PHYSICAL LAYER & MEDIA

- provide service to data link layer.
- converts 0s & 1s to signals i.e bits are encoded.
- Data rate i.e bits/sec.
- Transmission mode - simplex, half-duplex, full-duplex

SIGNALS → Analog, DIGITAL

Periodic & Nonperiodic Signal

Periodic signal completes a pattern within a mesurable time frame, called a period & repeats that pattern over subsequent identical periods. Completion of one full pattern is called a cycle.

Non Periodic signal changes without exhibiting a pattern or cycle that repeats over time.

In data communications, we commonly use periodic analog signals (∵ they need less bandwidth) & non periodic digital signals (∵ they can represent variation in data).

Period & Frequency

Period is time (taken in seconds) taken by a signal to complete one cycle.

Frequency refers to number of periods in 1 sec.

$$f = \frac{1}{T} \quad \text{OR} \quad T = \frac{1}{f}.$$

Frequency is rate of change w.r.t time. Change in short span means higher frequency. Change in large span of time means low frequency

<u>Wavelength</u> distance a simple signal can travel in one period.

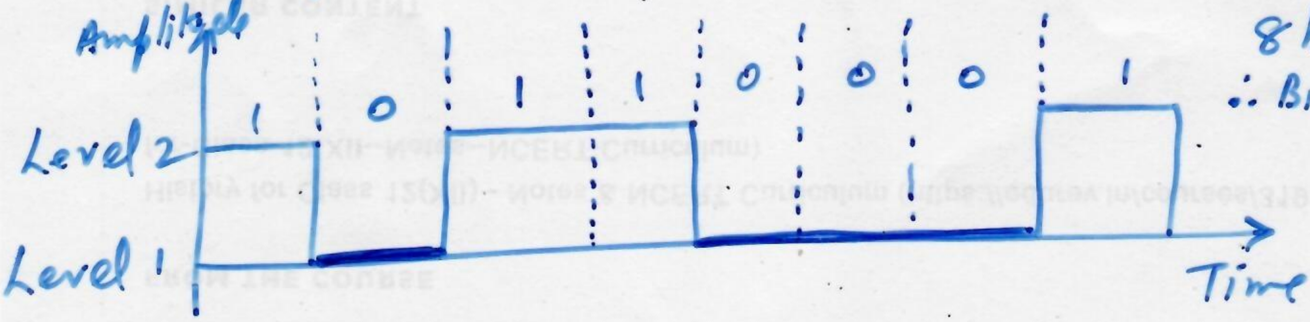
Wavelength = propagation speed × period

$= \frac{\text{propagation speed}}{\text{frequency}}$.

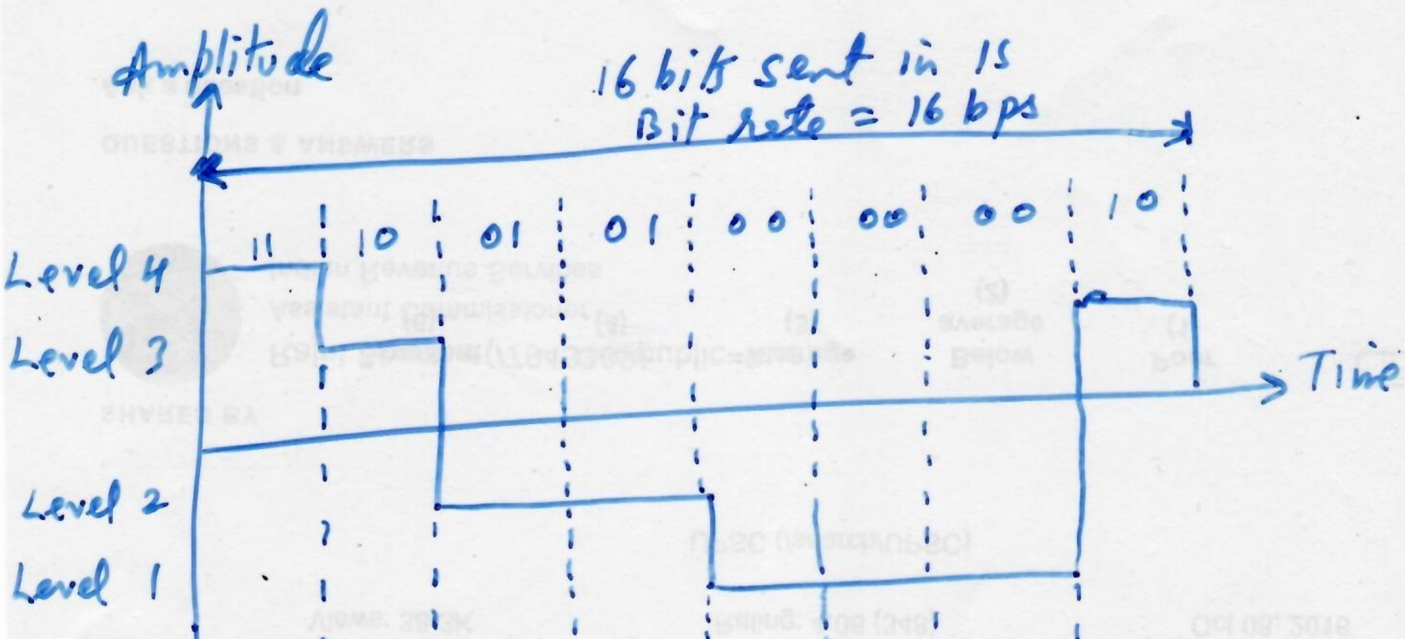
$\lambda = \frac{c}{f}$ (if propagation speed is speed of light).

