Practice Numericals From Text Book __/__/____

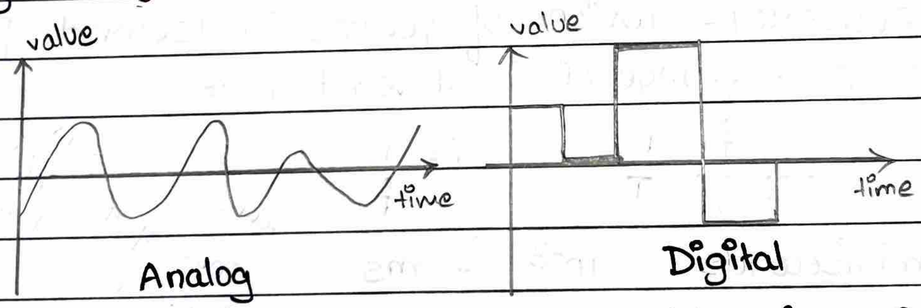
Date : 11.06.2023
Subject : Data communication and Networking
Chapter - 03 (Unit - 2)

→ Application, transport, network and data-link layers are logical.
→ communication at physical layer is physical. which means exchanging signals
→ Media have to change data to signals
→ Data & signals can be either in analog or digital form.

- Analog data - information that is continuous
- Digital data - information that has discrete

eg: Analog data - sounds by human voice
Digital data - data stored in computer memory.

- Analog signals - has infinitely many levels of intensity
- Digital signals - limited number of defined values.



pass through infinite points

sudden jump in values

- Periodic signals - completes a pattern within a measurable time frame called - period, pattern repeates
completion of one full pattern - cycle.
- Non-periodic signals - changes without exhibiting a pattern or cycle

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In data communication we use periodic analog signals and non periodic, digital signals.

PERIODIC ANALOG SIGNALS

→ Simple - sine wave
→ Composite - multiple sine waves.

SINE WAVE

→ most fundamental form of periodic analog signal
→ consistent, continuous, rolling, smooth flow
→ consists of single arc above time line & single arc below timeline.

PEAK AMPLITUDE - absolute value of its highest intensity, proportional to the energy it carries. [volts]

PERIOD - amount of time signal needs to complete 1 cycle. (seconds)

FREQUENCY - number of periods in 1second. [Hertz]
rate of change of signal w.r.t time.

$f = \frac{1}{T}$ $\quad$ $T = \frac{1}{f}$

value changes in
short span - high frequency
long span - low frequency.

- milliseconds - 10^{-3} - ms
- microseconds - 10^{-6} - μs
- nanoseconds - 10^{-9} - ns
- picoseconds - 10^{-12} - ps

- Kilo hertz - 10^3 - KHz
- Megahertz - 10^6 - MHz
- Gigahertz - 10^9 - GHz
- Terahetz - 10^{12} - THz

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conversions :

smaller unit $\longrightarrow$ bigger unit.

-ve.

bigger unit $\longrightarrow$ smaller unit

+ve.

→ signal does not change at all frequency is zero

→ signal changes instantaneously frequency is ∞

PHASE : position of waveform relative to time 0 [degrees]

$$1^\circ = \frac{2\pi}{360} \text{ rad}$$

$$1\text{rad} = \frac{360}{2\pi}$$

offset × 360 = phase in degree

WAVELENGTH

- relates the frequency of a simple sine wave to the propogation speed of the medium.

$$\lambda = c \times T = \frac{c}{f} \qquad c = 3 \times 10^8$$

Time-domain plot : changes in amplitude w.r.t time [amplitude vs time plot].

Frequency domain plot : to show relationship b/w amplitude & frequency.

- position of spike shows frequency
- height shows amplitude

→ complete sine wave in time domain can be represented by a single spike in frequency domain.

COMPOSITE SIGNALS

→ A single frequency sine wave is not useful in data - communications - [only a buzz is heard]
we need to send a composite signal - signal made up of many sine waves

Fourier analysis - composite signal is a combination of sine waves of different frequencies, amplitudes and phases.

