3.7. Differential Pulse Code Modulation

- ✧ Differential Pulse Code Modulation (DPCM) occurs can be used when adjacent samples are close to the same value.

- ✧ There may be a lot of redundancy in the samples and therefore bandwidth would be wasted.

- ✧ One way to avoid this is to only transmit the “differentials”.

- ✧ Also, the present value can be estimated from past values by using a *prediction filter*.

3.7. Differential Pulse Code Modulation

The present value can be estimated from past values by using a *prediction filter*.

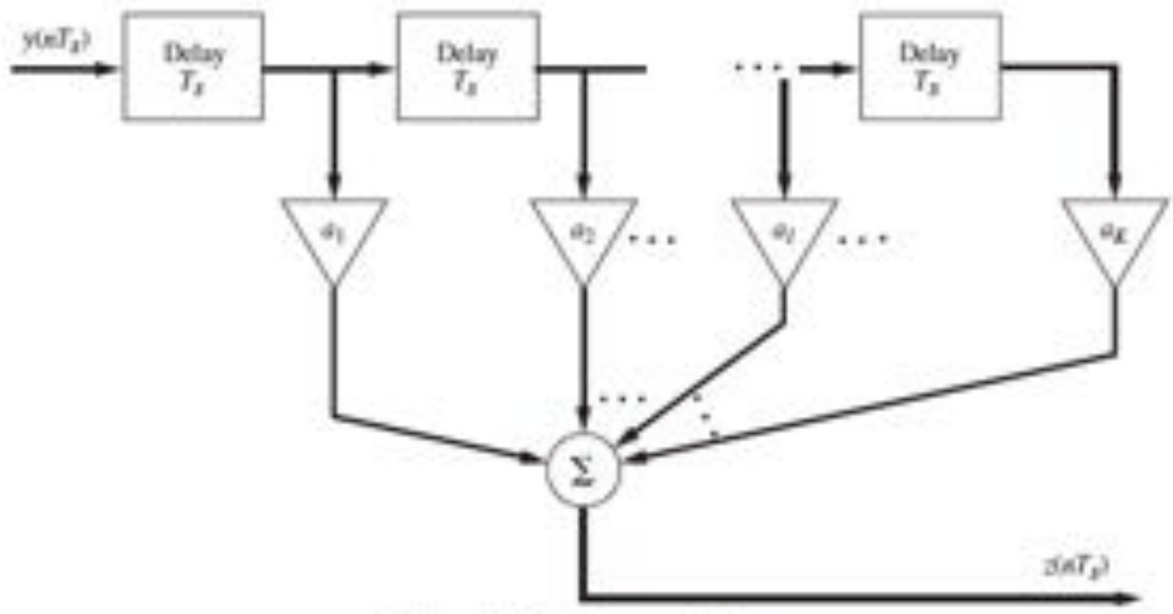


Figure 3–28 Transversal filter.

$$Z(nT_s) = \sum_{l=1}^{K} a_l y(nT_s - lT_s)$$

3.7. Differential Pulse Code Modulation

First DPCM configuration: uses predictor to obtain a **differential pulse amplitude-modulated (DPAM)** signal.

