PULSE MODULATION TECHNIQUES

INTRODUCTION

- Modulation is the process of frequency translation in which any one parameter(Amplitude, frequency or phase) of high frequency carrier signal is varied in accordance with instantaneous value of low frequency modulating signal.
- Modulation is either analog or digital.

INTRODUCTION

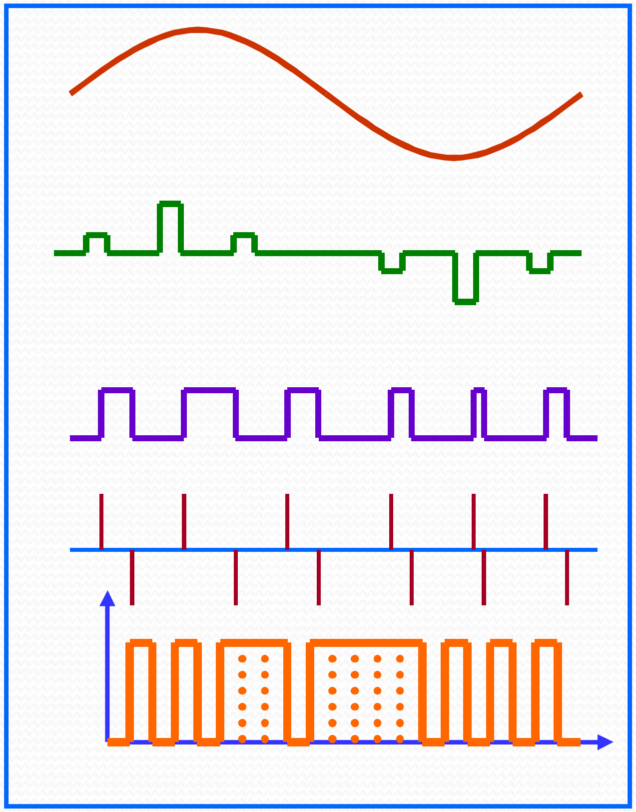
- Many signals in modern communication systems are digital
- Additionally, analog signals are transmitted digitally
- Digitizing a signal results in reduced distortion and improvement in signal-to-noise ratios

INTRODUCTION

- A digital signal is superior to an analog signal because it is more robust to noise and can easily be recovered, corrected and amplified. For this reason, the tendency today is to change an analog signal to digital data.
- The process of transmitting signals in the form of pulses (discontinuous signals) by using special techniques.

PULSE MODULATION INCLUDES

- Pulse Amplitude Modulation
- Pulse Width Modulation
- Pulse Position Modulation
- Pulse Code Modulation
- Delta Modulation



PULSE MODULATION

Analog Pulse Modulation

- Pulse Amplitude (PAM)
- Pulse Width (PWM)
- Pulse Position (PPM)

Digital Pulse Modulation

- Pulse Code (PCM)
- Delta Modulation(DM)

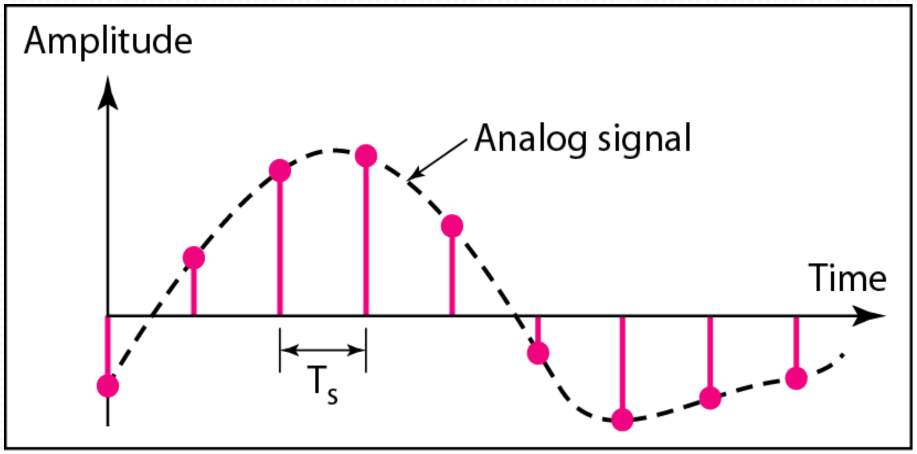
Sampling

- The process of transmitting signals in the form of pulses (discontinuous signals) by using special techniques.
- The signal is sampled at regular intervals such that each sample is propotional to the amplitude of signal at that instant.This technique is called "sampling".
- Sampling is common in all pulse modulation techniques.

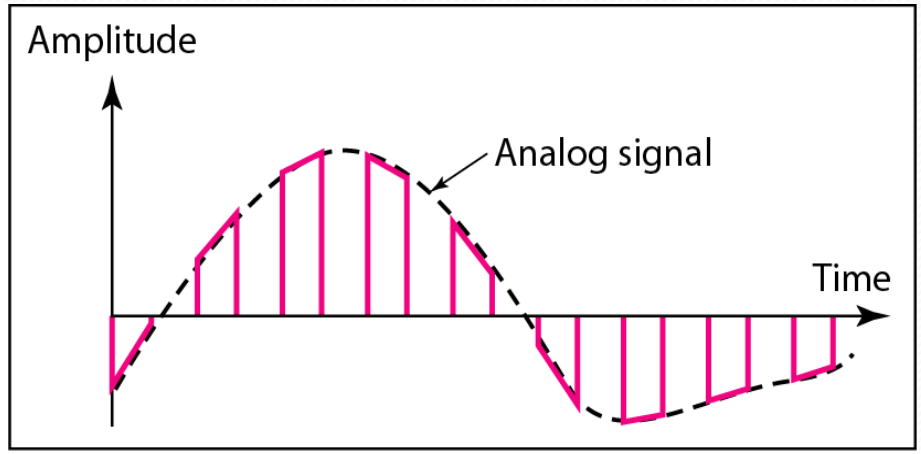
Sampling

- Analog signal is sampled every T_S secs.
- T_s is referred to as the sampling interval.
- $f_s = 1/T_s$ is called the sampling rate or sampling frequency.
- There are 3 sampling methods:
  - Ideal - an impulse at each sampling instant
  - Natural - a pulse of short width with varying amplitude
  - Flat top - sample and hold, like natural but with single amplitude value

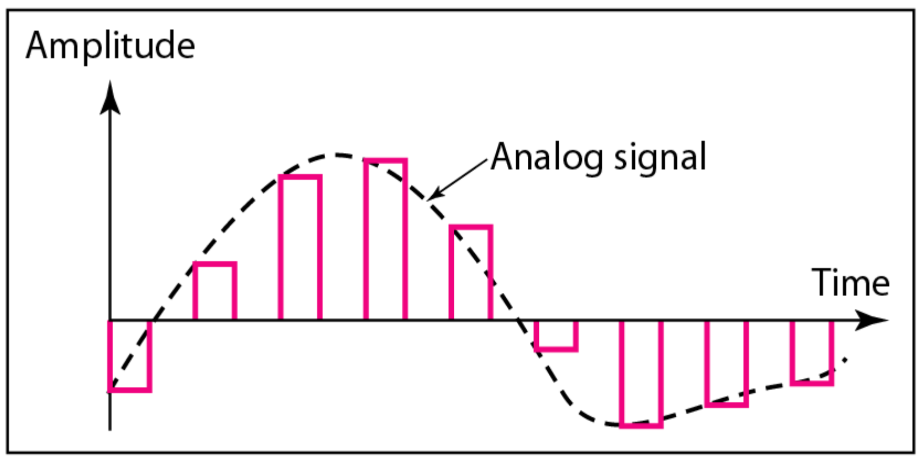
Three different sampling methods



a. Ideal sampling



b. Natural sampling



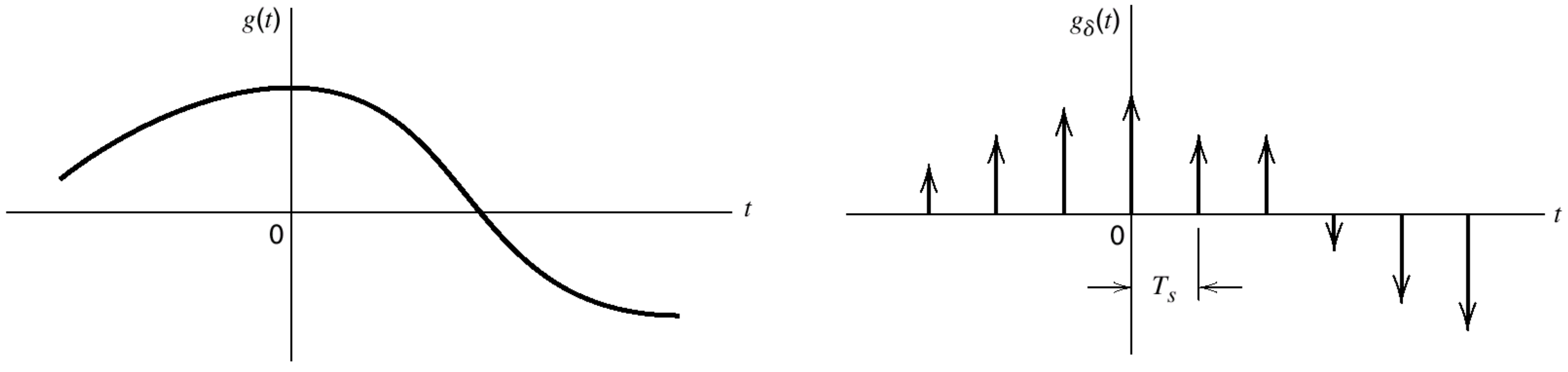
c. Flat-top sampling

Sampling Rate

- Nyquist showed that it is possible to reconstruct a band-limited signal from periodic samples, as long as the sampling rate is at least twice the frequency of the of highest frequency component of the signal i.e. $fs \geq 2fm$

  where fs is sampling rate
- Sampling rates that are too low result in **aliasing** or **foldover**

Sampling



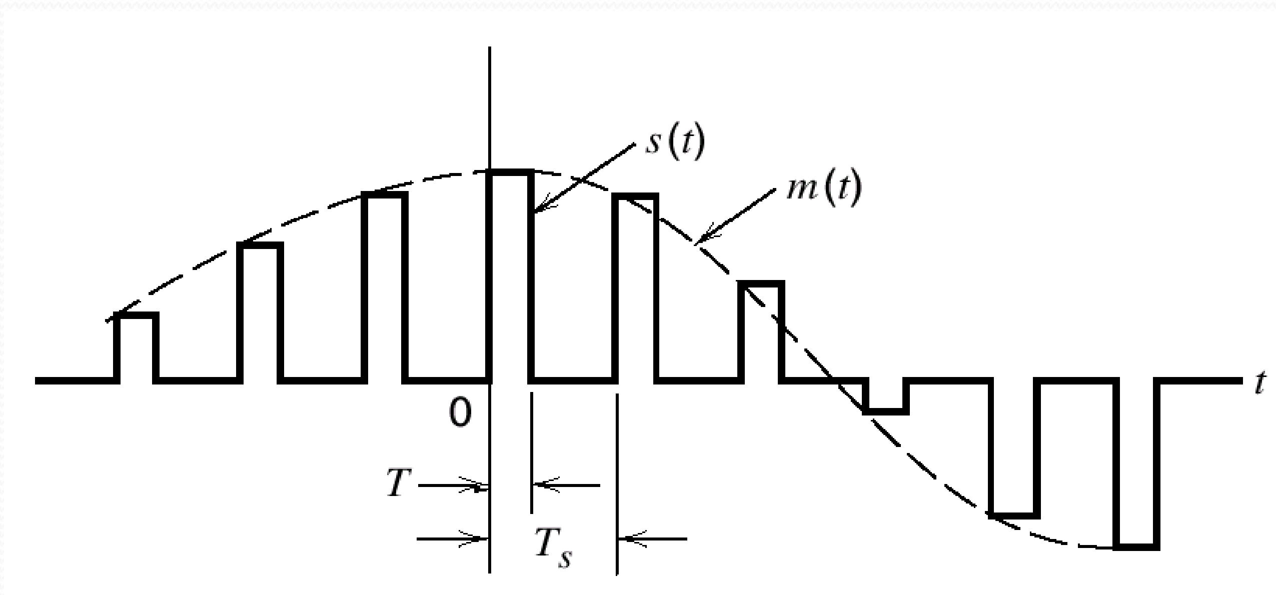
(a) (b)