<u>Bandwidth</u> is the difference between lowest & highest frequencies that a composite signal contains.

<u>DIGITAL SIGNALS</u> A digital signal can have more than 2 levels. In this case we can send more than 1 bit for each level.



8 bits in 1sec
∴ Bits rate = 8bps



We sent 1 bit per level in 1st Fig & 2 bits per level in 2nd Fig. In general if a signal has L levels, each level needs $\log_2 L$ bi[ts]

No of bits per level should be integer as well as a power of 2. If bits per level is not integer it is rounded off to next integer level. 2 19

Bit Length distance one bit occupies on the transmission medium.

Bit length = propagation speed × bit duration.

Baseband Transmission sending digital signal over a channel w/o changing digital signal to analog signal.

Broadband Transmission means changing digital signal to analog signal for transmission.

Bandwidth can be given 2 meanings

(a) Range of frequencies that a channel can pass

(b) speed of bit transmission in a channel i.e bits/s

TRANSMISSION MEDIA

- Guided
  - Twisted Pair Cable
  - Coaxial Cable
  - Fibre Optic Cable
- Unguided
  - Free space

means the way two or more communicating devices attach to a link. Two types of line configuration
8
20

1. Point to Point provides dedicated link between 2 devices. Entire capacity of channel is reserved for transmission between those 2 devices. E.g remote control of TV used for changing channels.

2. Multipoint more than 2 specific devices share a single link. Capacity of channel is shared.

TOPOLOGY implies how N/W is laid out either physically or logically. 5 possible topologies mesh, star, tree, bus & ring. Topology depends upon status of devices to be linked 2 relationships are peer to peer (where devices share the link equally) and primary-secondary (one device controls traffic & others must transmit thro' it)

Peer to Peer — Ring, Mesh
Primary-Secondary — Star, Tree
Bus topology equally convenient for both.

TRANSMISSION MODES

1. SIMPLEX Only one node can transmit & other can only receive

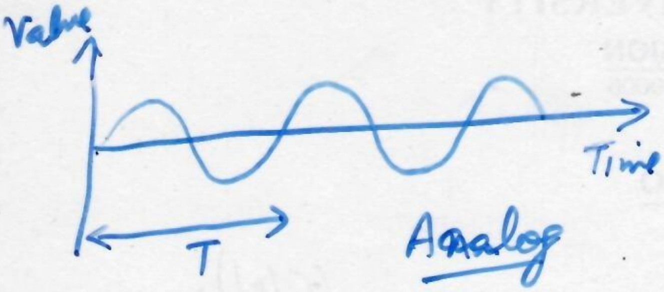
2. HALF DUPLEX Both nodes can transmit & receive but not a same time. When one device is sending other can only receive & vice-versa.

