3.16. Adaptive Delta Modulation

To overcome the quantization errors due to slope overload and granular noise, the step size (δ) is made adaptive to variations in the input signal $x(t)$. Particularly in the steep segment of the signal $x(t)$, the step size is increased. Also, if the input is varying slowly, the step size is reduced. Then this method is known as *Adaptive Delta Modulation (ADM)*.

The adaptive delta modulators can take continuous changes in step size or discrete changes in step size.

Fig. 3.17(a) shows the transmitter and 3.17(b) shows receiver of adaptive delta modulator. The logic for step size control is added in the diagram. The step size increases or decreases according to a specified rule depending on one bit quantizer output. As an example, if one bit quantizer output is high (*i.e.* 1), then step size may be doubled for next sample. If one bit quantizer output is low, then step size may be reduced by one step. Fig. 3.18 shows the staircase waveforms of adaptive delta modultor and the sequence of bits to be transmitted.

In the receiver of adaptive delta modulator shown in Fig. 3.17(b), there are two portions. The first portion produces the step size from each incoming bit.

Exactly the same process is followed as that in transmitter. The previous input and present input decides the step size. It is then applied to an accumulator which builds up staircase waveform. The low-pass filter then smoothens out the staircase waveform to reconstruct the original signal.

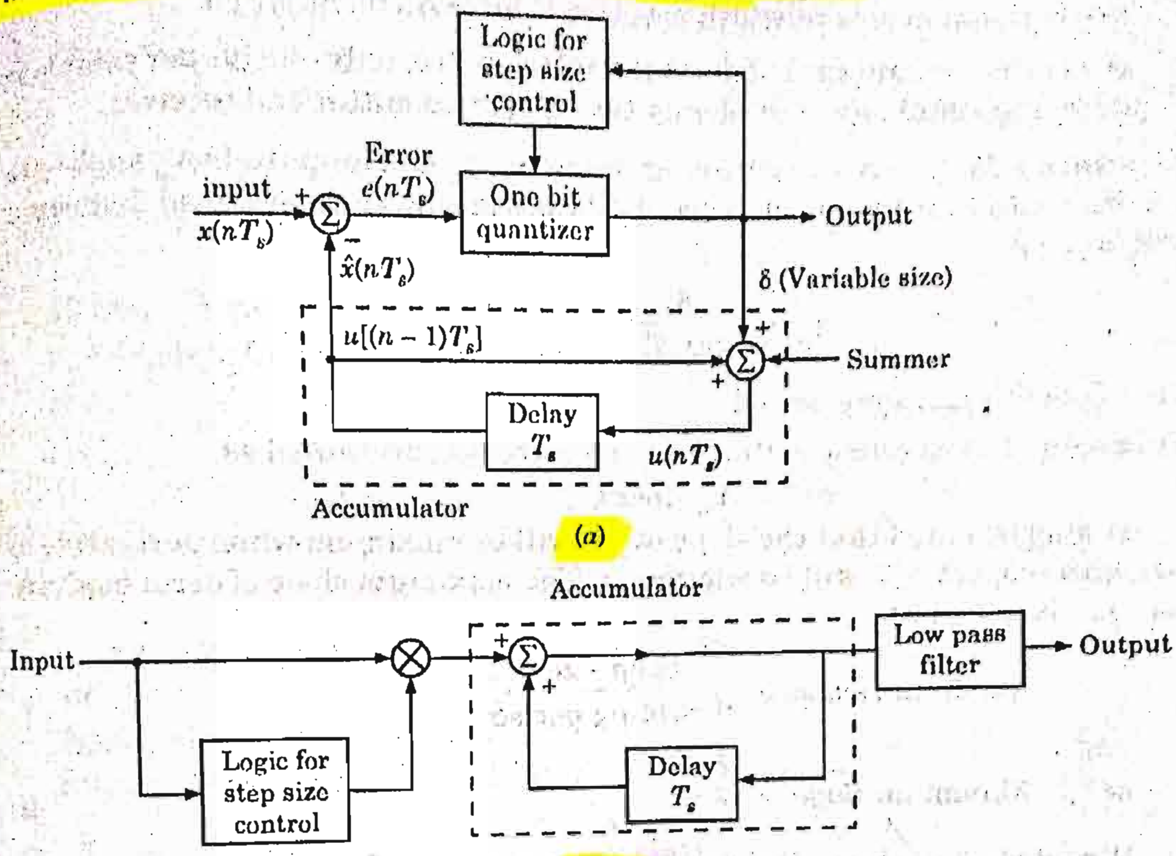

Fig 3.17. Adaptive Delta Modulator (a) Transmitter (b) Receiver

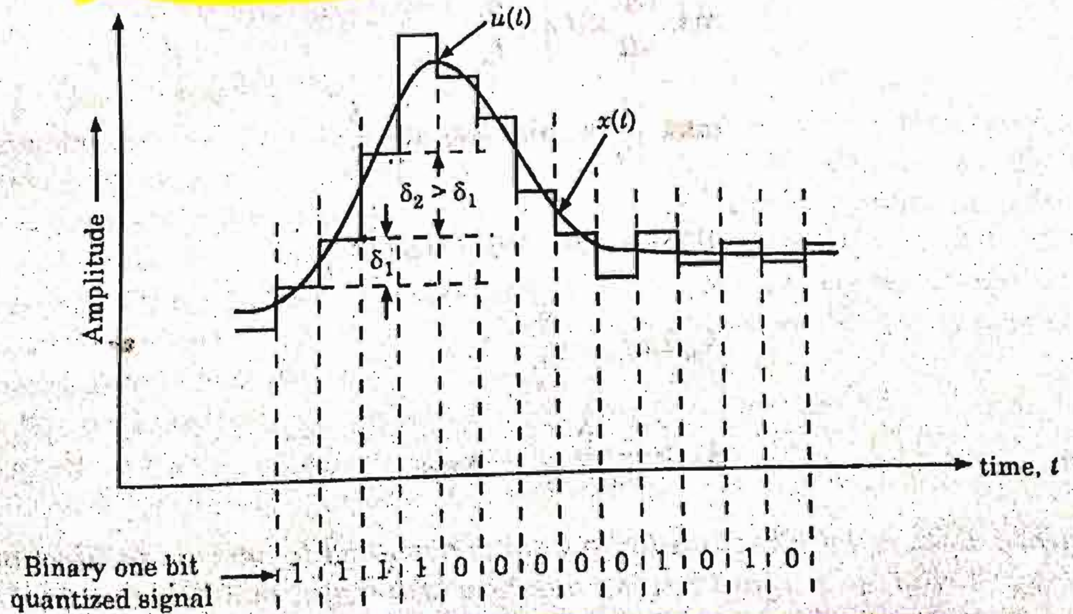

Fig. 3.18. Waveforms for adaptive delta modulation

Advantages of Adaptive Delta Modulation

Adaptive delta modulation has certain advantages over delta modulation as under :