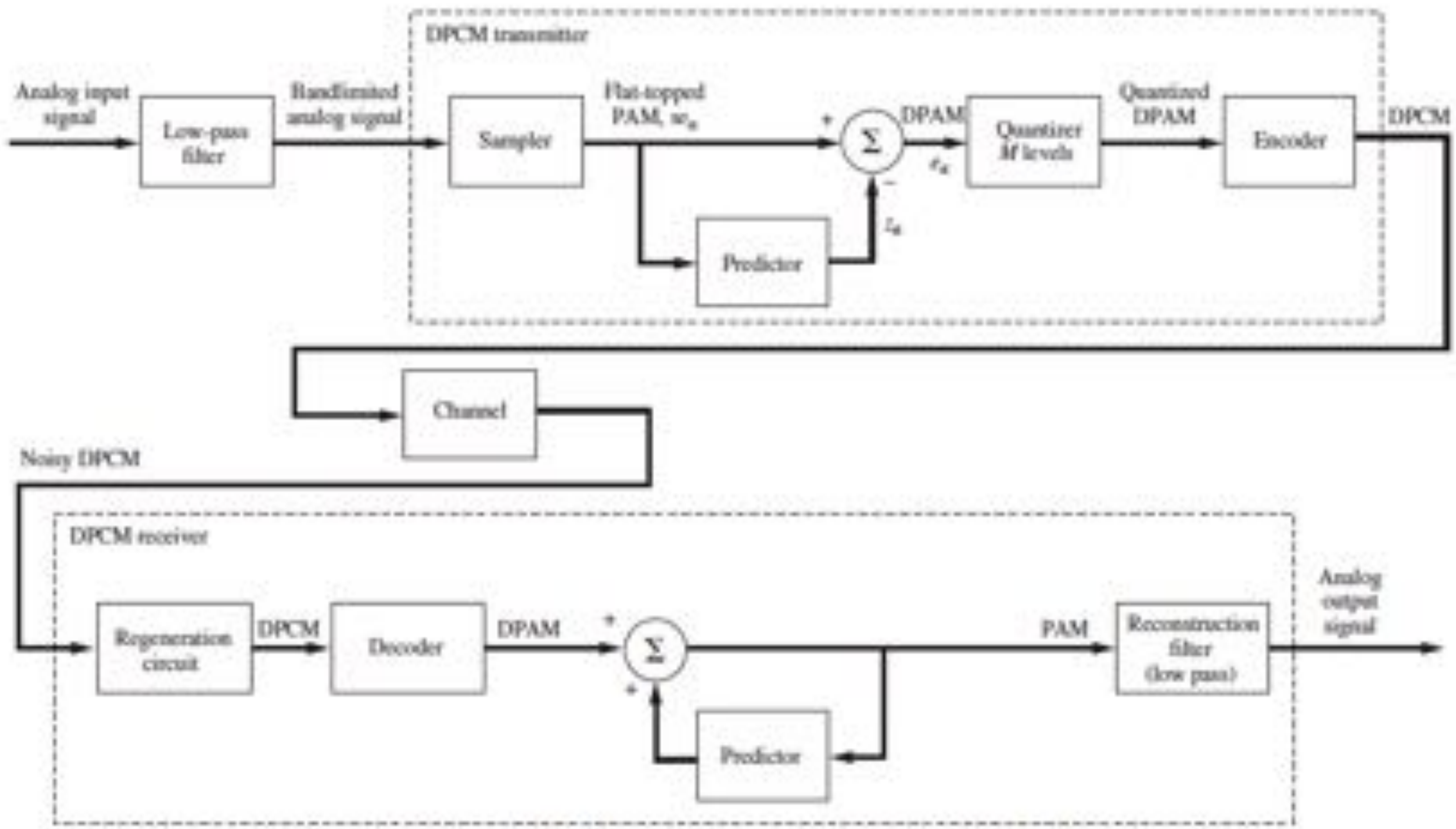


Figure 3–29 DPCM, using prediction from samples of input signal.

3.7. Differential Pulse Code Modulation

Second DPCM configuration: to minimize the quantization noise on the recovered analog signal.