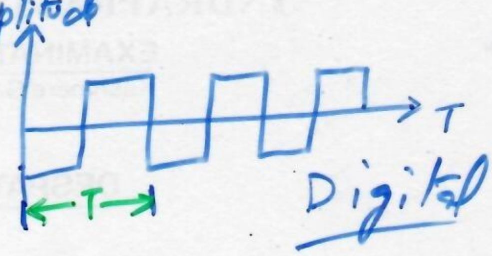
3. FULL DUPLEX Both nodes can transmit & receive simultaneously

SIGNALS 1. ANALOG (Continuous) 2. DIGITAL (Discrete)

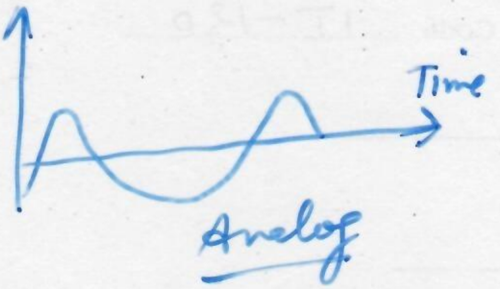
e.g human voice is analog data
e.g data in memory of computer is digital data.

PERIODIC SIGNAL which completes a pattern within a measurable time, called a period, and repeats that pattern over identical subsequent periods. Completion of one full pattern is called cycle.



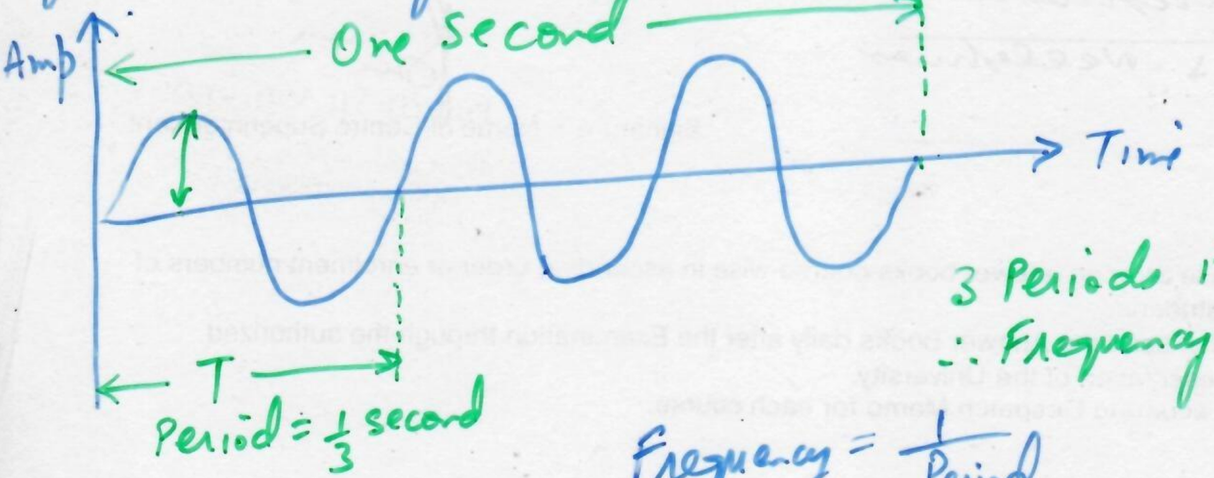


APERIODIC SIGNAL changes constantly w/o exhibiting a pattern or cycle that repeats over time.



Amplitude, Period & Frequency of a Signal

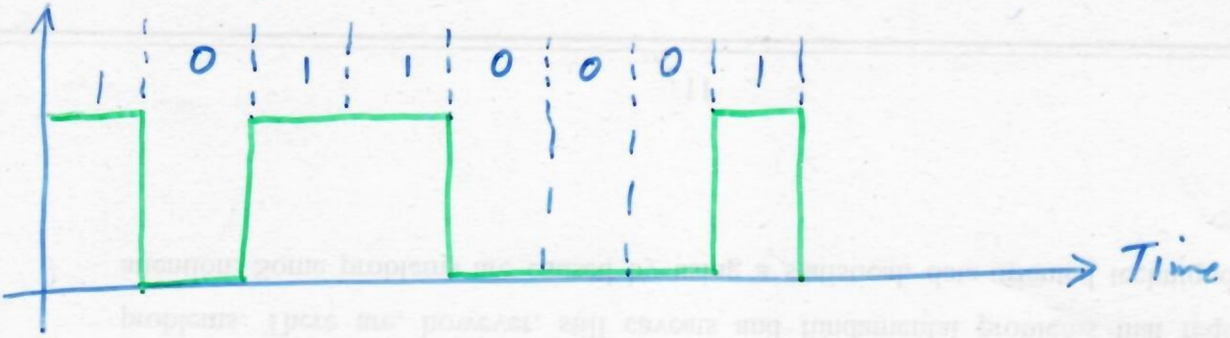
Amplitude refers to height of signal. It can be measured in volts, amperes or watts depending upon type of signal. Period means time needed by signal to complete one cycle. Frequency is number of periods per second.