Sampling

- Sampling alone is not a digital technique
- The immediate result of sampling is a **pulse-amplitude modulation (PAM)** signal
- PAM is an analog scheme in which the amplitude of the pulse is proportional to the amplitude of the signal at the instant of sampling
- Another analog pulse-forming technique is known as **pulse-duration modulation (PDM).** This is also known as **pulse-width modulation (PWM)**
- **Pulse-position modulation** is closely related to PDM

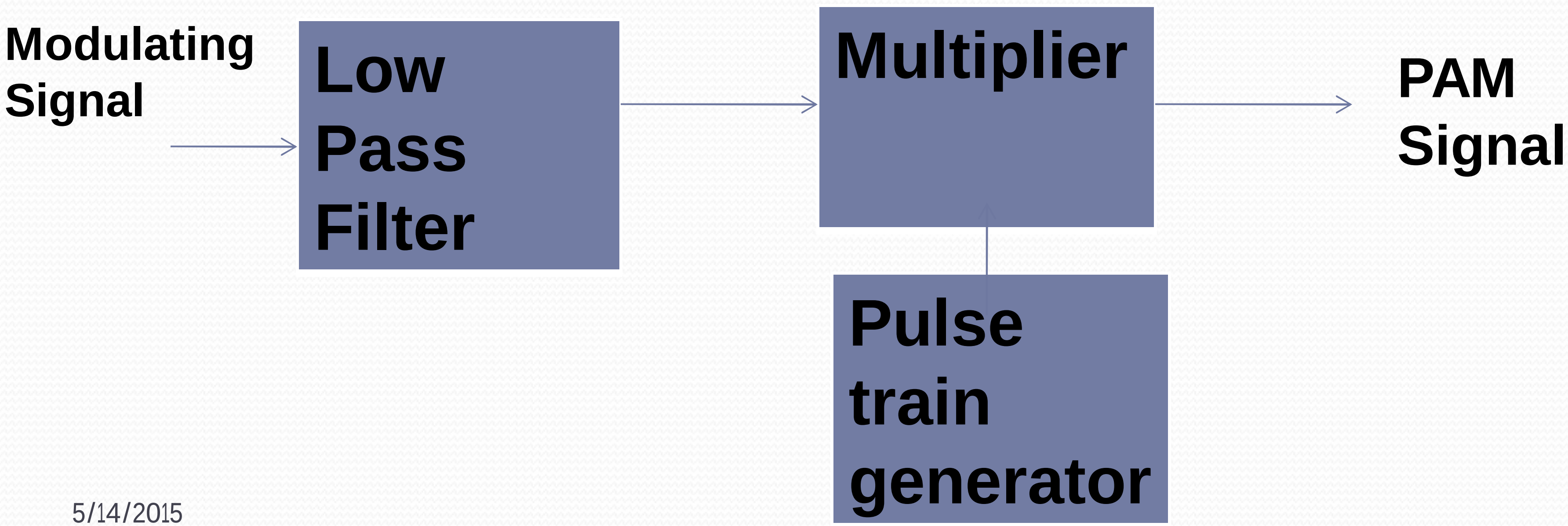
Pulse Amplitude Modulation

- In PAM,amplitude of pulses is varied in accordance with instantaneous value of modulating signal.



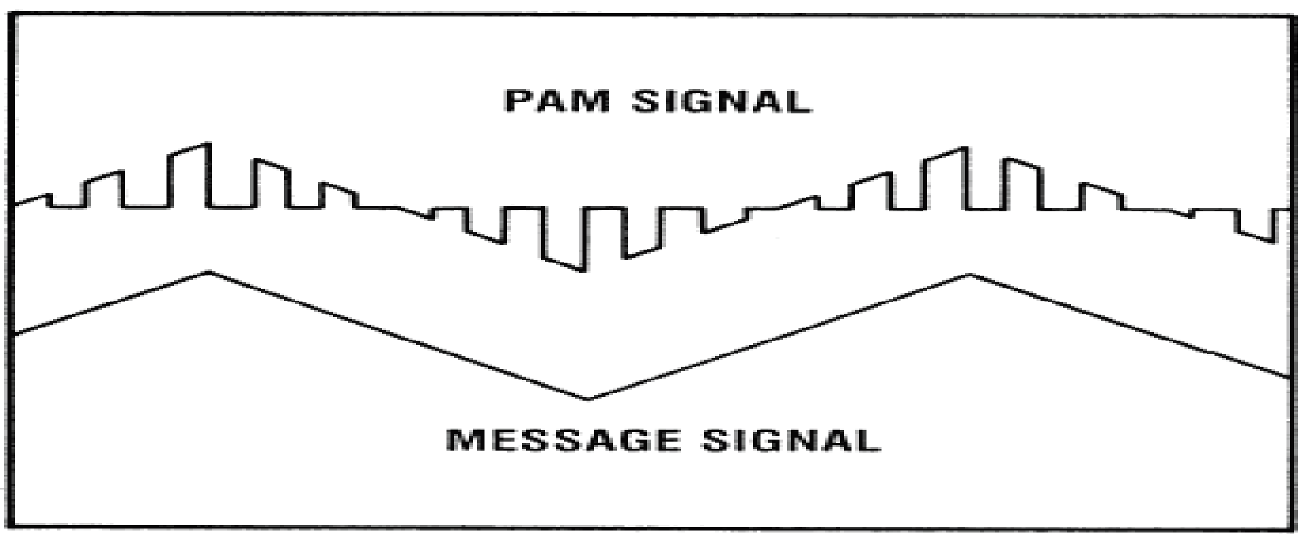
Pulse Amplitude Modulation

The carrier is in the form of narrow pulses having frequency fs.The uniform sampling takes place in multiplier to generate PAM signal.Samples are placed Ts sec away from each other.



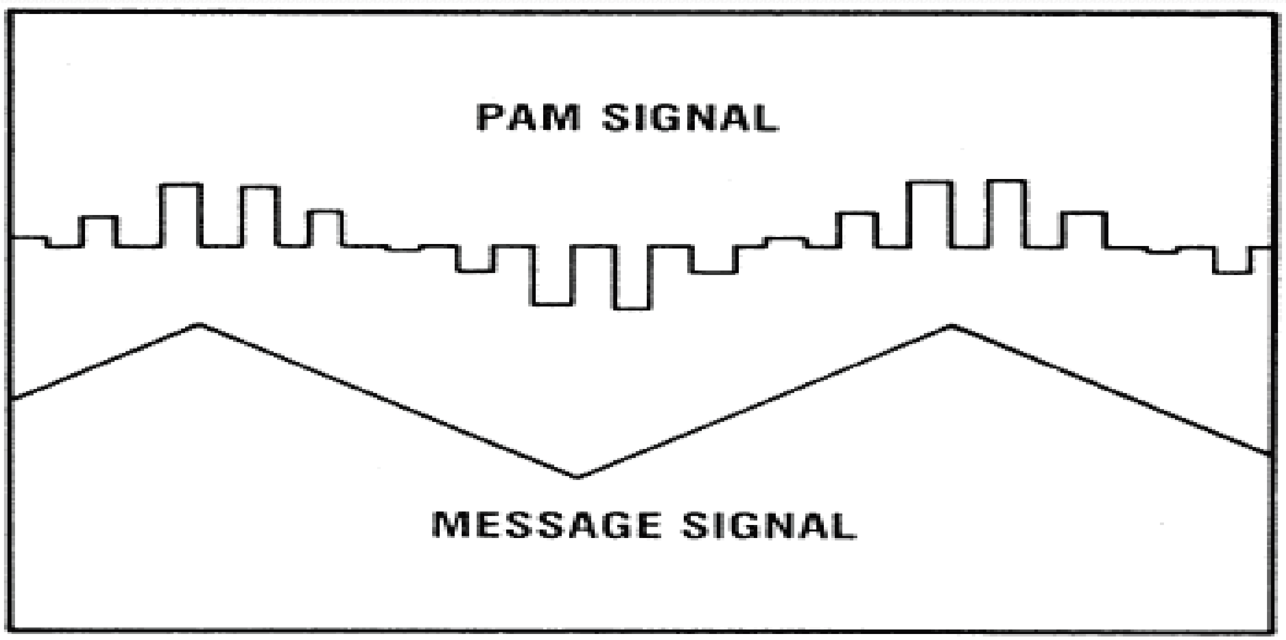
Pulse Amplitude Modulation

- Depending upon the shape and polarity of the sampled pulses, PAM is of two types,
- **Natural PAM** sampling occurs when top portion of the pulses are subjected to follow the modulating wave.



Pulse Amplitude Modulation

- **Flat topped PAM** sampling is often used because of the ease of generating the modulated wave. In this pulses have flat tops after modulation.



Pulse Amplitude Modulation

- The PAM signal can be detected by passing it through a low pass filter.

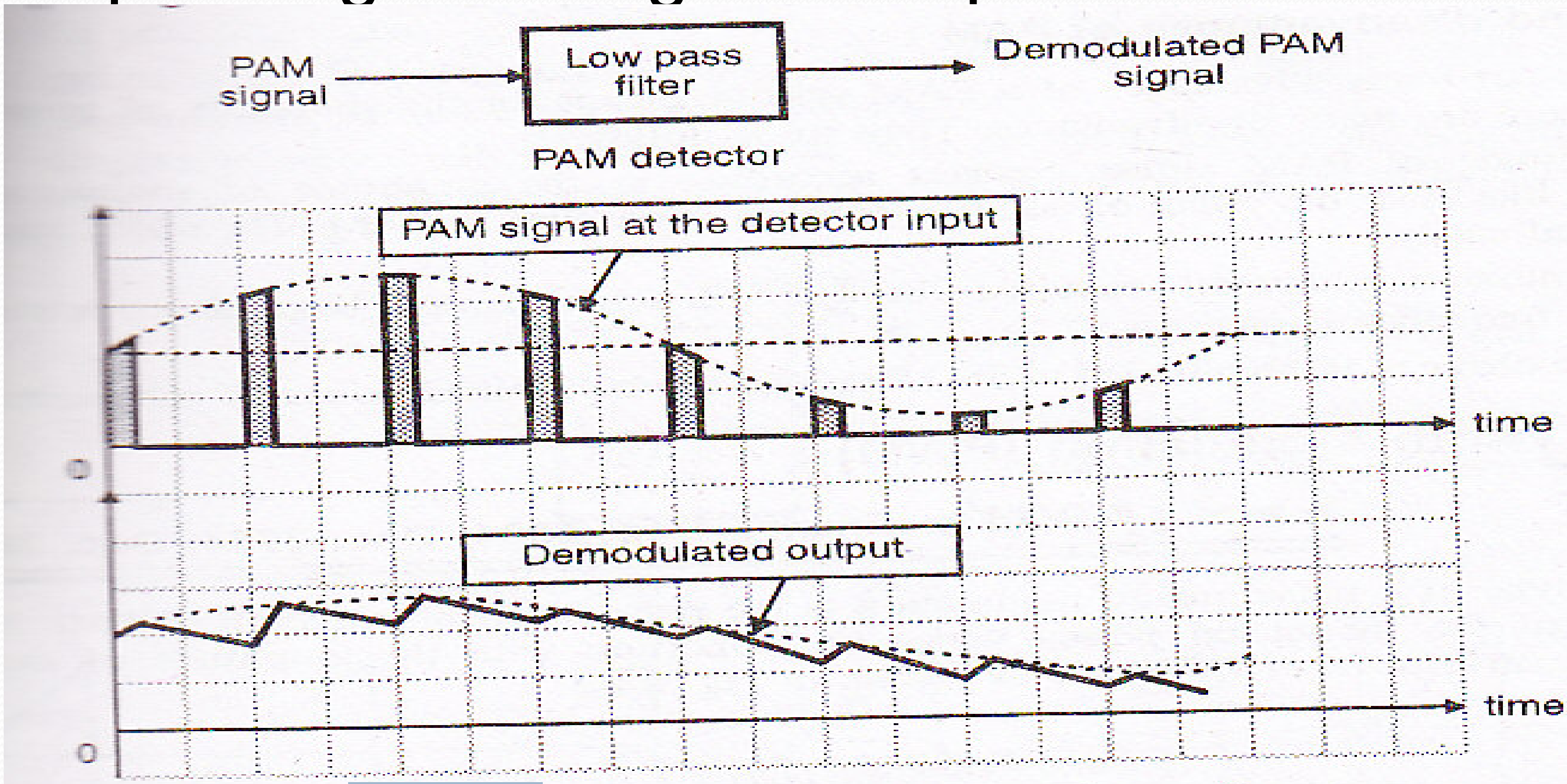
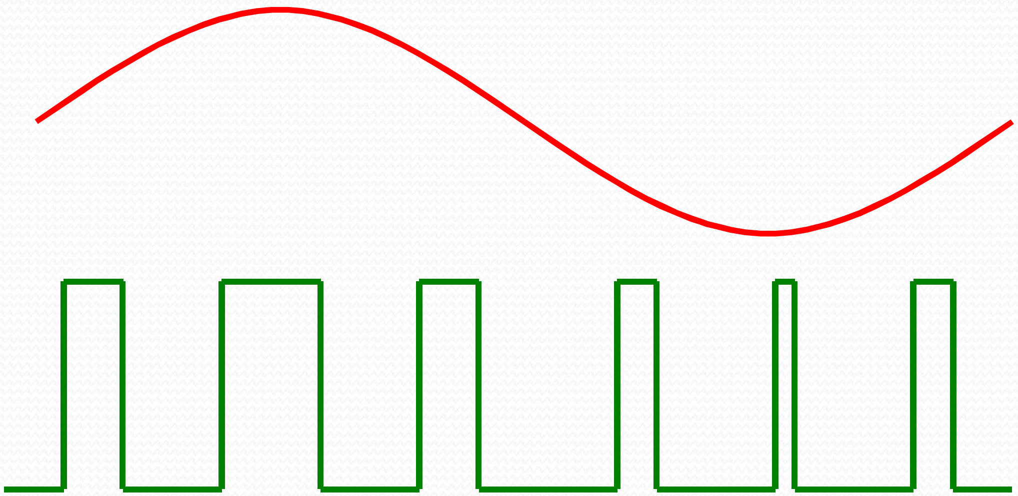