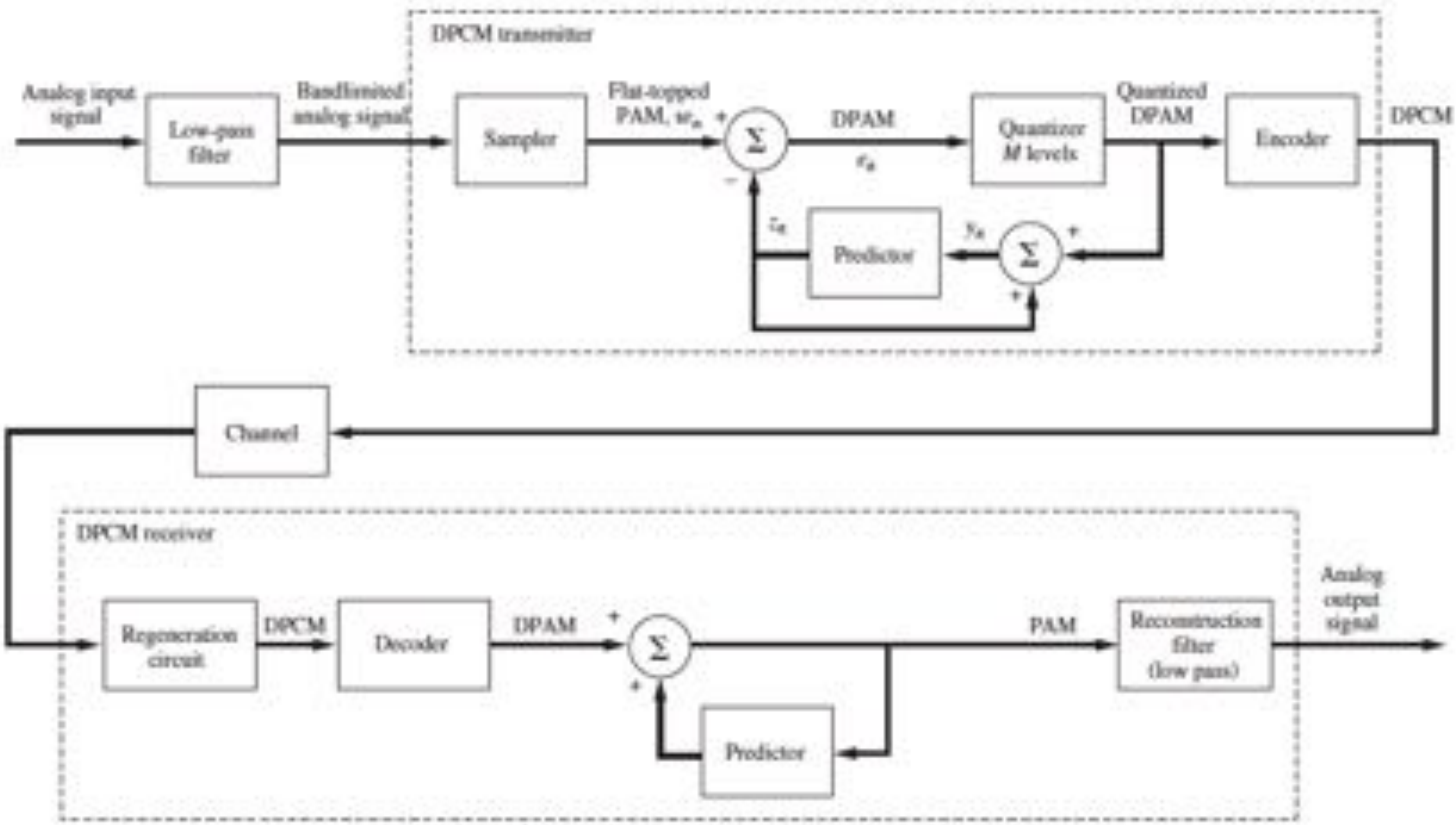


Figure 3–30 DPCM, using prediction from quantized differential signal.

3.7. Differential Pulse Code Modulation

Same as PCM, the DPCM follows the **6-dB rule**

$$\left(\frac{S}{N}\right)_{dB} = 6.02n + \alpha$$ where n is the bit number

For **PCM**: α = 4.77 for peak SNR, α = 0 for average SNR.

For **DPCM**: α has a wide range depending on the properties of the input analog signal.

For example: α = -10 dB for μ = 255 companded PCM (μ-*law*) signal .
The SNR improvement of 25 dB for DPCM.

3.8. Delta Modulation

Delta Modulation (**DM**) is a special case of DPCM in which there are two quantizing levels. It's main features are:

✧ The transmitted data are reduced to 1-bit data stream.

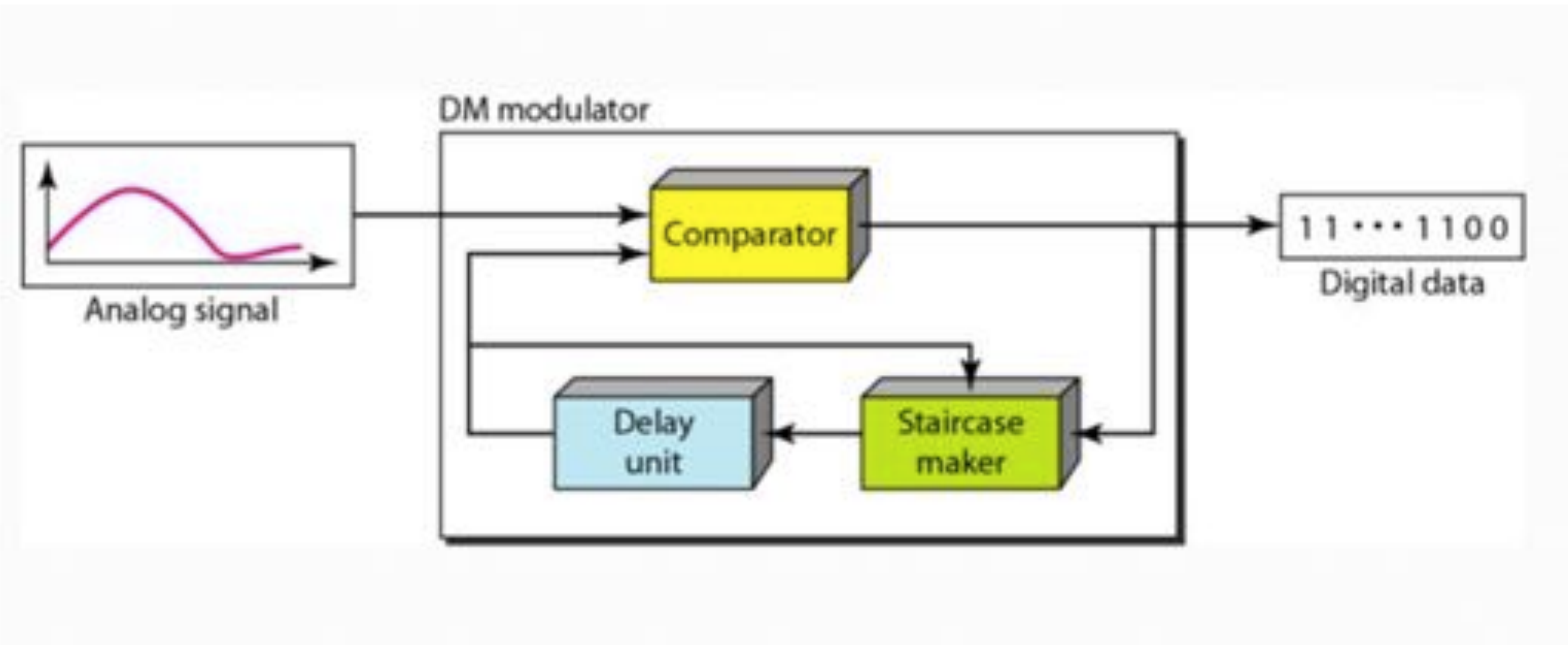
✧ The analog signal is approximated with a series of segments.