3 Periods in One Second
$\therefore$ Frequency = 3 Hz

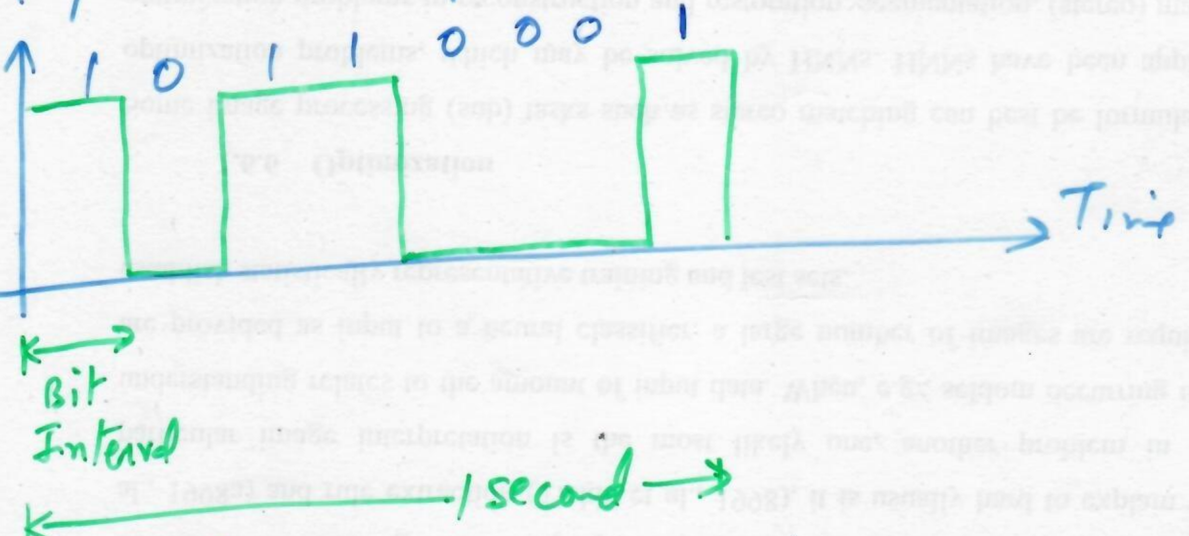
$$\text{Frequency} = \frac{1}{\text{Period}}$$

DIGITAL SIGNALS e.g 1 can be encoded as +ive signal & voltage 0 as zero voltage.



Bit Interval & Bit Rate Bit interval is the time required to send one single bit.

Bit rate is no of bit intervals per second or no of bits sent per second (bps).



1 second = 8 bit intervals ∴ bit rate = 8bps

DATA & SIGNALS Information to be sent should be transformed into signals by two nodes in agreed upon patterns of 0s & 1s for e.g using ASCII codes.

Data stored in computer to be carried to other place needs to be converted into digital signals. This is called digital to digital conversion or encoding digital data into a digital signal.

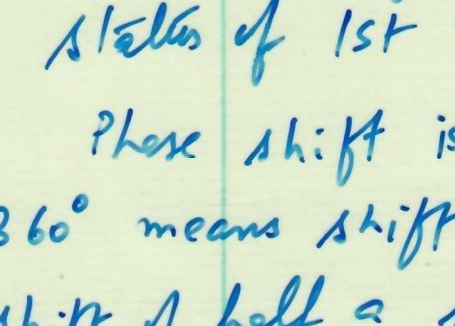
Digital signal may be reqd to be converted into analog signal for e.g sending data over public Telephone line

If a signal doesn't change at all, its frequency is zero. If a signal changes instantaneously its frequency is infinity.