→ Periodic - decomposition gives a series of signals with discrete frequencies and ∞ bandwidth
→ Non-periodic - decomposition gives combination of sine wave with continuous frequencies.
and ∞ bandwidth
→ Frequency of sine wave with frequency f is same as frequency of composite signals - fundamental frequency or harmonic

BANDWIDTH

→ Range of frequencies in a composite signal.
→ difference between the highest & lowest frequencies contained in a composite signal

DIGITAL SIGNALS

- number of bits per level = $\log_2 L$
  L = no. of levels.

Bit Rate : number of bits sent in 1second.
expressed in bits per second (bps)

To download 100 pages

assume : 24 lines

80 characters

8 bit / character

$100 \times 24 \times 80 \times 8$

Voice channel

4KHz - bandwidth

2 x highest frequency.

each sample = 8 bits.

$2 \times 4000 \times 8$

TV

1920 x 1080 pixels

30 times per seconds

24 bits per pixel.

$1920 \times 1080 \times 30 \times 24$

BIT LENGTH

- distance one bit occupies on transmission medium.

Bit length = c x bit duration

Digital signal as a composite analog signal → with ∞ bandwidth

→ Based on Fourier analysis.

In time domain :

vertical line = $f = \infty$

horizontal line - $f = 0$

Transmission of Digital signals.

based on

→ baseband transmission

→ broadband transmission

BASE BAND TRANSMISSION

→ sending digital signal over a channel without changing the digital signal to an analog signal.

→ requires we have a low-pass channel.

→ low-pass channel - bandwidth that starts from zero

case 1 : low-pass channel with wide bandwidth

→ to preserve exact form of non-periodic digital signal

bandpass channel takes only analog signal

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BROADBAND TRANSMISSION

→ or modulation means changing digital signal to an analog signal for transmission.

→ use bandpass channel - bandwidth that does not start from zero.

eg: sending data in computer through a telephone subscriber line.

digital cellular telephone

TRANSMISSION IMPAIRMENT

- signal at the beginning of the medium is not the same as signal at the end of medium

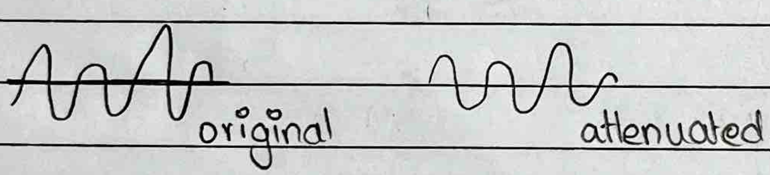
what is sent is not what is received.

Attenuation

→ loss of energy in overcoming the resistance of the medium.

→ electric wires carrying electric signals get hot.

→ to compensate for this loss, amplifiers are used



decibel - measures relative strength of two signals.

is -ve → attenuated

+ve → amplified.

$$dB = 10 \log_{10} \frac{P_2}{P_1} \quad \text{[Power]}$$

$$dB = 20 \log_{10} \frac{V_2}{V_1} \quad \text{[voltage]}$$

- loss is given as dB/Km
- On taking $10\log_{10}$ to LHS
  - → take ten first to LHS
  - → $\log_e$ will be $e^{\square}$