Fig : Detection of PAM and waveforms

Pulse Width Modulation

- In this type, the amplitude is maintained constant but the width of each pulse is varied in accordance with instantaneous value of the analog signal.



Pulse Width Modulation

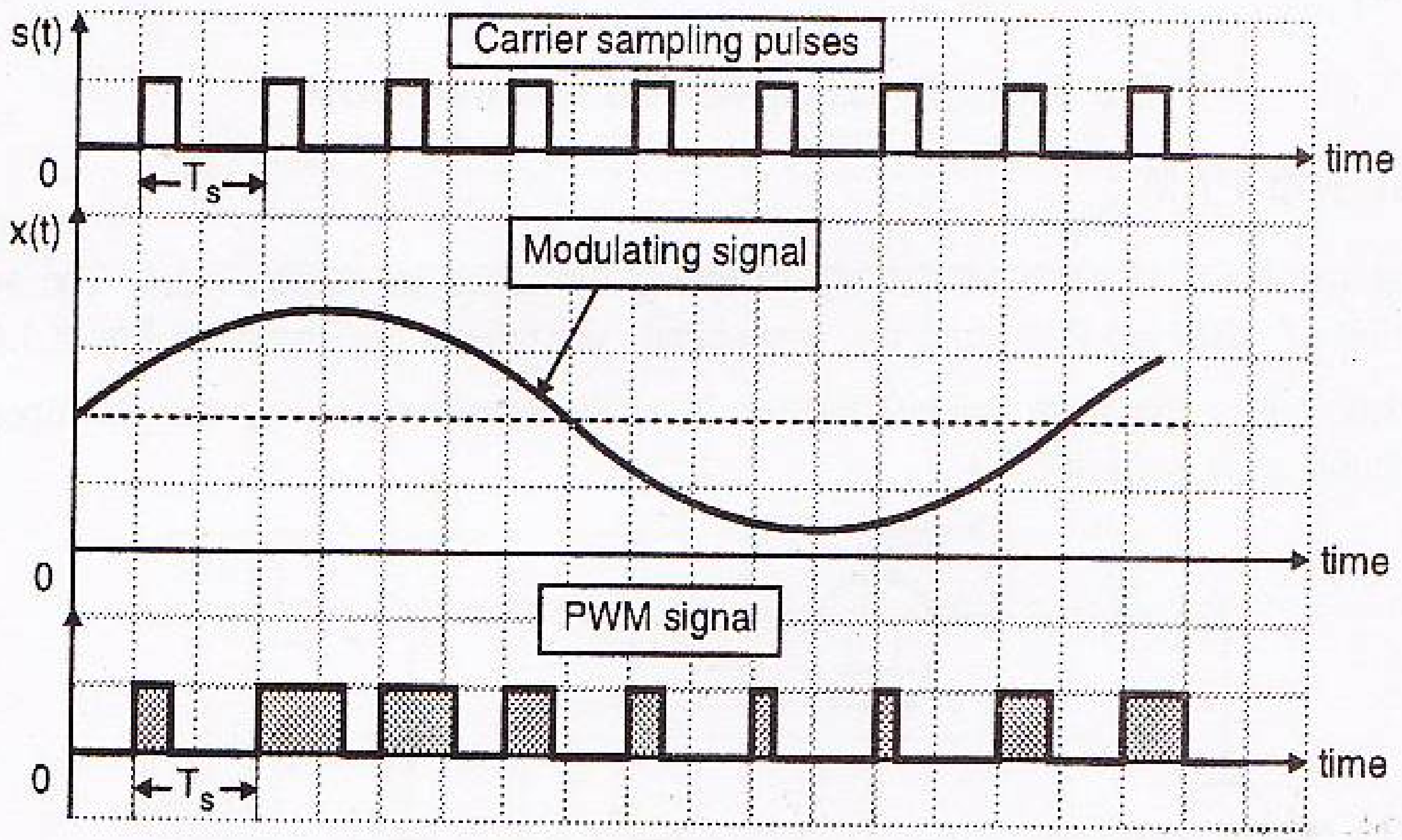
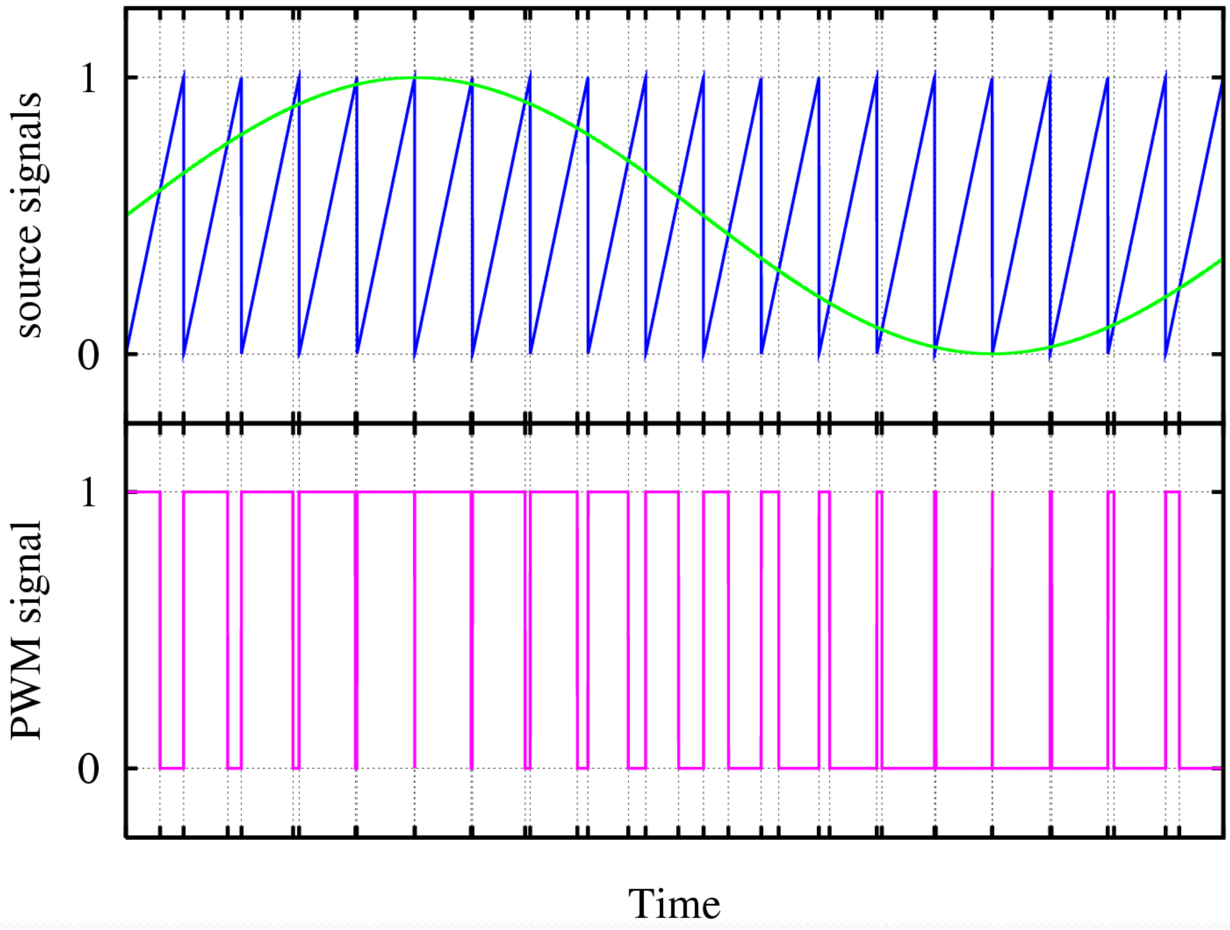


Fig: PWM signal [Trail edge modulated signal]

Pulse Width Modulation

- That is why the information is contained in width variation. This is similar to FM.
- In pulse width modulation (PWM), the width of each pulse is made directly proportional to the amplitude of the information signal.