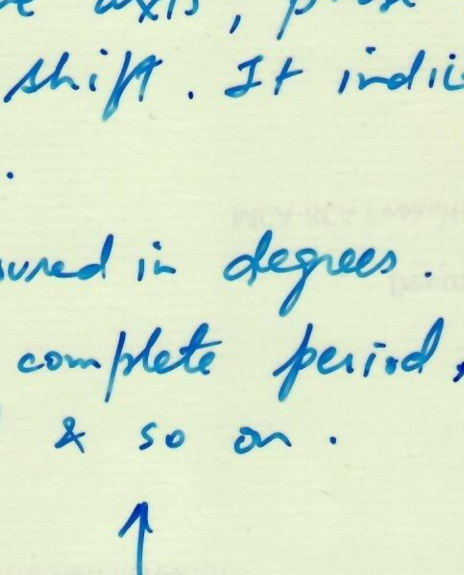
PHASE

Describes the position of the waveform relative to time zero. If we think of the wave as something that can be shifted backward or forward along the time axis, phase describes the amount of that shift. It indicates the status of 1st cycle.

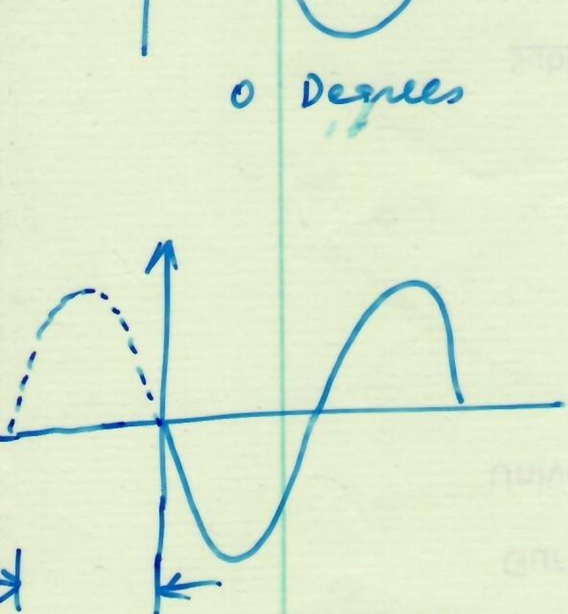
Phase shift is measured in degrees. A phase shift of 360° means shift of a complete period, 180° = shift of half a period & so on.



0 Degrees



$\frac{1}{4}$ cycle 90°



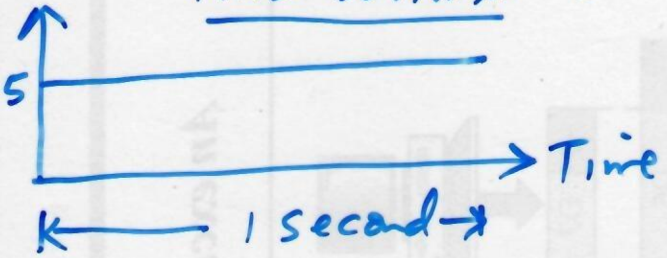
$\frac{1}{2}$ cycle 180 degrees

TIME & FREQUENCY DOMAINS

Time domain plot shows changes in signal amplitude w.r.t time. Phase & frequency are not explicitly measured on a time-domain.

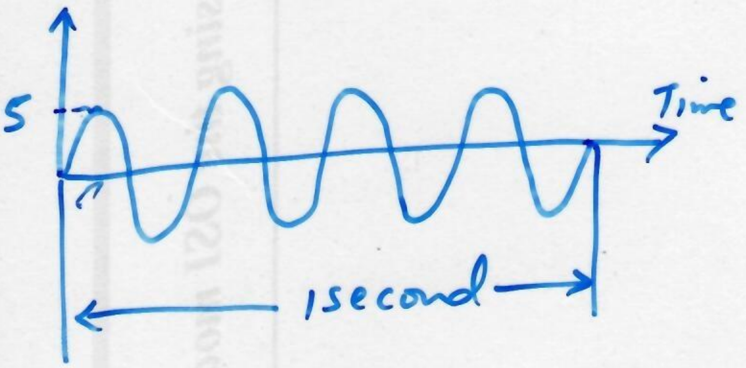
Relationship b/w Amplitude & frequency can be shown on a frequency-domain plot.

