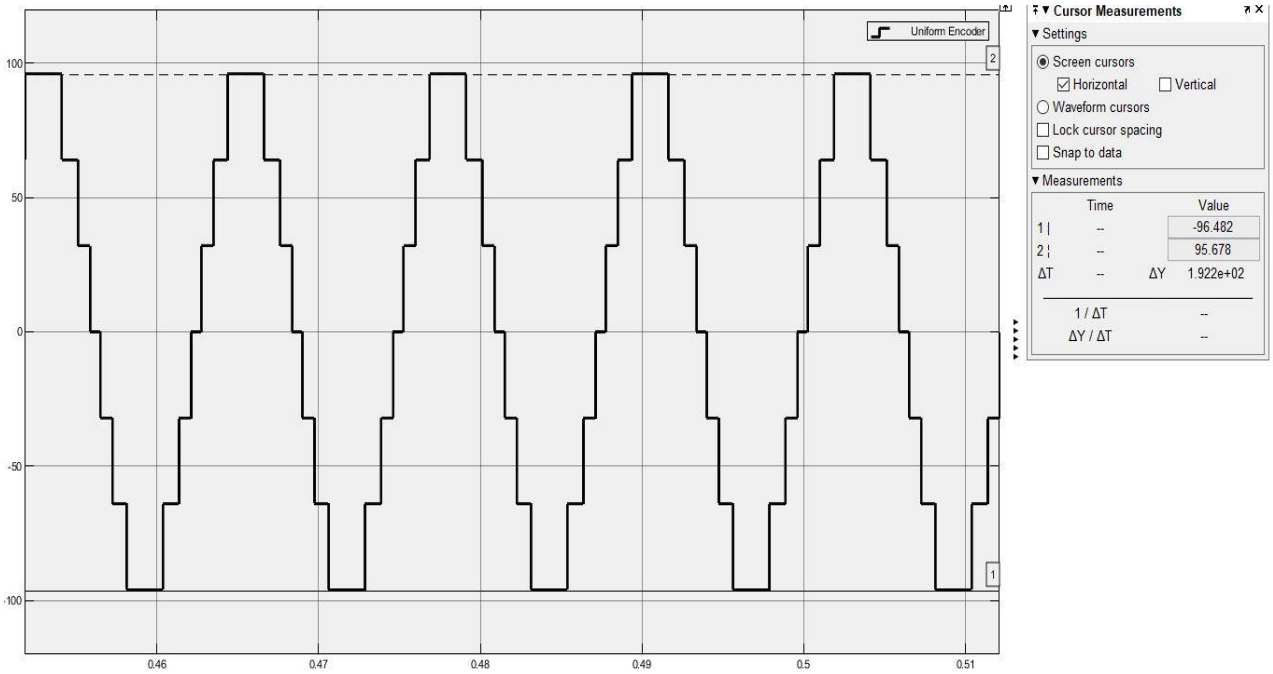

Figure 6: Uniformly Encoded Data

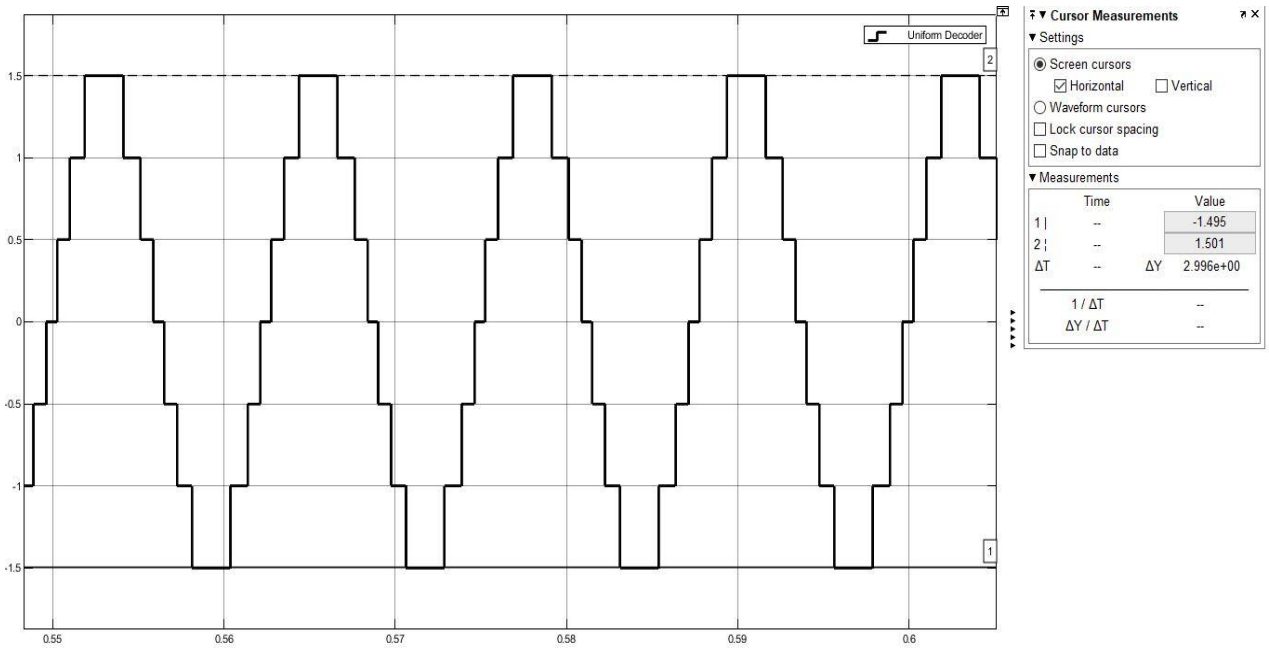

Figure 7: Uniformly Decoded Data

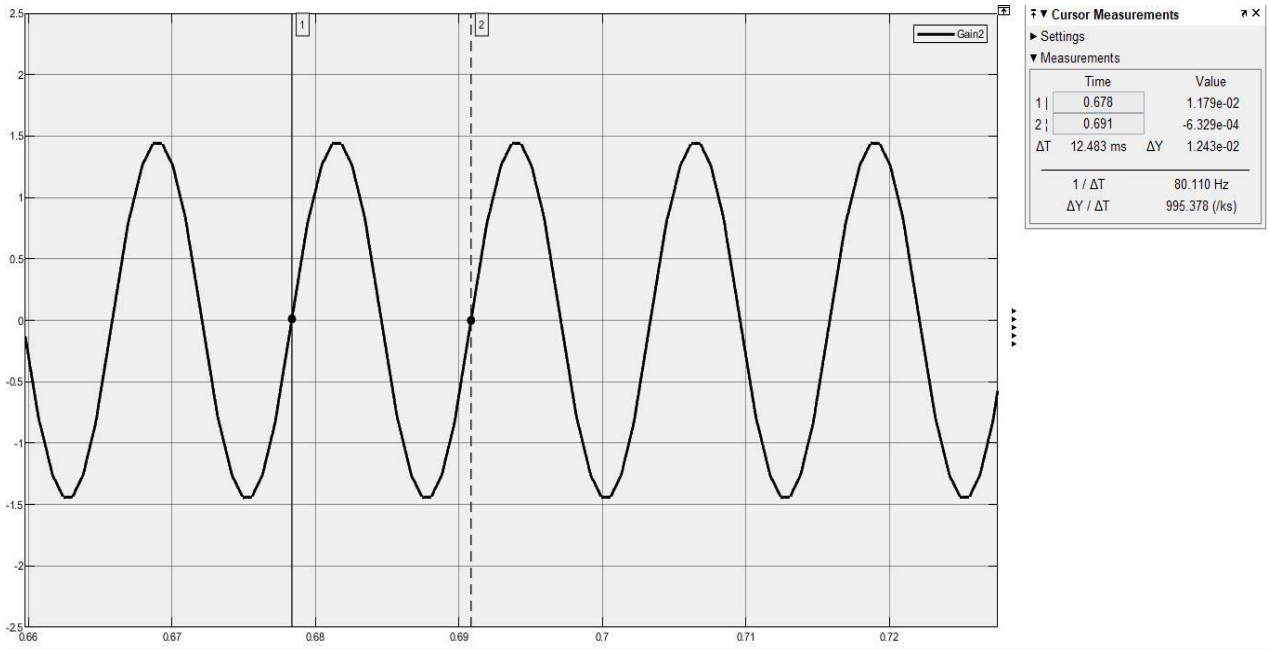

Figure 8: Demodulated waveform

Advantages:

- Delta modulation offers high SNR compared other conventional modulation techniques.
- Compared to DPCM and other techniques it consumes lower bandwidth which makes the process of data communication more cost effective.

Disadvantages:

- The key to the effective use of delta modulation is the intelligent choice of parameters, namely staircase approximation δ and sampling rate fs. Increasing the sampling frequency leads to larger bandwidth requirement. Increasing step size increases quantization error.
- If the steps are small it experiences *slope overload* condition where the staircase cannot track rapid changes in the analog signal.
- On the other hand, if steps are too large considerable overshoots will occur during the period which leads to *granular noise*.

These problems are solved by another type of modulation called Adaptive delta modulation where step size δ is varied depending upon the slope or amplitude characteristics of the analog input signal.

Inference and Conclusion:

Delta modulation and demodulation model is constructed and verified using Simulink® software. It's observed that the demodulated signal has the same frequency and shape as that of message signal which indicates successful decoding and demodulation.