Pulse Width Modulation



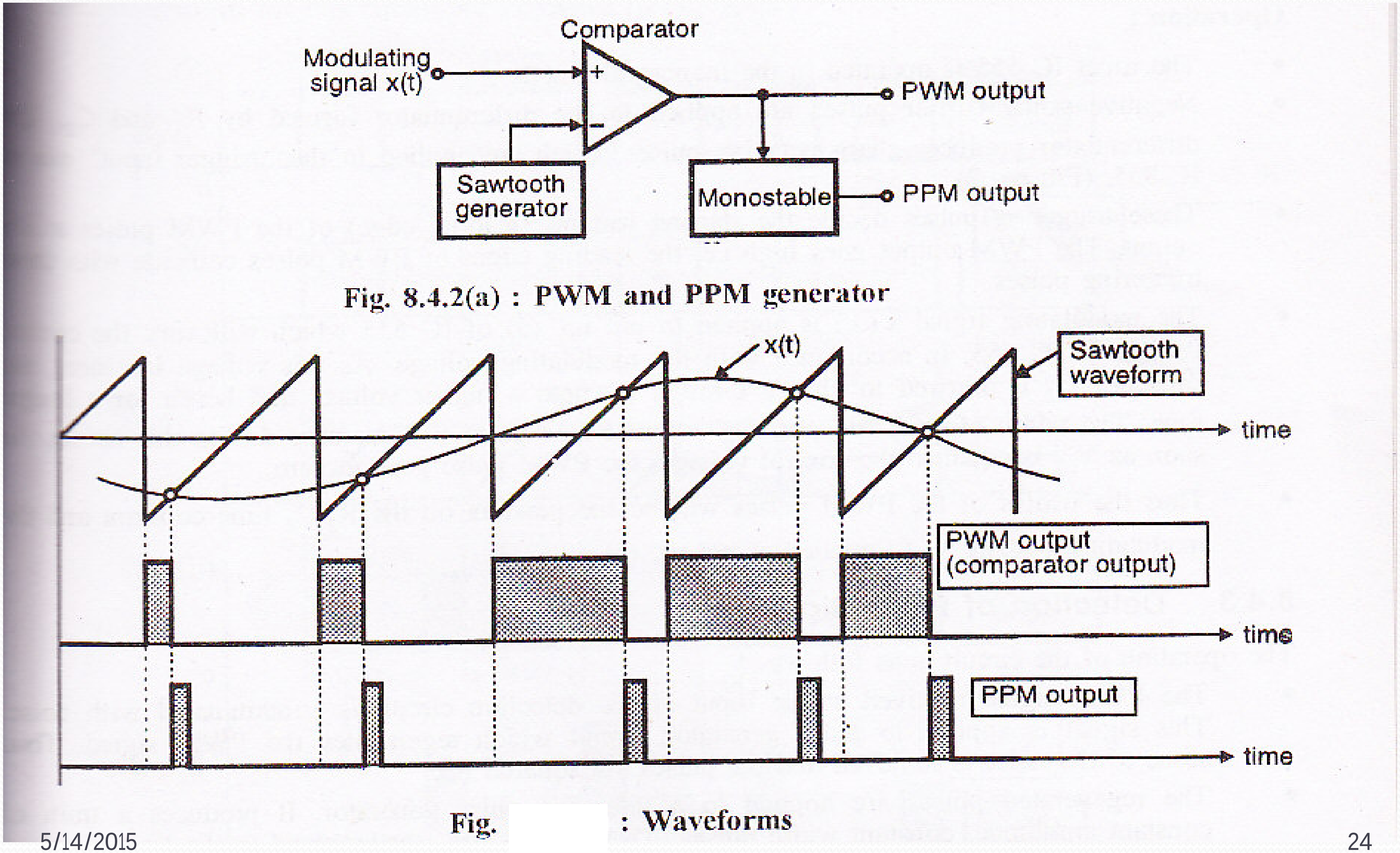
Pulse Width Modulation

- A simple method to generate the PWM pulse train corresponding to a given signal is the intersective PWM: the signal (here the green sinewave) is compared with a sawtooth waveform (blue). When the latter is less than the former, the PWM signal (magenta) is in high state (1). Otherwise it is in the low state (0).

Pulse Width Modulation

- The block diagram of next slide can be used for generation of PWM as well as PPM.In this case a sawtooth signal of frequency fs is a sampling signal.
- It is applied to inverting terminal of a comparator with modulating signal at non inverting terminal.
- O/P remains high as long as modulating signal is higher than that of ramp signal.

Pulse Width Modulation



Pulse Position Modulation

- In this type, the sampled waveform has fixed amplitude and width whereas the position of each pulse is varied as per instantaneous value of the analog signal.
- PPM signal is further modification of a PWM signal.

Pulse Position Modulation

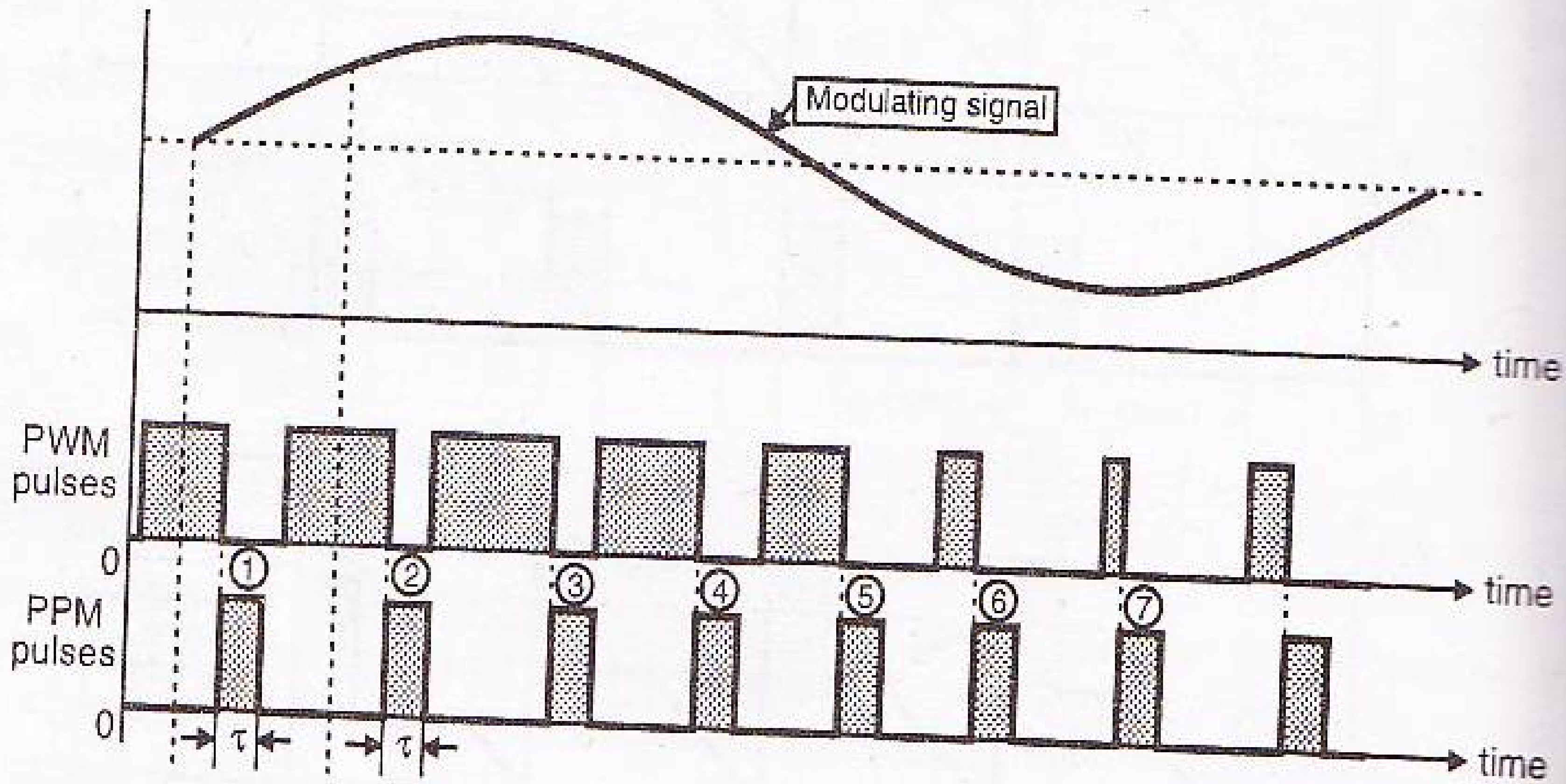


Fig. : PPM pulses generated from PWM signal

Pulse Position Modulation

- The vertical dotted lines shown in last slide treated as reference lines.
- The PPM pulses marked 1,2 and 3 go away from their respective reference lines.This corresponds to increase in modulating signal amplitude.
- Then as modulating signal decreases the PPM pulses 4,5,6,7 come closer to their respective reference lines.

Pulse Position Modulation

- The PPM signal can be generated from PWM signal.
- The PWM pulses obtained at the comparator output are applied to a monostable multivibrator which is –ve edge
- triggered.
- Hence for each trailing edge of PWM signal, the monostable output goes high.It remains high for a fixed time decided by its own RC components.

Pulse Position Modulation

- Thus as the trailing edges of the PWM signal keeps shifting in propotion with the modulating signal,the PPM pulses also keep shifting.
- Therefore all the PPM pulses have the same amplitude and width.The information is conveyed via changing position of pulses.

Digital Pulse Modulation

- **Merits of Digital Communication:**

1. Digital signals are very easy to receive. The receiver has to just detect whether the pulse is low or high.

2. AM & FM signals become corrupted over much short distances as compared to digital signals. In digital signals, the original signal can be reproduced accurately.

Digital Pulse Modulation

- **Merits of Digital Communication**

3. The signals lose power as they travel, which is called attenuation. When AM and FM signals are amplified, the noise also get amplified. But the digital signals can be cleaned up to restore the quality and amplified by the regenerators.

4. The noise may change the shape of the pulses but not the pattern of the pulses.

Digital Pulse Modulation

- Merits of Digital Communication:

5. AM and FM signals can be received by any one by suitable receiver. But digital signals can be coded so that only the person, who is intended for, can receive them.

6. AM and FM transmitters are ‘real time systems’. i.e. they can be received only at the time of transmission. But digital signals can be stored at the receiving end.

7. The digital signals can be stored.

Digital Pulse Modulation

- The process of Sampling which we have already discussed in initial slides is also adopted in Digital pulse modulation.
- It is mainly of two types:

❑ Pulse Code Modulation(PCM)

❑ Delta Modulation(DM)

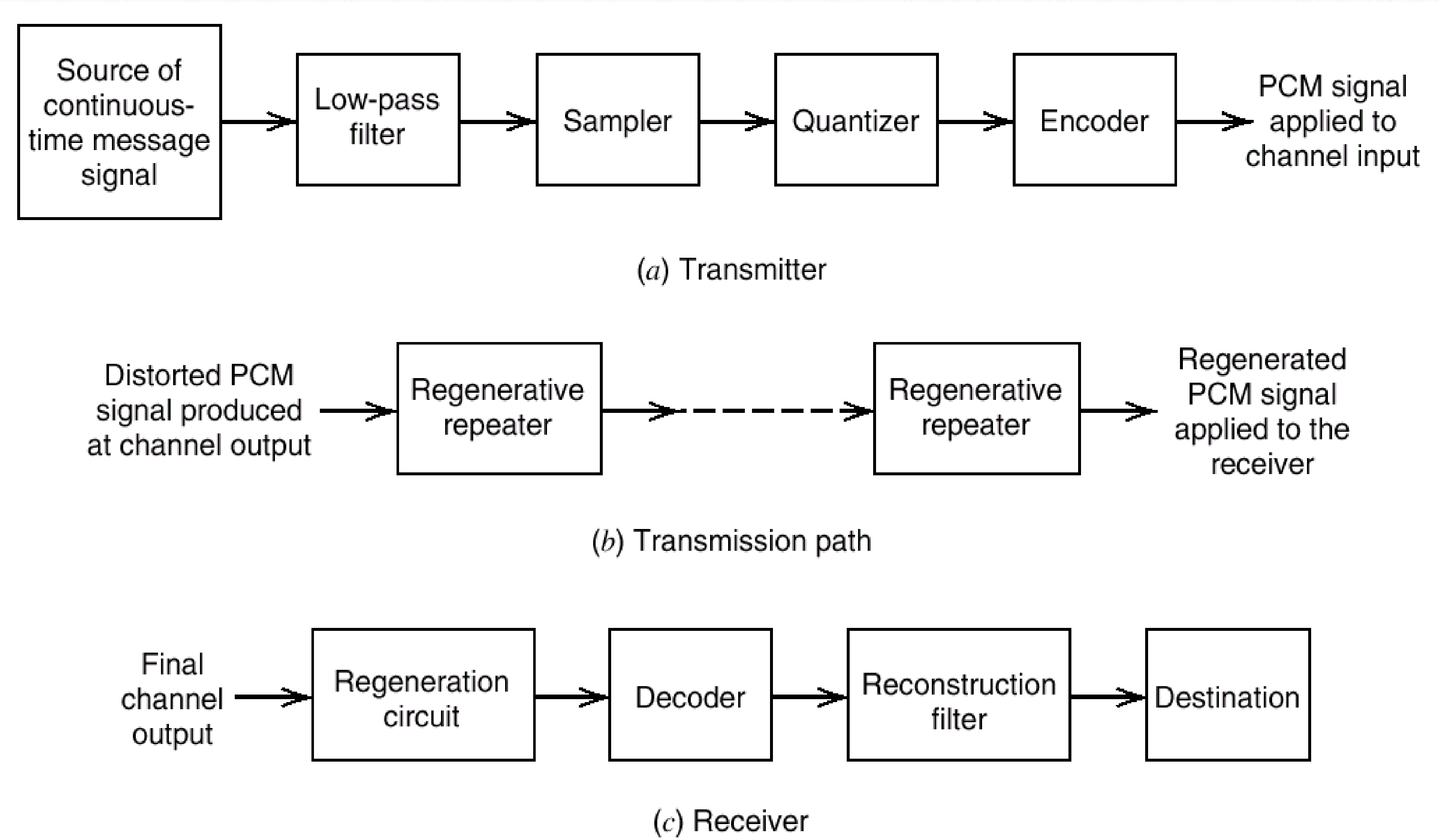
Pulse Code Modulation(PCM)

- Pulse-Code Modulation (PCM) is the most commonly used digital modulation scheme
- In PCM, the available range of signal voltages is divided into levels and each is assigned a binary number
- Each sample is represented by a binary number and transmitted serially
- The number of levels available depends upon the number of bits used to express the sample value
- The number of levels is given by: $\boldsymbol{N = 2^m}$

Pulse Code Modulation(PCM)

- PCM consists of three steps to digitize an analog signal:
  1. Sampling
  2. Quantization
  3. Binary encoding
- Before we sample, we have to filter the signal to limit the maximum frequency of the signal .Filtering should ensure that we do not distort the signal, ie remove high frequency components that affect the signal shape.