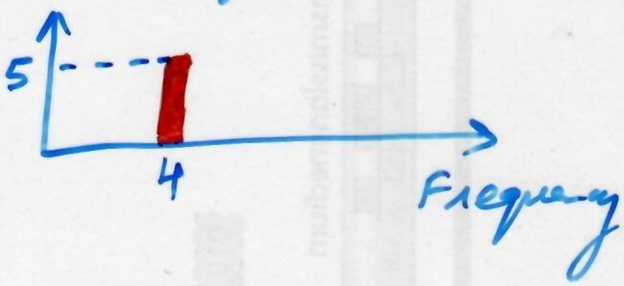
TIME DOMAIN



FREQUENCY DOMAIN

A signal with frequency zero





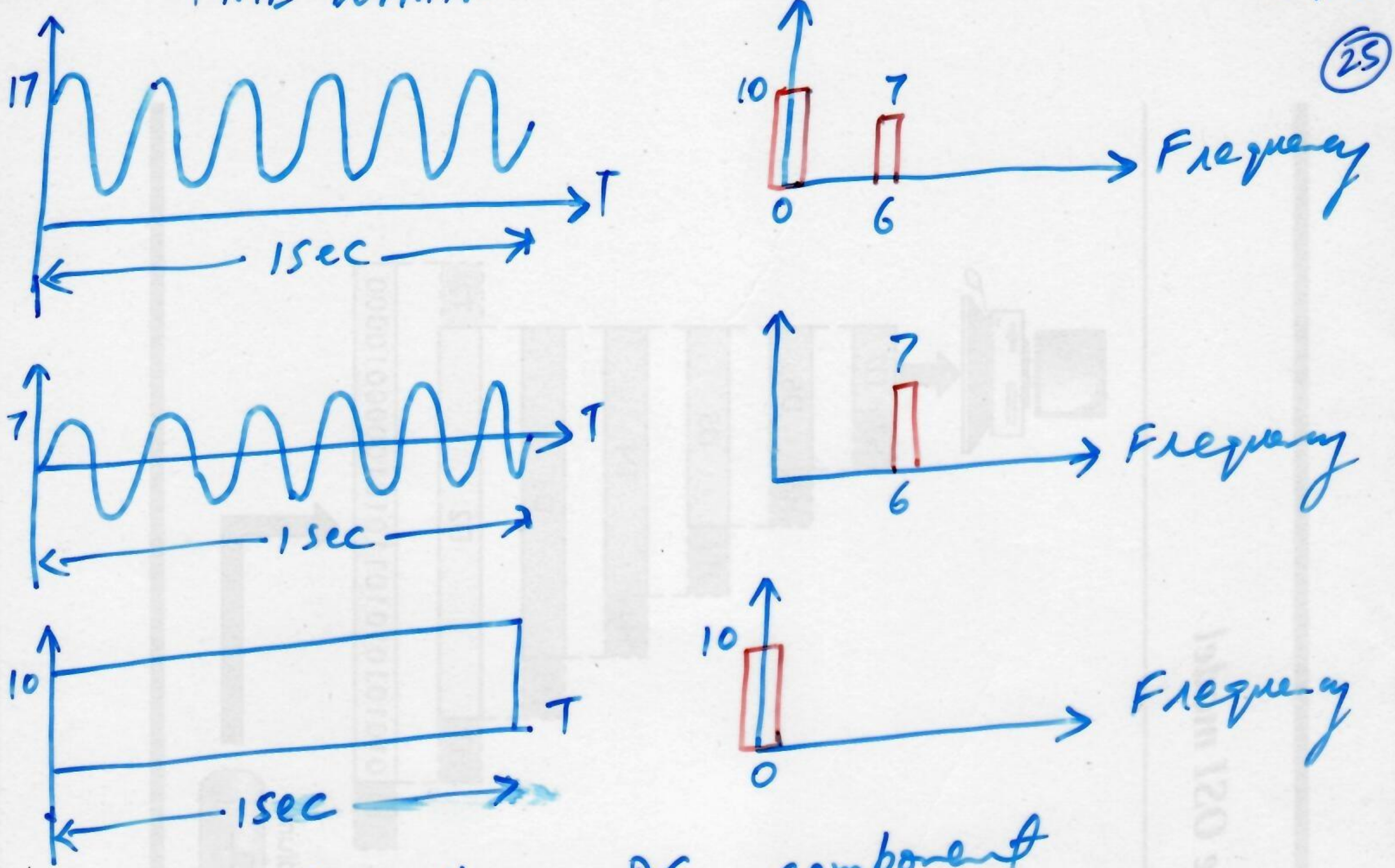
A signal with frequency 4

COMPOSITE SIGNALS

Any periodic signal, howsoever complex can be decomposed into a collection of sine waves, each having a measurable amplitude, frequency & phase.