✧ Each segment of approximated signal is determined by comparison.

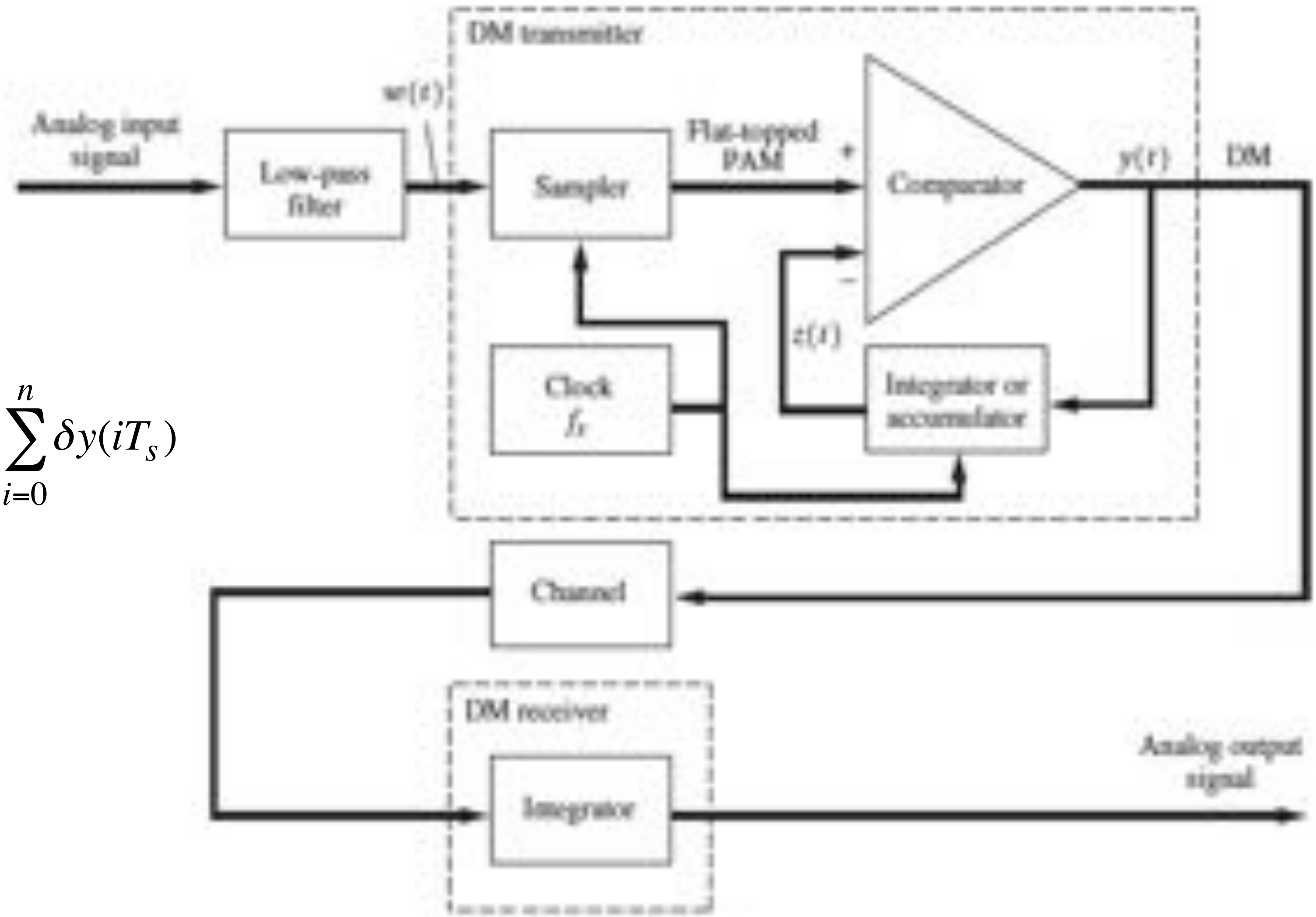
✧ Only the change of information is sent. Generally speaking, "1" indicate amplitude "increasing", and "0" indicate amplitude "decrease", and alternative "1" and "0" indicates amplitude remains.