Pulse Code Modulation(PCM)



The basic elements of a PCM system.

Pulse Code Modulation(PCM)

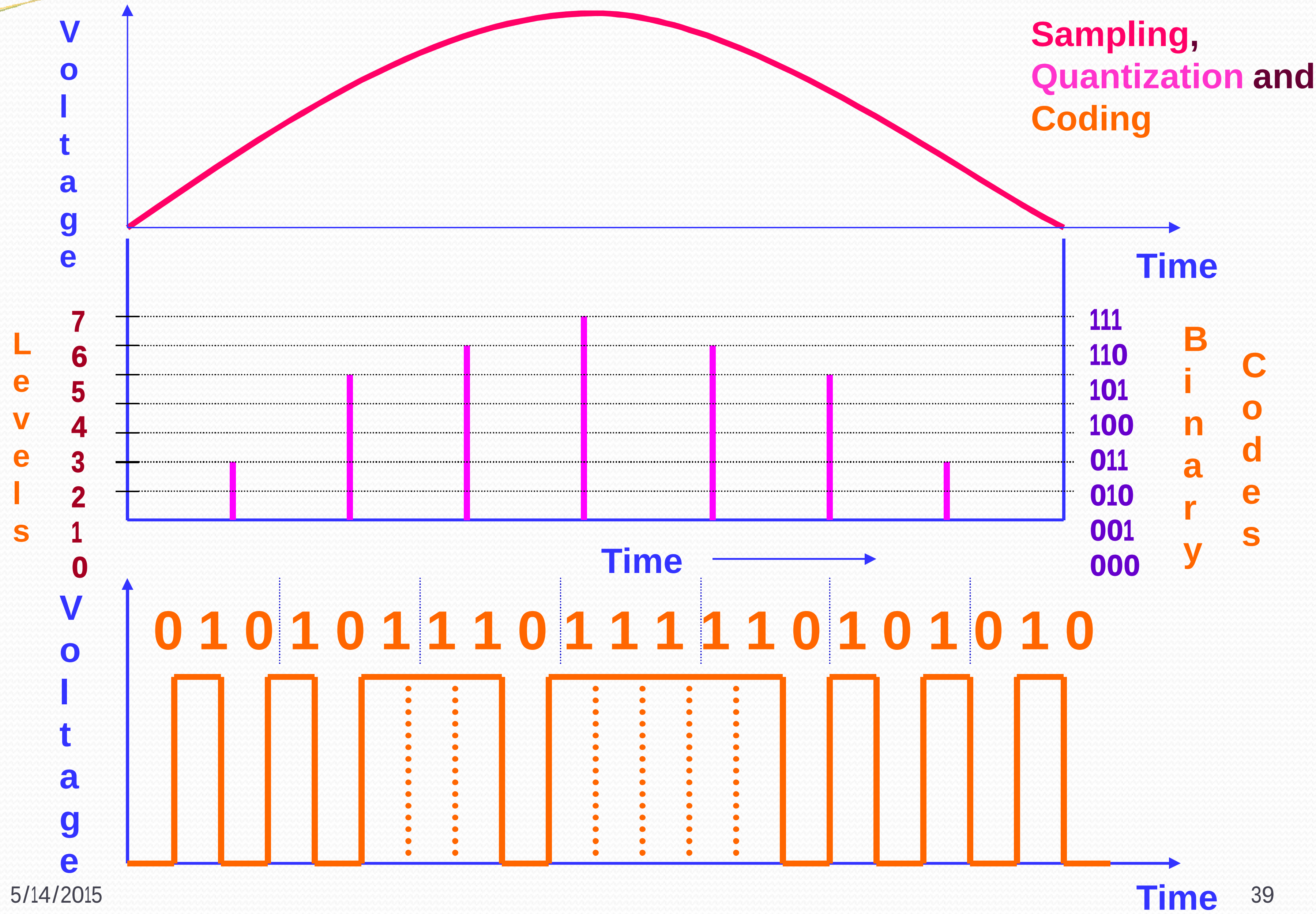
Analog to digital converter employs two techniques:

1. Sampling: The process of generating pulses of zero width and of amplitude equal to the instantaneous amplitude of the analog signal. The no. of pulses per second is called “sampling rate”.

Pulse Code Modulation(PCM)

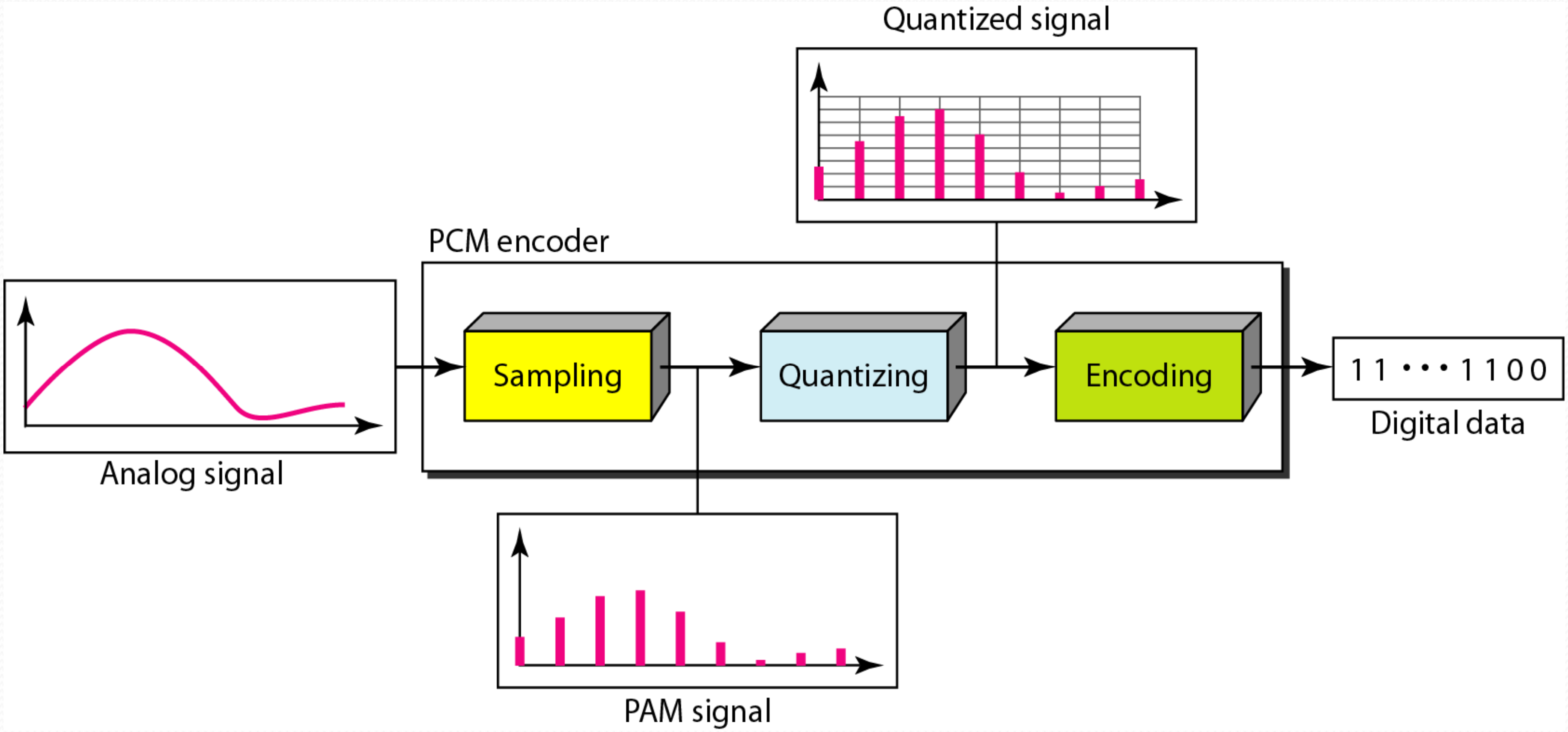
- 2. Quantization: The process of dividing the maximum value of the analog signal into a fixed no. of levels in order to convert the PAM into a Binary Code.

  The levels obtained are called "quanization levels".



Sampling, Quantization and Coding
Voltage
Time
Levels
7
6
5
4
3
2
1
0
111
110
101
100
011
010
001
000
Binary Codes
Time
Voltage
0 1 0 1 0 1 1 1 0 1 1 1 1 1 0 1 0 1 0 1 0
Time

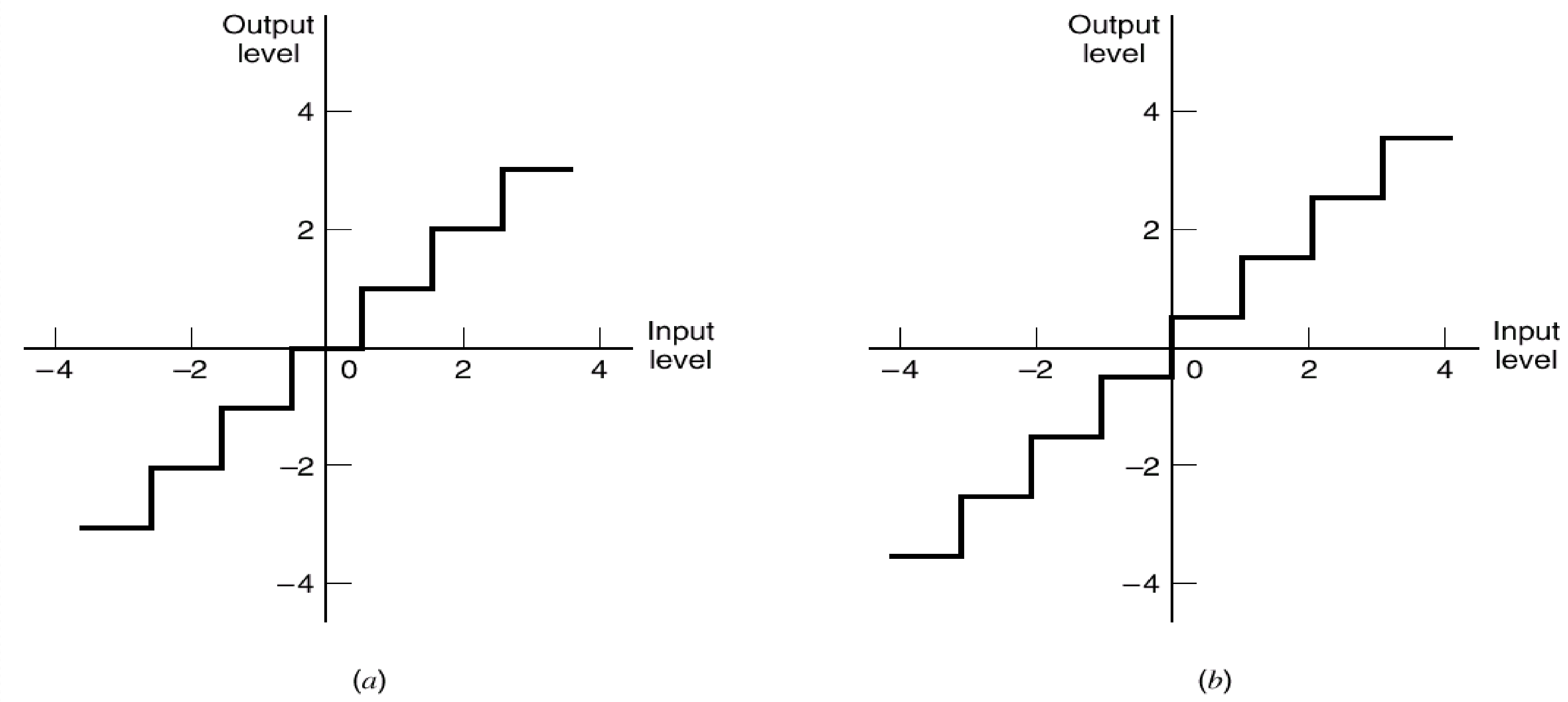
Pulse Code Modulation(PCM)