→ $dBm = 10\log_{10} P_m$

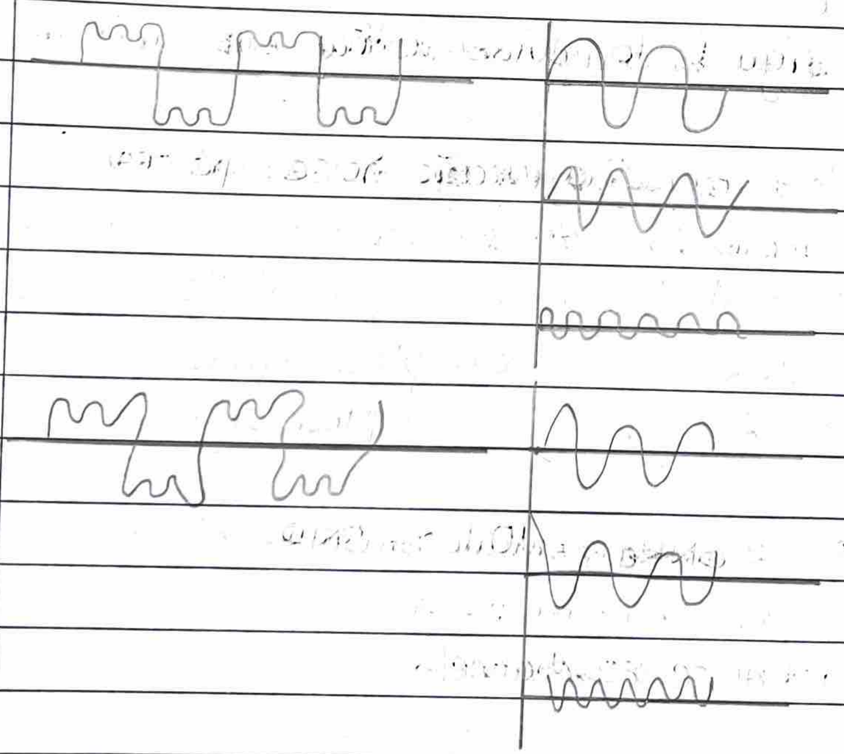
P_m = mill watts

DISTORTION

→ signal changes its form or shape.

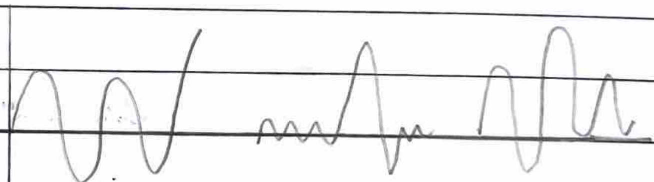
→ each signal has its own propogation speed and own delay in arriving at the destination

→ signal at the receiver has a different phase from what they had at sender.



NOISE

- thermal noise
- induced noise
- crosstalk
- impulse noise



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Thermal : is due to random motion of electrons in a wire which creates extra signals not sent by transmitter

Induced : from sources like motors or appliences devices act as sending antenna and transmission medium acts as receiving antenna.

Crosstalk : when one wire is on another wire one acts as sending antenna and other acts as receiving antenna.

Impulse : spike (high energy in short time) that comes from power lines or lightning.

SNR : signal to noise ratio

$$SNR = \frac{\text{average signal power}}{\text{average noise power}}$$

SNR :
ratio of what is wanted to what is not wanted
High SNR - less corrupted signal
low SNR - more corrupted signal

$$SNR_{dB} = 10 \log_{10} SNR$$

SNR for noiseless channel

$$SNR = \frac{(\text{signal power})}{0} = \infty$$

$$SNR_{dB} = 10 \log_{10} \infty = \infty$$

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DATA RATE LIMITS

→ how fast data can be sent, in bits per second.

→ It depends on 3 factors:

1. Bandwidth available
2. level of signals we use
3. quality of channel {level of noise}

To calculate data rate

<a> Nyquist Bit Rate for noiseless channel {levels}

$$\text{Bit Rate} = 2 \times \text{bandwidth} \times \log_2 L$$

Increasing levels of a signal may reduce reliability of the system

theorem and baseband transmission bit rates match when we have only 2 levels.

bit rate = 2 × bandwidth according to baseband transmission only if we use first harmonic.

Nyquist bit is more general and can be applied for baseband transmission and modulation.

<b> Shanon capacity for noisy channel. {upper limit}

→ In reality there is no noiseless channel.

$$\text{capacity} = \text{bandwidth} \times \log_2 [1 + SNR]$$

- data rate higher than the capacity of the channel cannot be achieved.
- formula defines a characteristics of the channel not method of transmission.

PERFORMANCE :

→ an overall measurement.

BANDWIDTH

(i) in Hertz :

Range of frequencies in a composite signal. or range of frequencies a channel can pass.

(ii) in bits per second :

also number of bits a channel, link or network can transmit.

Increase in bandwidth in hertz ⇒ Increase in bandwidth in bps.