✧ To achieve high SNR, delta modulation must use ***oversampling*** techniques, that is, the analog signal is sampled at a rate **several times** higher than the Nyquist rate.

3.8. Delta Modulation



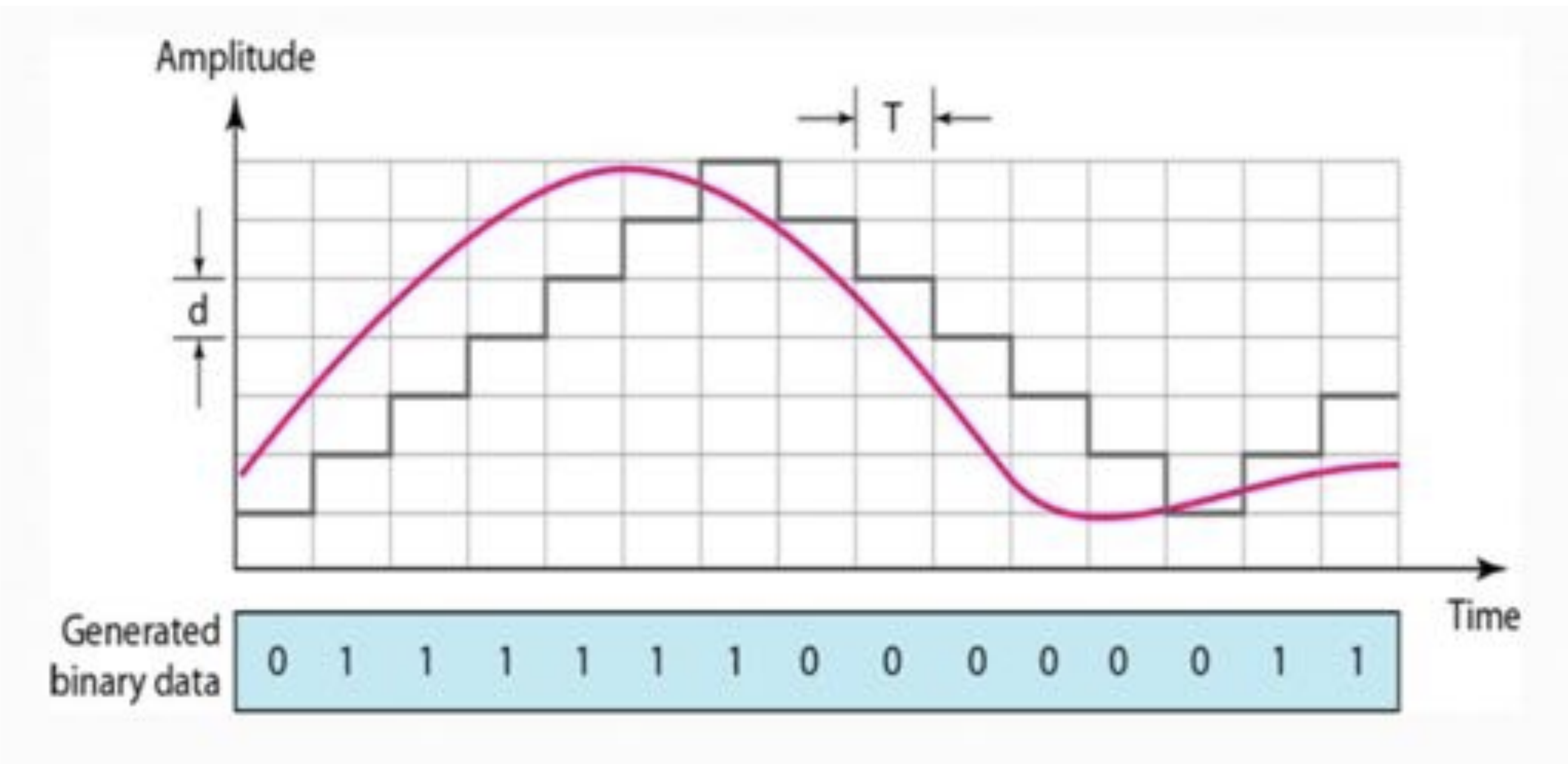
3.8. Delta Modulation



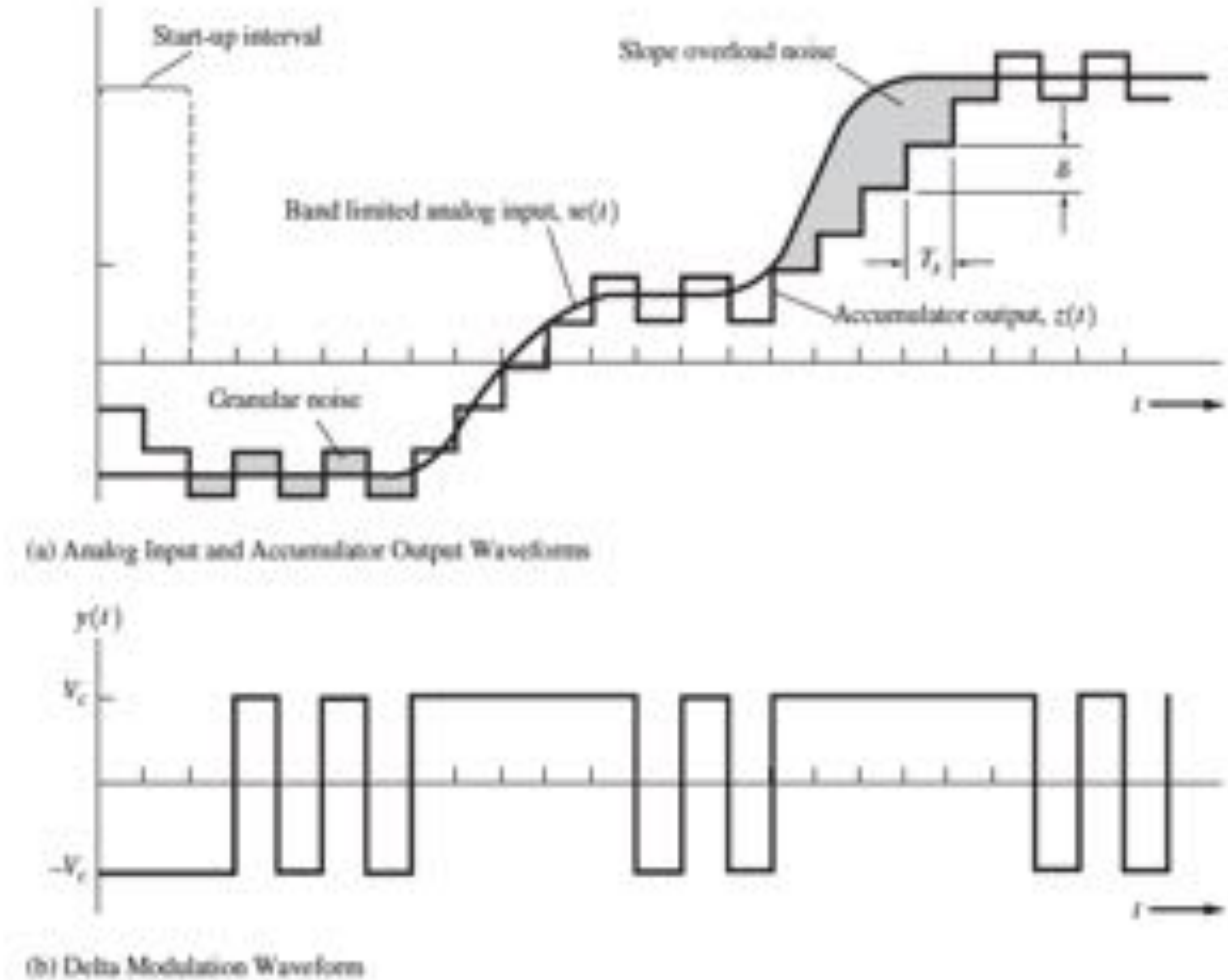
$$z_n = \frac{1}{V_c}\sum_{i=0}^{n}\delta y(iT_s)$$

Figure 3–31 DM system.