Quantization

- By quantizing the PAM pulse, original signal is only approximated
- The process of converting analog signals to PCM is called *quantizing*
- Since the original signal can have an infinite number of signal levels, the quantizing process will produce errors called **quantizing errors** or **quantizing noise**

Quantization

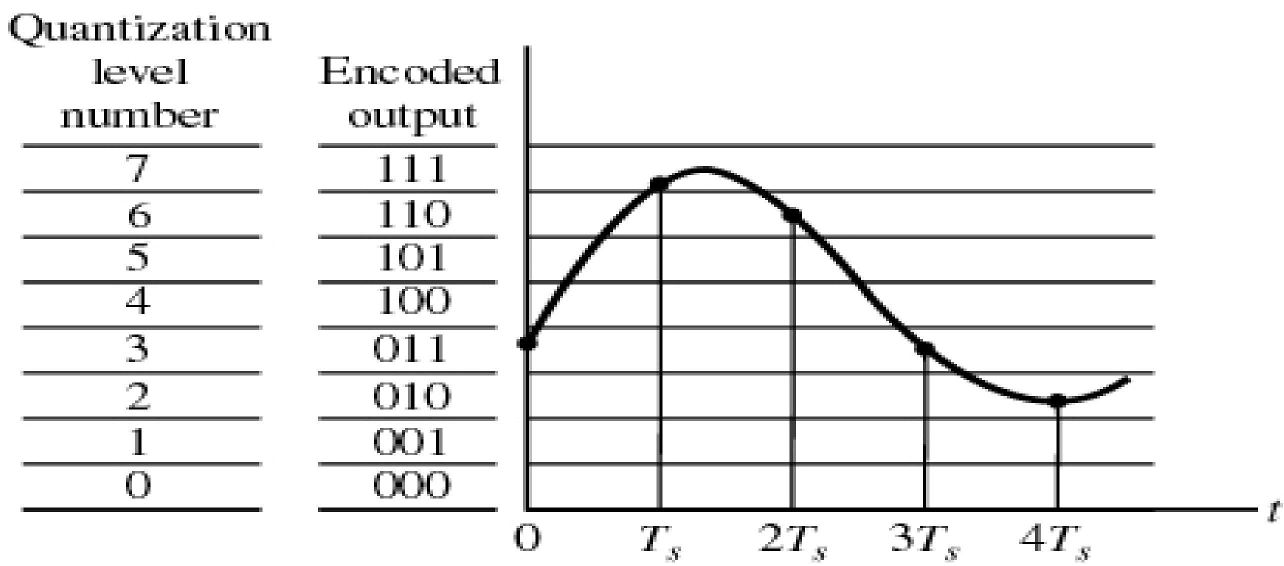


Two types of quantization: (*a*) midtread and (*b*) midrise

Quantization

- Coding and Decoding
- The process of converting an analog signal into PCM is called coding, the inverse operation is called decoding
- Both procedures are accomplished in a **CODEC**

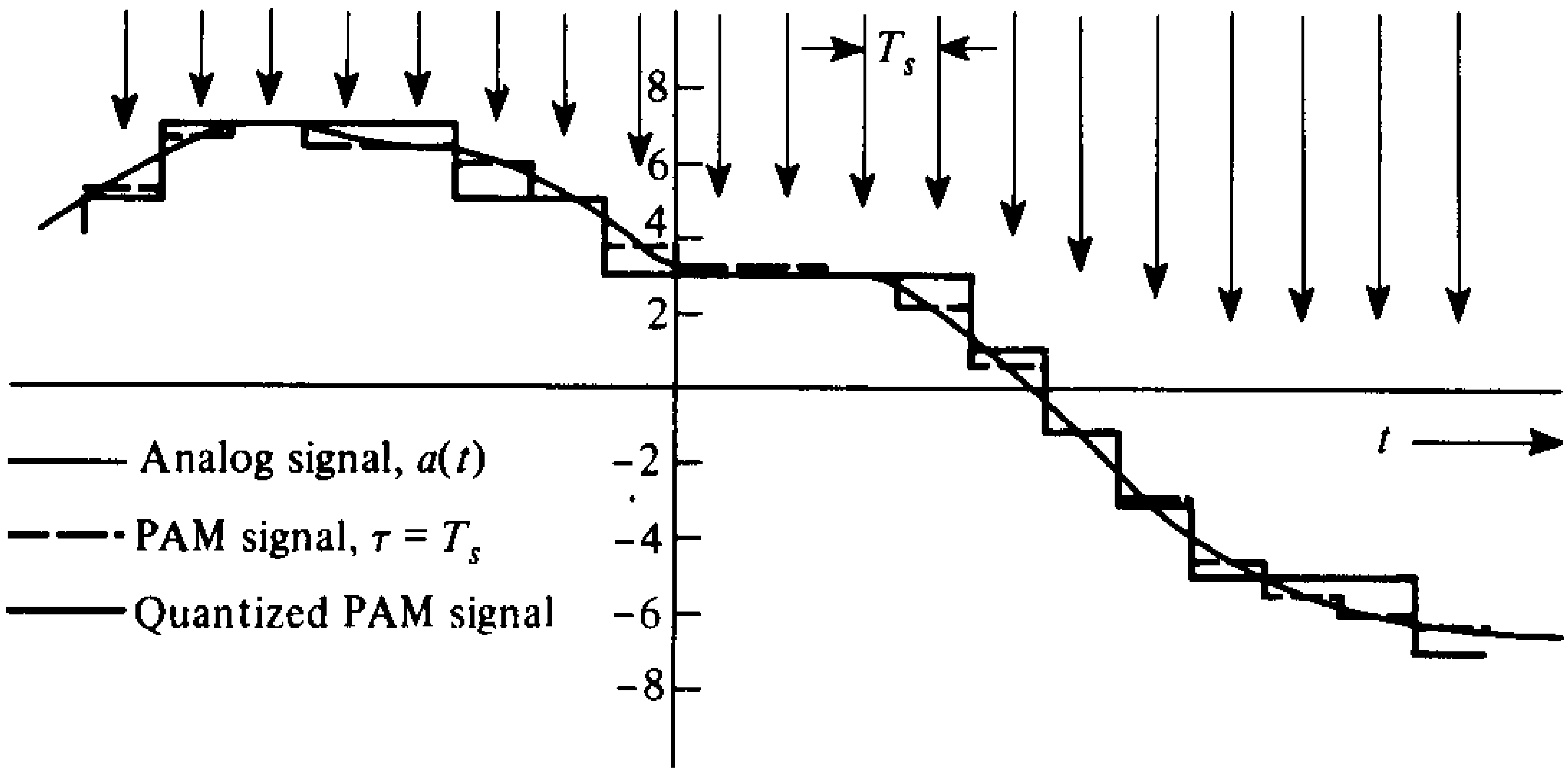
Quantization



(b)

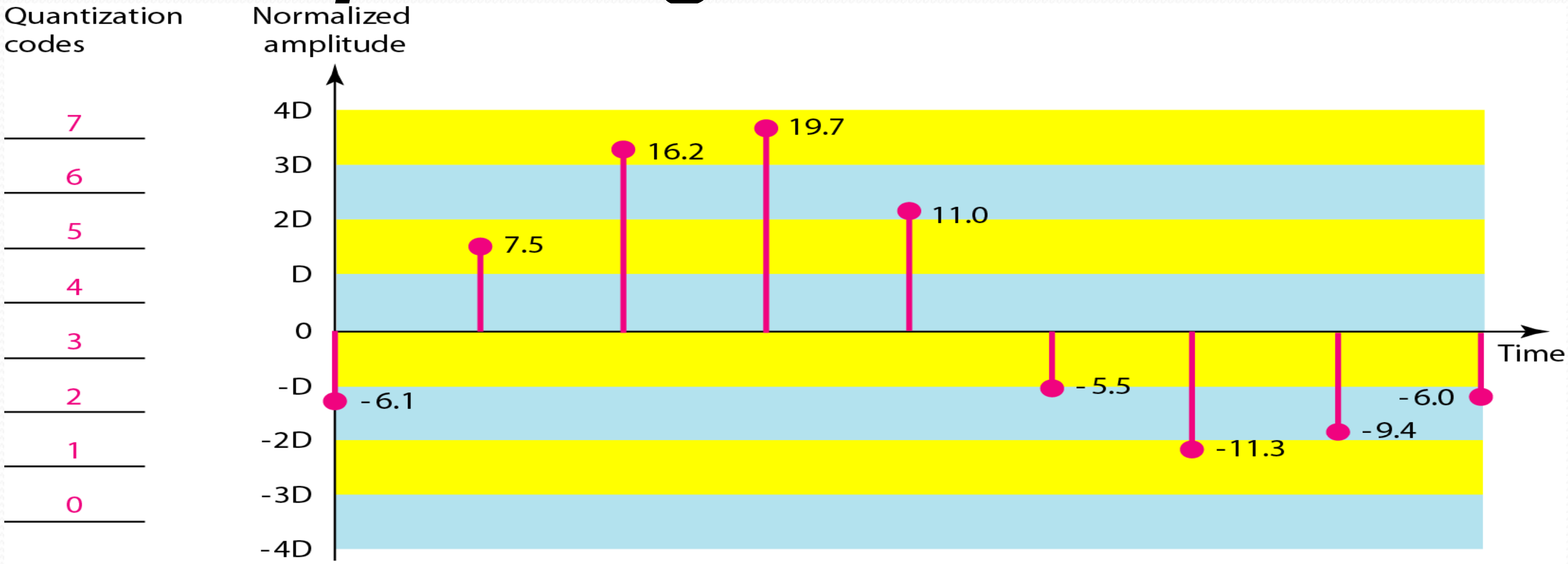
(c)