To decompose a composite signal into its components Fourier Analysis is needed. Example of decomposition of a periodic signal is shown below

TIME DOMAIN FREQUENCY DOMAIN



A signal with a DC component

Original signal (1st one) looks like a sine wave whose time axis has been shifted downwards. 2nd & 3rd signals combined together produce the 1st signal. Average amplitude of original signal is non-zero. This factor indicates presence of a zero-frequency component, a direct current (DC) component. This DC component is responsible for 10-unit upward shift of the sine wave

Frequency Spectrum & Bandwidth

Frequency spectrum of a signal is the collection of all the component frequencies it contains & is shown using frequency domain graph.

Bandwidth of a signal is the width/range of the frequency spectrum.

Bandwidth = Highest Frequency − Lowest Frequency.

Load Allocation Even Sem Jan 2011

Sartaj Sodhi	14	IT 708 (4)	IT722(4)	IT 752(2+4)	
Ravinder Purwar	16	IT 310(CSE)(4)	IT 408(IT)(4)	IT 152(CSE)(4)	IT 458(4)
Parijat Mathur	12	IT 316(4)	EC112(4)	IT 362(4)	
Ashish Payal	8	IT 702 (4)	IT 754(4)		
Jyotsna	14	ITR 604(IT+CSE)(4)	IT 302(IT)(4)	ITR 654 (IT)/ ITR658(CSE)(2)	IT 352(IT)(4)
Reena Gupta		IT 128(IT)(4)	IT 304(IT)(4)	IT 152(IT)(4)	
M. Balakrishna	12	IT 202(IT)(4)	IT 202 (CSE)(4)	IT 252(IT)(4)	
R.L Ujwal	16	IT 206(IT)(4)	IT 306(IT)(4)	IT 256(IT)(4)	IT 354(IT)(4)
Anuradha Chugh		IT 606(4)	IT 308(CSE)(4)	IT 356(CSE)(4)	IT 652(4) GPA
Rahul Johri	14	ITR 630(IT+CSE+DUAL DEG)(4)	ITR658(IT)/ITR656(CSE)/IT554(DUAL DEG)(2)	IT 414 (CSE)(4)	IT 458(CSE)(4)
Priyanka Bhutani		IT 502(IT+CSE)(4)	IT 552(4)	IT 252 (CSE)(4)	
Kamaldeep Kaur	16	IT 206(CSE)(4)	IT 302(CSE)(4)	IT 256(CSE)(4)	IT 352(CSE)(4)
Dr.Vandana Nath	16	ITD 602(4)	ITD 654(2)	EC152(4)	ITR 628(IT+DUAL DEG)

Decomposition of a Digital Signal

A digital signal can be decomposed into an infinite sum of simple sine waves called harmonics, each with different amplitude, frequency & phase.

To receive exact replica of the digital signal, all the frequency components must be faithfully transferred thro' the transmission medium. If some components are not passed, corruption of signal occurs at receiver end. Since no practical medium (such as cable) is capable of transferring the entire range of frequencies, we always have corruption.

Therefore, we send only those components whose amplitudes are significant (above an acceptable threshold), we can still recreate the signal with reasonable accuracy (minimum distortion). We call this part of the infinite spectrum the significant spectrum & its bandwidth as significant bandwidth.

TRANSMISSION IMPAIRMENT

Three causes of impairment are
(i) Attenuation (ii) Distortion (iii) Noise

Attenuation means loss of energy due to resistance of the medium, so cables gets warm due to loss of energy in the form of heat. Amplifiers are used to amplify the signal.