3.8. Delta Modulation



3.8. Delta Modulation

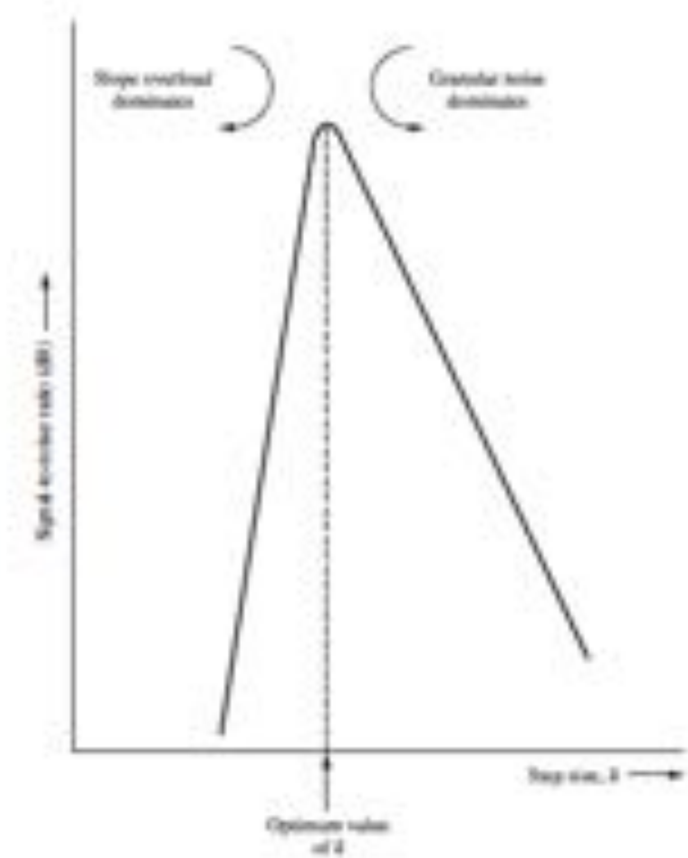


3.8. Delta Modulation

Granular Noise and Slope Overload Noise

The quantizing noise error signal may be classified into two types of noise: ***slope overload noise*** and ***granular noise***

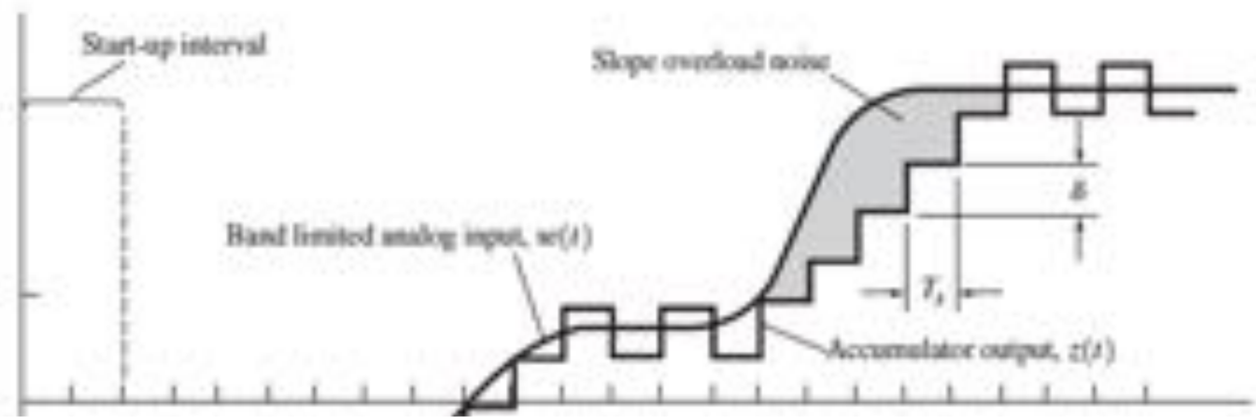
- ***slope overload noise:*** when the step size δ ***is too small***
- ***granular noise:*** occurs for any step size δ***. The smaller step the smaller noise***



3.8. Delta Modulation

<u>Example 3-16 Design of a DM system</u>

Find the step size δ required to prevent slope overload noise for the case when the input signal is a sine wave.



3.8. Delta Modulation

PSD and NSR of Noise

The PSD for the noise is:

$$p_n(f) = \frac{\delta^2}{6f_s}$$

Granular noise power in the analog signal band:

$$N = \langle n^2 \rangle = \int_{-B}^{B} p_n(f)\,df = \frac{\delta^2 B}{3f_s}$$

3.8. Delta Modulation

A delta modulation (DM) system is tested with a 10-kHz sinusoidal signal, 1 V peak-to-peak, at the input. The signal is sampled at 10 times the Nyquist rate.

a) What is the step size required to prevent slope overload and to minimize granular noise?
b) What is the PSD for the granular noise?

3.9. Time-Division Multiplexing

DEFINIATION: *Time-division multiplexing* (TDM) is the time interleaving of samples form several sources so that the information from these sources can be transmitted serially over a single communication channel.

At the Transmitter

- Simultaneous transmission of several signals on a time-sharing basis.
- Each signal occupies its own distinct time slot, using all frequencies, for the duration of the transmission.
- Slots may be permanently assigned on demand.