Quantization



(b) Analog Signal, Flat-top PAM Signal, and Quantized PAM Signal

Quantization and encoding of a sampled signal



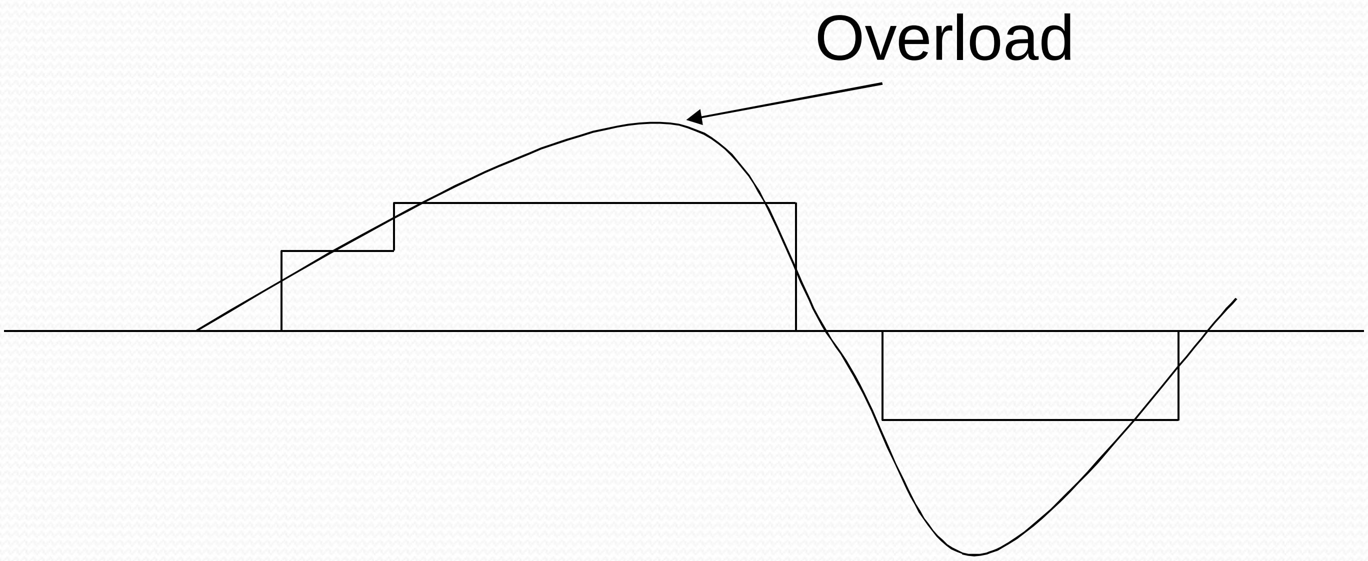
Normalized PAM values	-1.22	1.50	3.24	3.94	2.20	-1.10	-2.26	-1.88	-1.20
Normalized quantized values	-1.50	1.50	3.50	3.50	2.50	-1.50	-2.50	-1.50	-1.50
Normalized error	-0.38	0	+0.26	-0.44	+0.30	-0.40	-0.24	+0.38	-0.30
Quantization code	2	5	7	7	6	2	1	2	2
Encoded words	010	101	111	111	110	010	001	010	010

Quantization Error

- When a signal is quantized, we introduce an error - the coded signal is an approximation of the actual amplitude value.
- The difference between actual and coded value (midpoint) is referred to as the quantization error.
- The more zones, the smaller Δ which results in smaller errors.
- BUT, the more zones the more bits required to encode the samples -> higher bit rate

Quantization Error (cont.)

- Round-off error
- Overload error



Quantization Noise

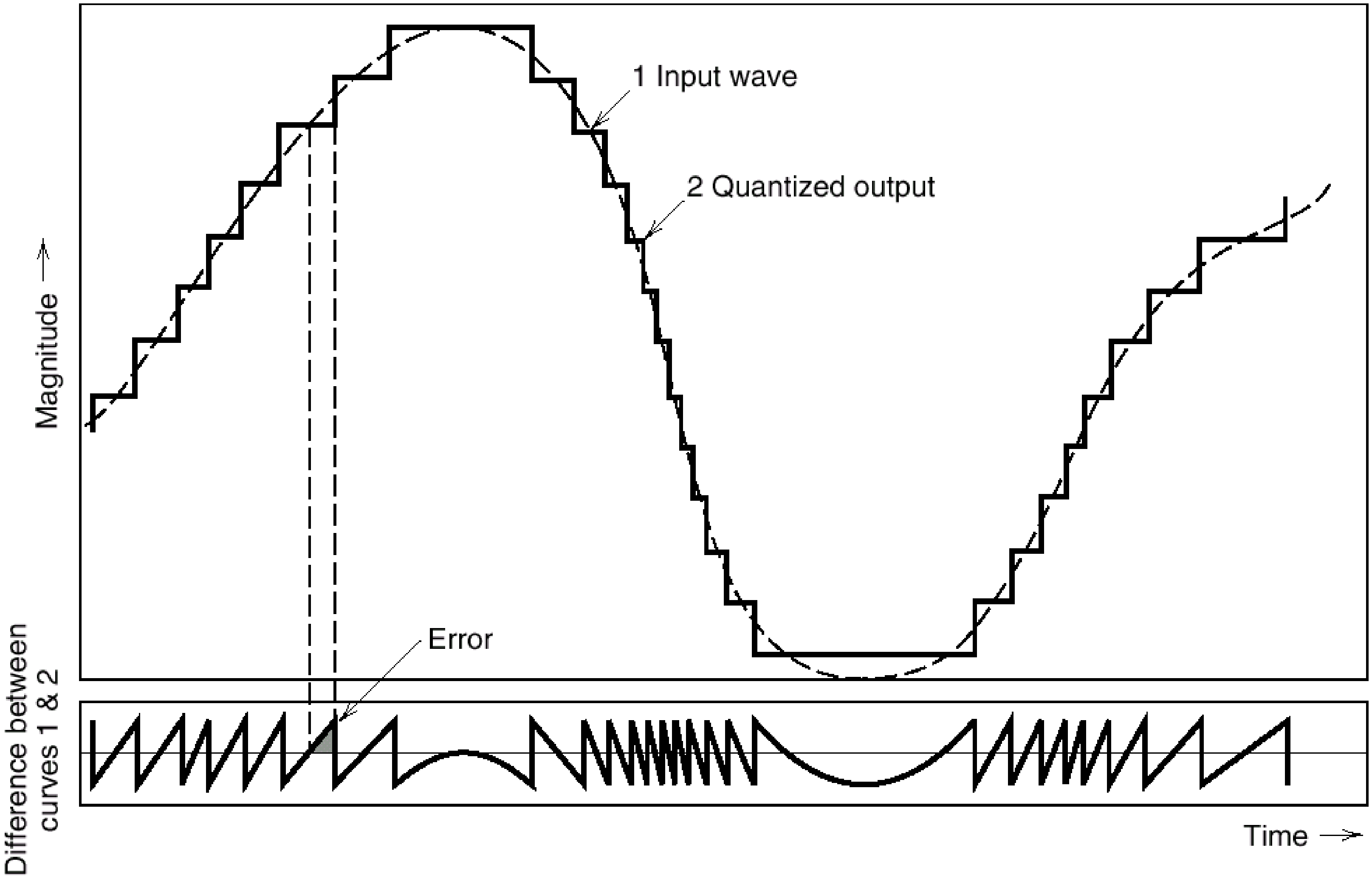


Illustration of the quantization process

Pulse Code Modulation

- In PCM system,N number of binary digits are transmitted per sample.Hence the signaling rate and channel bandwidth of PCM are very large.
- Also encodind,decoding and quantizing circuitary of PCM is complex.

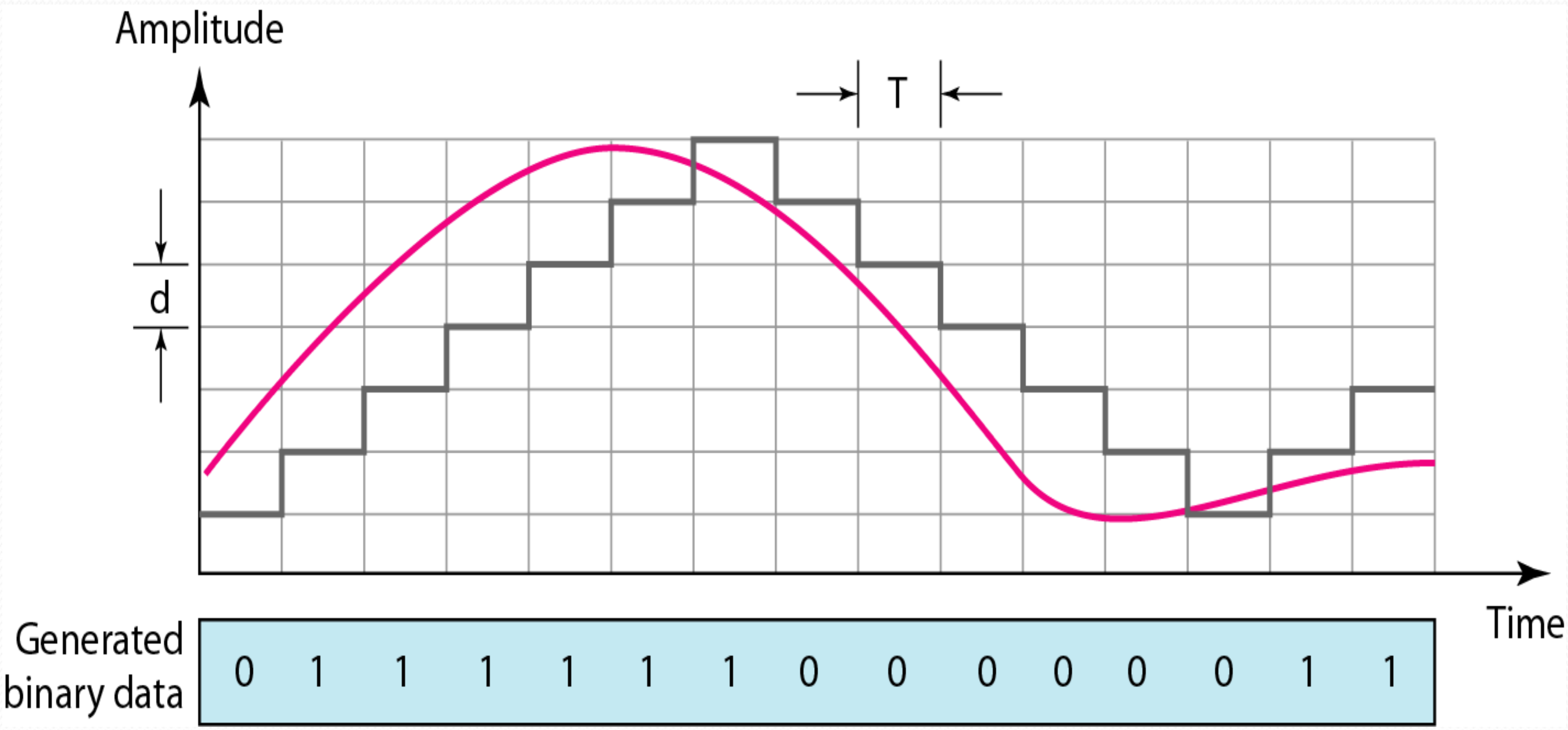
Delta Modulation

- In Delta Modulation, only one bit is transmitted per sample
- That bit is a one if the current sample is more positive than the previous sample, and a zero if it is more negative
- Since so little information is transmitted, delta modulation requires higher sampling rates than PCM for equal quality of reproduction

Delta Modulation

- This scheme sends only the difference between pulses, if the pulse at time t_{n+1} is higher in amplitude value than the pulse at time t_n, then a single bit, say a "1", is used to indicate the positive value.
- If the pulse is lower in value, resulting in a negative value, a "0" is used.
- This scheme works well for small changes in signal values between samples.
- If changes in amplitude are large, this will result in large errors.