(i) The signal to noise ratio becomes better than ordinary delta modulation because of the reduction in slope overload distortion and idle noise.

(ii) Because of the variable step size, the dynamic range of ADM is wider than simple DM.

(iii) Utilization of bandwidth is better than delta modulation.

Plus other advantages of delta modulation are, only one bit per sample is required and simplicity of implementation of transmitter and receiver.

or $\therefore A_m \geq 0.6$ volts **Ans.**

3.17. Differential Pulse Code Modulation

It may be observed that the samples of a signal are highly correlated with each other. This is because any signal does not change fast. This means that its value from present sample to next sample does not differ by large amount. The adjacent samples of the signal carry the same information with little difference. When these samples are encoded by a standard PCM system, the resulting encoded signal contains some redundant information. Fig. 3.19 illustrates this redundant information.

Fig. 3.19 shows a continuous time signal $x(t)$ by dotted line. This signal is sampled by flat top sampling at intervals T_s, $2T_s$, $3T_s$ ... nT_s. The sampling frequency is selected to be higher than nyquist rate. The samples are encoded by using 3 bit (7 levels) PCM. The sample is quantized to the nearest digital level as shown by small circles in the figure 3.19. The encoded binary value of each sample is written on the top of the samples. We can observe from fig. 3.19. that the samples taken at $4T_s$, $5T_s$ and $6T_s$ are encoded to same value of (110). This information can be carried only by one sample. But three samples are carrying the same information means it is redundant. Consider another example of samples taken at $9T_s$ and $10\,T_s$. The difference between these samples s only due to last bit and first two bits are redundant, since they do not change.