TROUGHPUT

→ measure of how fast data can be sent

→ bandwidth is potential measurement and throughput is an actual measurement.

$$T = \frac{(\text{Frames} \times \text{bits})}{60}$$

LATENCY

- time taken for an entire message to arrive at the destination from the time the first bit is sent out.

Latency = propogation time + transmission time + queuing time + processing delay.

Propogation Time :

- time taken by 1 bit to travel from source to destination.

$$Pg\ \text{time} = \frac{\text{Distance}}{c}$$

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$$\text{Transmission Time} = \frac{\text{message size}}{\text{bandwidth}}$$

time taken by entire message to move from source to destination.

Queuing Time

→ Time needed for device to hold message before it can get processed.

Processing Delay

when message is received by intermediate node, it has to be processed.

JITTER - is also a performance issue.

BANDWIDTH - DELAY PRODUCT

→ Bandwidth × delay - maximum number of bits that can fill the link.

→ To use maximum capacity of link -

2 × Bandwidth × delay - to fill up the full-duplex channels

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Chapter - 04 {unit - 2}

part - 11.

ANALOG TO DIGITAL CONVERSION

→ analog signals - microphone or camera.

→ To change analog signal to digital data {digitization}

1. PCM - pulse code modulation
2. DM - delta modulation.

PCM - pulse code modulation.

- has 3 processes:

1. Analog signal is sampled
2. Sampled signal is quantized.
3. quantized values are encoded as streams of bits.

Step - 01 - Sampling

- analog signal is sampled every Ts seconds, where Ts is sample interval.
- Inverse of sampling interval is called sampling rate or sampling frequency.

$$fs = \frac{1}{Ts}$$

- There are 3 sampling methods.
  1. Ideal
  2. Natural
  3. Flat - top

Ideal - pulses from analog signal are sampled.
- cannot be easily implemented.

Natural - high speed switch is turned on for a small period of time, result is a sequence of samples that

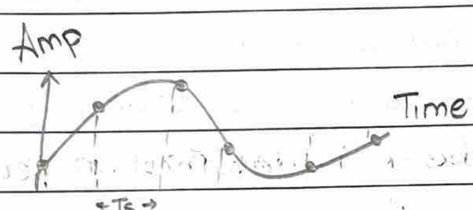
. retains shape of analog signal.
Flat top or sample and hold - using a circuit.

→ Sampling is also called as PAM - pulse amplitude modulation.

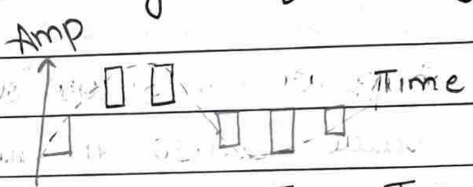
→ Acording to Nyquist theorem, sampling rate must be atleast 2 times the highest frequency of original signal.

→ sampling can be done only if signal is band - limited i.e it cannot be done with a signal having infinite bandwidth.

→ If analog signal is low pass - bandwidth is same as highest frequency.
band pass - bandwidth is lower than highest frequency.



IDEAL



FLAT-TOP

NATURAL.

Step - 02 - Quantization

→ Result of swapping is series of pulses within max. & min. amplitudes of signal.

1) → assume orignal signal has instantaneous amplitude b/w V_{max} and V_{min}

2) → Range divided into L zones, each of height Δ

$$\Delta = \frac{V_{max} - V_{min}}{L}$$

→ quantized values 0 to L-1. is assigned to midpoint of each zone.
→ approximate value of sample amplitude to quantized values.

Quantization Levels : To choice of L depends on
- range of amplitudes of analog signal
- how accurately signal needs to be recovered.

→ choosing lower values of L increases quantization error
→ more fluctuations the higher should be the value of L.

Quantization Error :
- Input values to the quantizer are real values and output values are approximated values.
- output values are chosen to be middle value, if input value is also in the middle - no quantization error.
- It changes signal to noise ratio

no. of bits per sample (nb)

$$SNR_{dB} = 6.02\,nb + 1.76\ dB$$

Uniform & Non-uniform Quantization
→ changes in amplitude occur more frequently in lower amplitudes - which uses non-uniform zones.
i.e height of Δ is not fixed.
↑ in low amplitude
↓ in high amplitude.