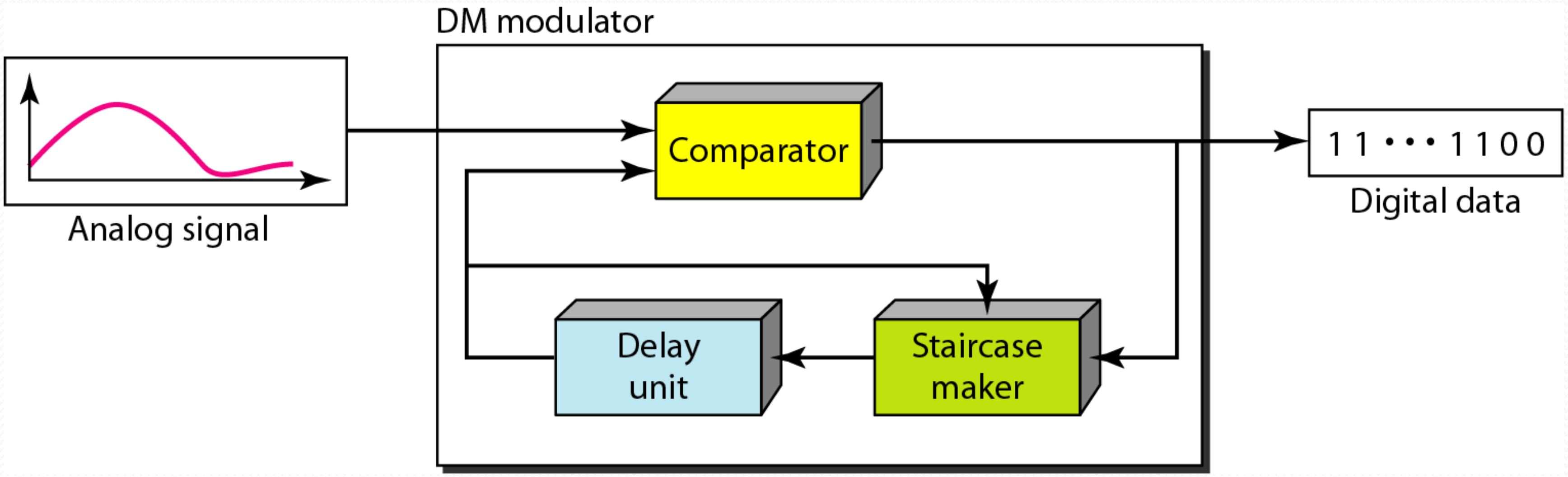
Delta Modulation



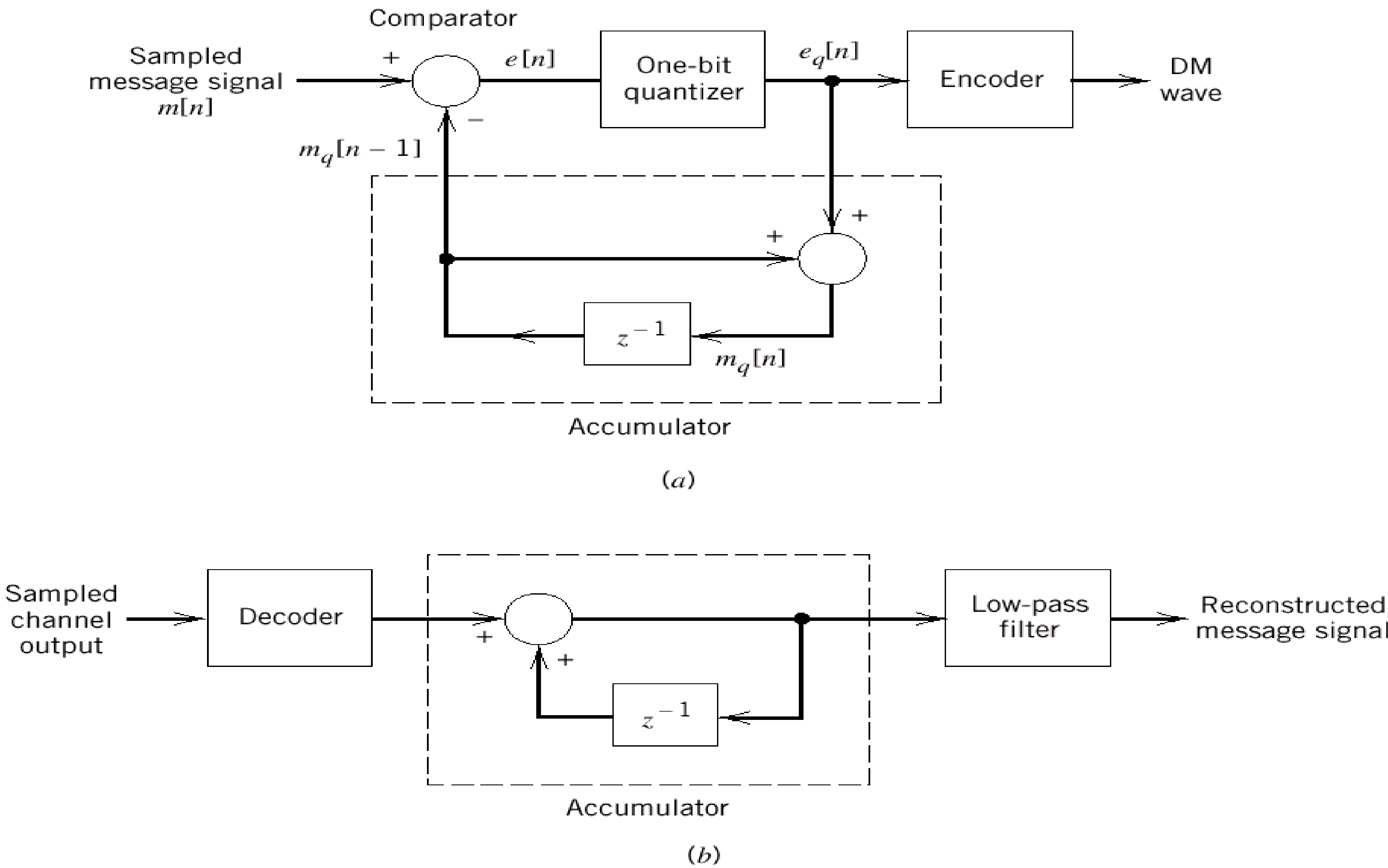
The process of delta modulation

Delta Modulation

Components of Delta Modulation



Delta Modulation



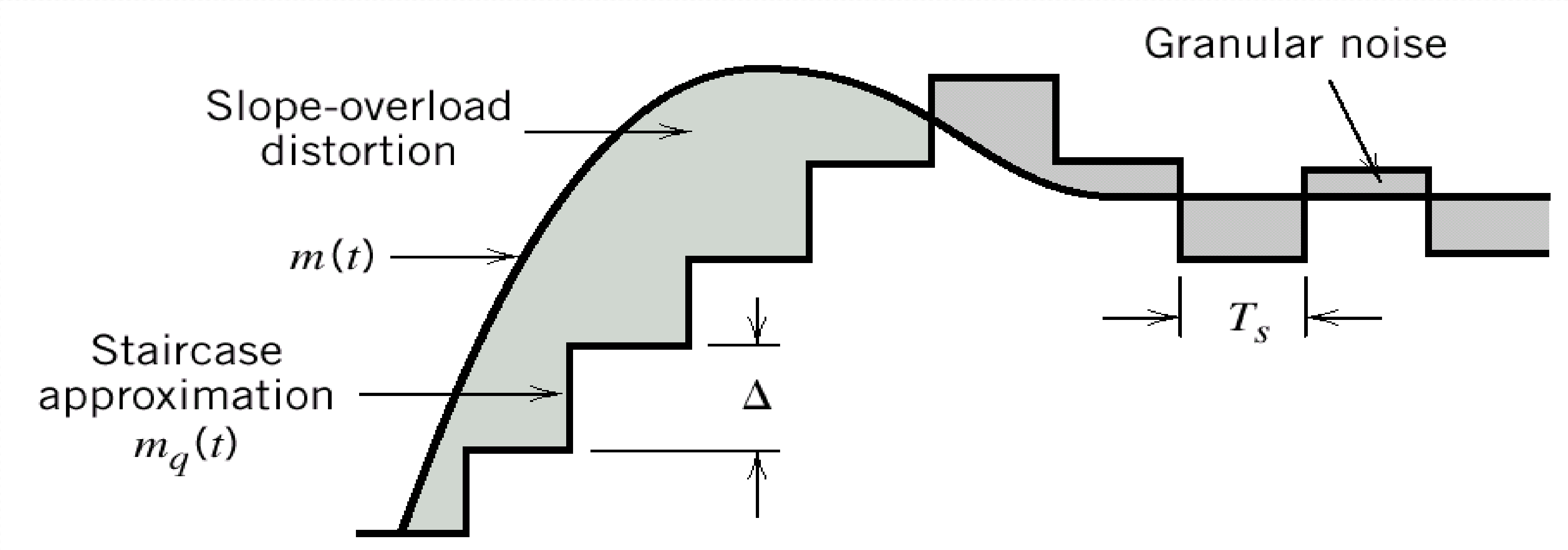
DM system. (*a*) Transmitter. (*b*) Receiver.

Delta Modulation

- Distortions in DM system

1. If the slope of analog signal is much higher than that of approximated digital signal over long duration,than this difference is called **Slope overload distortion**.
2. The difference between quantized signal and original signal is called as **Granular noise.** It is similar to quantisation noise.

Delta Modulation



Two types of quantization errors :
Slope overload distortion and **granular noise**

Delta Modulation

- Distortions in DM system

Granular noise occurs when step size ▲ is large relative to local slope m(t).

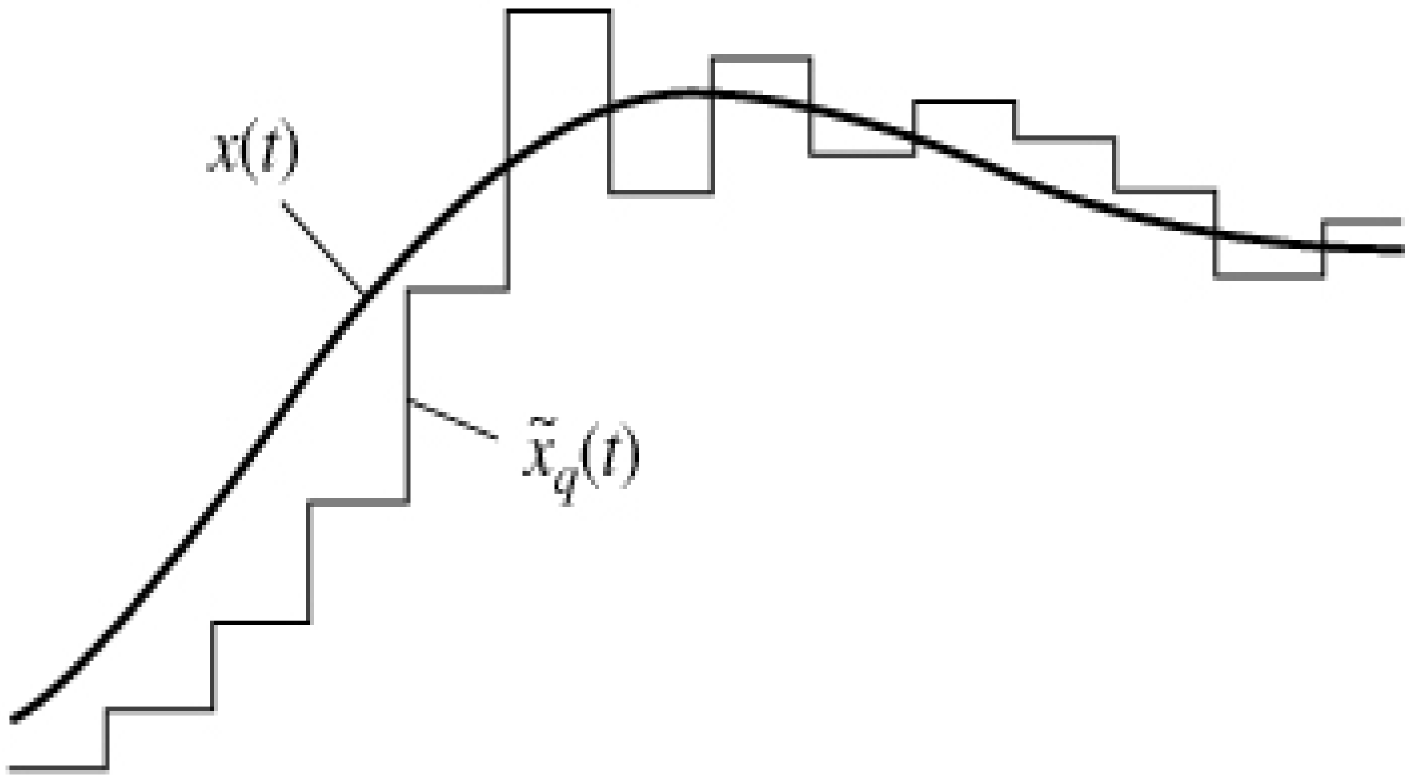
There is a further modification in this system,in which step size is not fixed.

That scheme is known as **Adaptive Delta Modulation**.

Adaptive Delta Modulation

- A better performance can be achieved if the value of ▲ is not fixed.
- The value of ▲ changes according to the amplitude of the analog signal.
- It has wide dynamic range due to variable step size.
- Also better utilisation of bandwidth as compared to delta modulation.
- Improvement in signal to noise ratio.

Adaptive Delta Modulation



Conclusion

- The main advantage of these pulse modulation schemes are better noise immunity and possibility of use of repeaters which makes communication more reliable and error free.