3.9. Time-Division Multiplexing

At the Receiver

- Decommutator (sampler) has to be synchronized with the incoming waveform → *Frame Synchronization*
- Low pass filter
- ISI – poor channel filtering
- Feedthrough of one channel's signal into another channel -- *Crosstalk*

Applications of TDM: Digital Telephony, Data Communications, Satellite Access, Cellular Radio.

3.9. Time-Division Multiplexing

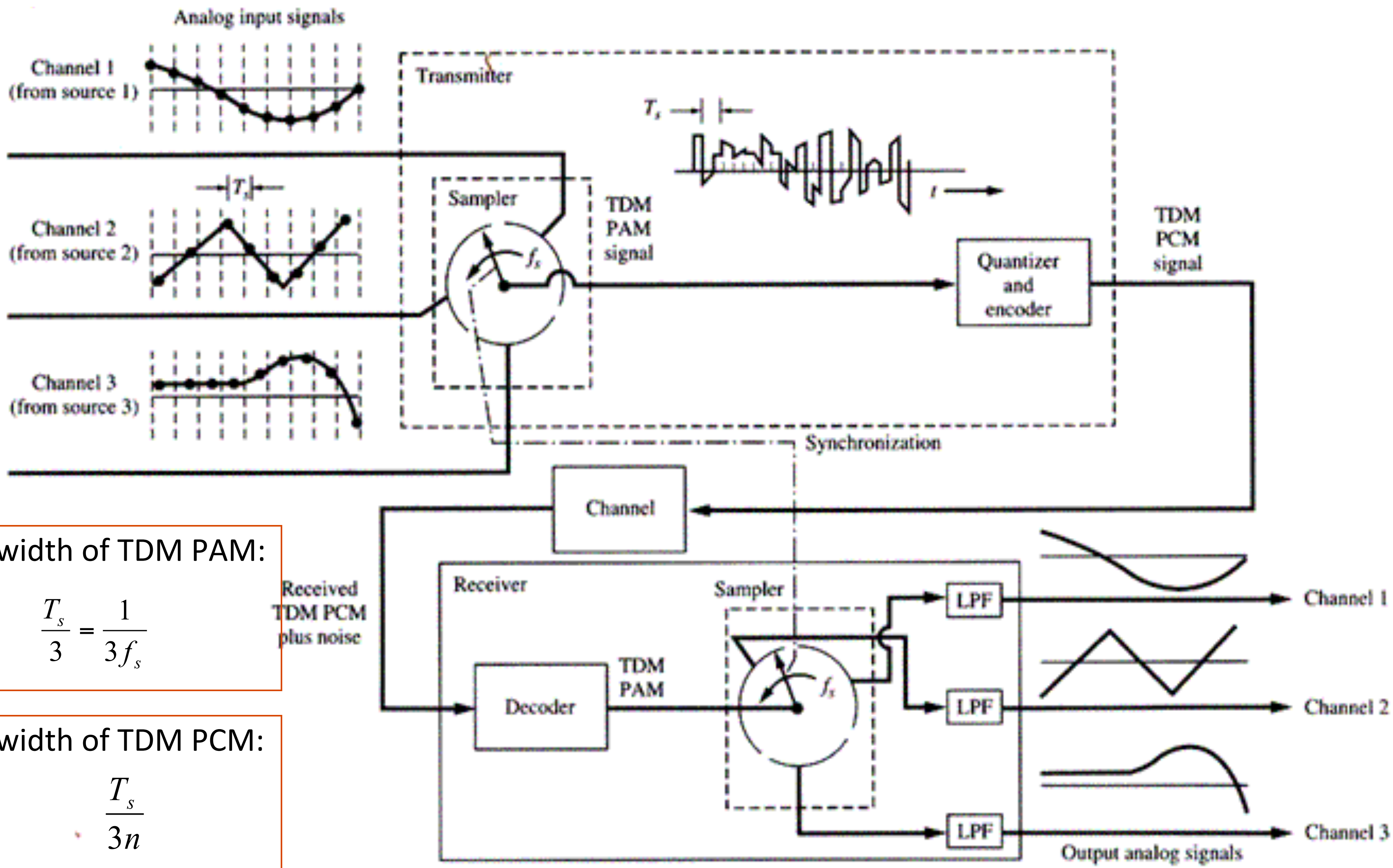


Figure 3–35 Three-channel TDM PCM system.

Pulse width of TDM PAM:

$$\frac{T_s}{3} = \frac{1}{3f_s}$$

Pulse width of TDM PCM:

$$\frac{T_s}{3n}$$

$f_s = \frac{1}{T_s}$ f_s satisfies Nyquist rate