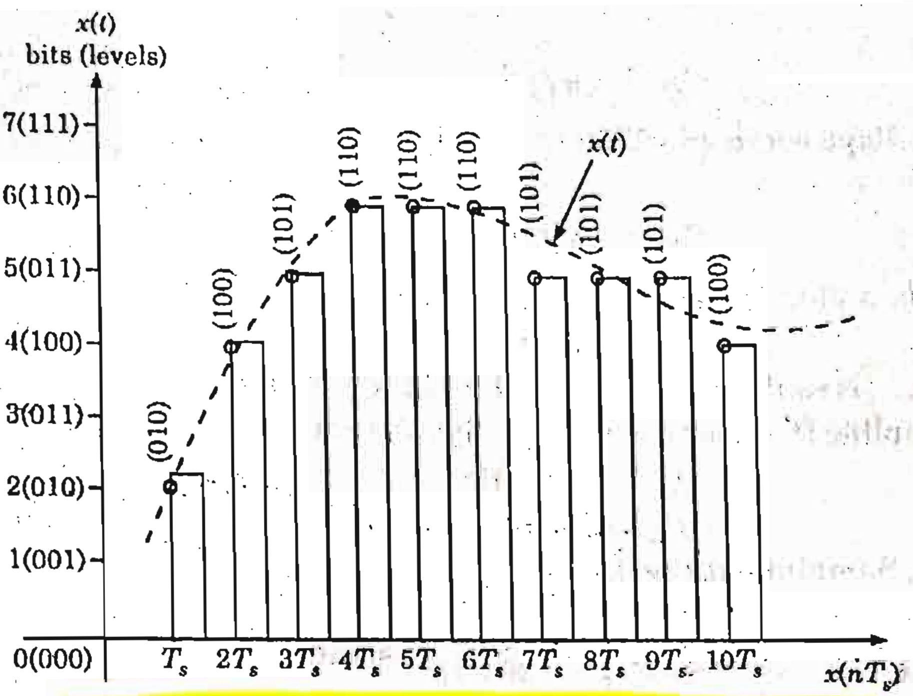

Fig 3.19. Illustration of redundant information in PCM

If this redundancy is reduced, then overall bit rate will decrease and number of bits required to transmit one sample will also be reduced. This type of digital pulse modulation scheme is known as **Differential Pulse Code Modulation.**

The differential pulse code modulation works on the principle of prediction. The value of the present sample is predicted from the past samples. The prediction may not be exact but it is very close to the actual sample vlaue. Fig 3.20 shows the transmitter of Differential Pulse Code Modulation (DPCM) system. The sampled signal is denoted by $x(nT_s)$ and the predicted signal is denoted by $\hat{x}(nT_s)$. The comparator finds out the difference between the actual sample value $x(nT_s)$ and predicated sample value $\hat{x}(nT_s)$. This is known as Prediction error and it is denoted by $e(nT_s)$. It can be defined as,

$$e(nT_s) = x(nT_s) - \hat{x}(nT_s) \qquad ...(3.50)$$

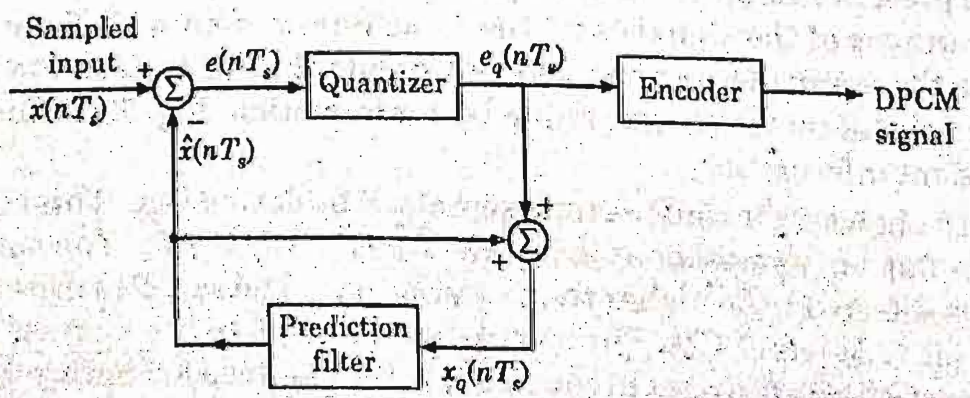

Fig. 3.20. A Differential pulse code modulation transmitter

Thus, error is the difference between unquantized input sample $x(nT_s)$ and prediction of it $\hat{x}(nT_s)$. The predicted value is produced by using a prediction filter. The quantizer output signal $e_q(nT_s)$ and previous prediction is added and given as input to the prediction filter. This signal is called $x_q(nT_s)$. This signal is called $x_q(nT_s)$. This makes the prediction more and more close to the actual sampled signal. We can see that the quantized error signal $e_q(nT_s)$ is very small and can be encoded by using small number of bits. Thus number of bits per sample are reduced in DPCM.