Non-uniform quantization can be done by
Companding. - at sender - before conversion
Expanding - at receiver - after conversion
- reduces SNR_{dB} of quantization

Step . 03 - Encoding

→ after sample is quantized and no. of bits per sample is decided, each sample to be changed to code-word

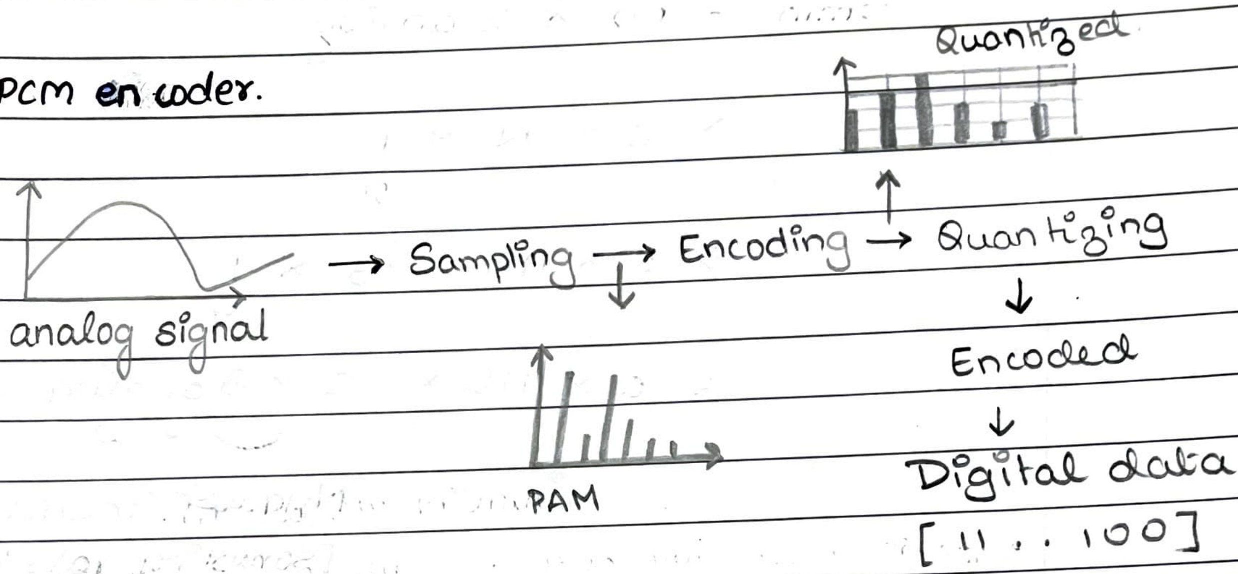
$L \rightarrow$ quantization level

$n_b \rightarrow \log_2 L$

Bit rate = sampling rate × n_b

= $f_s \times n_b$

PCM encoder.

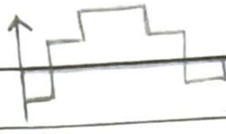


PCM decoder

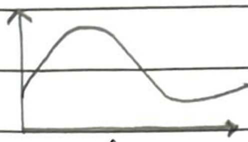
1. CIRCUITRY - convert code words into pulse-signal

2. Passed through low pass filter to smooth signal to analog signal.

→ If signal is sampled at or > than Nyquist sampling rate original signal is recreated.



11 . . . 011 digital data → Make & connect samples → low-pass filter →



analog signal

PCM BANDWIDTH

$$B_{min} = n_b \times B_{analog}$$

$$\Rightarrow c \times N \times \frac{1}{r}$$

$$\Rightarrow c \times n_b \times f_s \times \frac{1}{r}$$

$$= c \times n_b \times \underbrace{2 \times B_{analog}}_{\text{Nyquist Theorem [sampling rate]}} \times \frac{1}{r}$$

$c = 1/2$,

$1 = 1/r$ $\therefore$ $B_{min} = n_b \times B_{analog}$

$$B_{max} = 2 \times B_{analog} \times \log_2 L$$

$$= 2 \times B_{analog} \times n_b$$