The quantizer output can be written as,

$$e_q(nT_s) = e(nT_s) + q(nT_s) \quad ...(3.18)$$

Here $q(nT_s)$ is the quantization error. As shown in figure 3.20, the prediction filter input $x_q(nT_s)$ is obtained by sum $\hat{x}(nT_s)$ and quantizer output *i.e.*,

$$x_q(nT_s) = \hat{x}(nT_s) + e_q(nT_s) \quad ...(3.52)$$

Putting the value of $e_q(nT_s)$ from equation 3.51 in the above equation we get,

$$x_q(nT_s) = \hat{x}(nT_s) + e(nT_s) + q(nT_s) \quad ...(3.53)$$

Equation (3.50) is written as,

$$e(nT_s) = x(nT_s) - \hat{x}(nT_s)$$

$$\therefore \quad e(nT_s) + \hat{x}(nT_s) = x(nT_s) \quad ...(3.54)$$

$\therefore$ Putting the value of $e(nT_s) + \hat{x}(nT_s)$ from above equation into equation (3.53) we get,

$$x_q(nT_s) = x(nT_s) + q(nT_s) \quad ...(3.55)$$

Thus the quantized version of the signal $x_q(nT_s)$ is the sum of original sample value and quantization error $q(nT_s)$. The quantization error can be positive or negative. Thus equation (3.55) does not depend on the prediction filter characteristics.

Reconstruction of DPCM Signal :

Fig. 3.21 shows the block diagram of DPCM receiver.

The decoder first reconstructs the quantized error signal from incoming binary signal. The prediction filter output and quantized error sigals are summed up to give the quantized version of the orginal signal. Thus the signal at the receiver differs from actual signal by quantization error $q(nT_s)$, which is introduced permanently in the reconstructed signal.

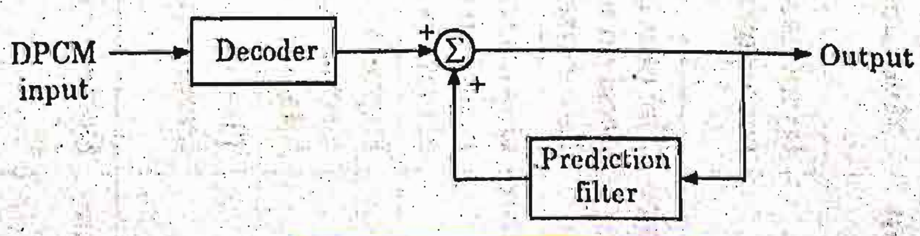

Fig. 3.21. DPCM receiver

3.18. Comparision of Digital Pulse Modulation Methods

After discussing all the digital pulse modulation methods in details let us now compare all these methods from different aspects.

Table 3.1 shows the comparision of PCM, Differential PCM, Delta Modulation and Adaptive Delta Modulation. This comparison is carried out on the

Table 3.1. Comparison between PCM, Adaptive Delta Modulation and Differential Pulse Code Modulation

S. No.	Parameter of comparison	Pulse Code Modulation (PCM)	Delta modulation (DM)	Adaptive Delta Modulation (ADM)	Differential Pulse Code Modulation (DPCM)
1.	Number of bits.	It can use 4, 8 or 16 bits per sample.	It uses only one bit for one sample.	Only one bit is used to encode one sample.	Bits can be more than one but are less than PCM.
2.	Levels and step size	The number of levels depend on number of bits. Level size is kept fixed.	Step size is kept fixed and cannot be varied.	According to the signal variation, step size varies (*i.e.* Adapted).	Here, Fixed number of levels are used.
3.	Quantization error and distortion	Quantization error depends on number of levels size is fixed.	Slope overload distortion and granular noise are present.	Quantization noise is present but other errors are absent.	Slope overload distortion and quantization noise are not encountered.
4.	Transmission bandwidth	Highest bandwidth is required since number of bits are high	Lowest bandwidth is required.	Lowest bandwidth is required.	Bandwidth required is lower than PCM.
5.	Feedback	There is no feedback in transmitter or receiver.	Feedback exists in transmitter.	Feedback exists.	Here, Feedback exists.
6.	Complexity of notation	System complex.	Simple.	Simple.	Simple