Decibel (dB) measures the relative strengths of two signals or one signal at two different points. Decibel is negative if signal is attenuated & positive if signal is amplified.

$$dB = 10 \log_{10} \frac{P_2}{P_1}$$

P_2 & P_1 are powers of signals at point 2 & point 1

If terms of voltage,

$$dB = 20 \log_{10} \frac{V_2}{V_1}$$

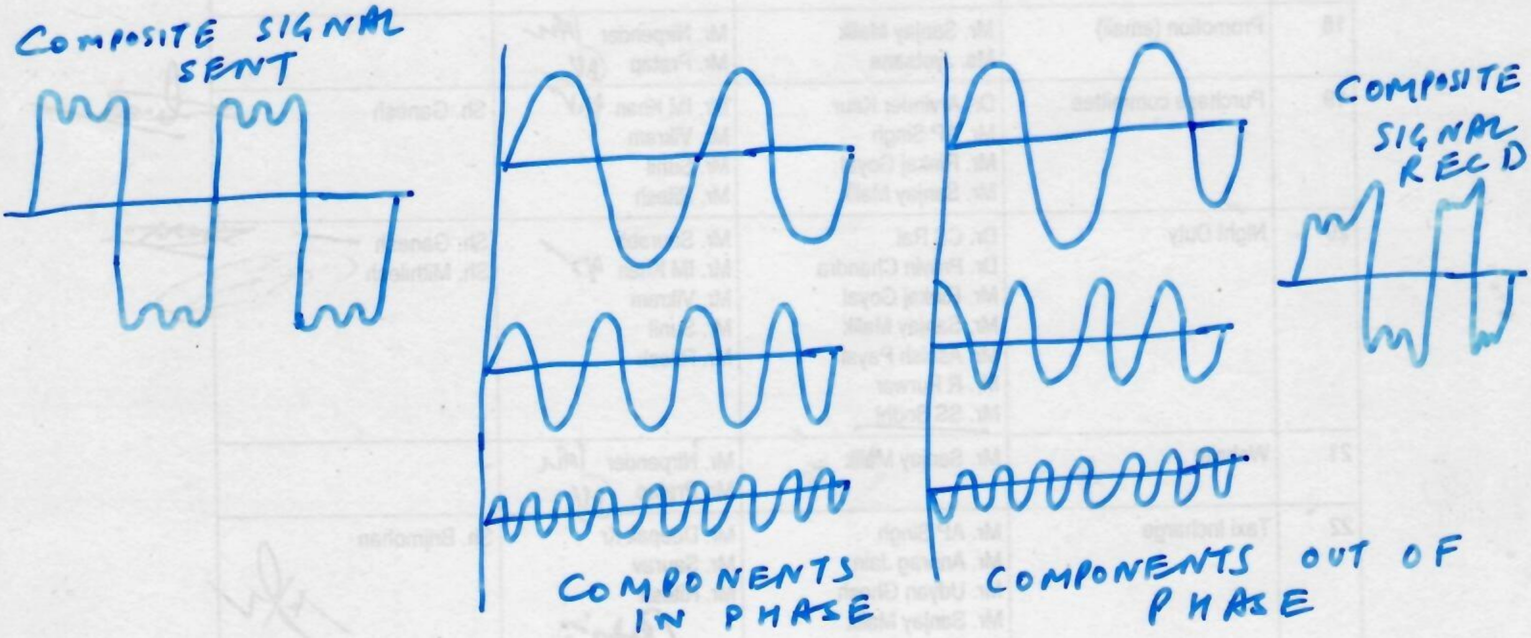
DISTORTION means signal changes its form or shape. (29)

Distortion can occur in a composite signal made of different frequencies. Each signal component has its own propagation speed thro' a medium & therefore its own delay in arriving at the final destination.

Hind 450 15 6.67
ITC 80 120

Differences in delay may create difference in phase. 50 67

In other words, signal components at the receiver have phases different from what they had at the sender. Shape of composite signal is therefore not the same.



~~NOISE~~ **NOISE**
- Thermal
- Induced
- Crosstalk
- Impulse

Thermal: random motion of electrons, creates extra signal
Induced: from motors & appliances
Crosstalk: effect of one wire on another.
Impulse: is a spike (a signal of high energy in short duration e.g lightning, power lines.

SIGNAL TO NOISE RATIO (SNR)

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

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

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

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

For NOISELESS Channel

Data Rate Limits

∴ Data rate depends upon 3 factors

1. The bandwidth available
2. The level of the signals we use
3. The quality of the channel (the level of noise)

2 Theoretical formulas were developed to calculate data rate

Nyquist developed for noiseless channel

Shannon " " noisy channel.

Nyquist bit rate $\quad BitRate = 2 \times bandwidth \times \log_2 L$

L = no of signal levels to represent data

BitRate = bit rate in ~~b.p.~~ bits/second.

Increasing bit rate by increasing levels leads to a high ability of receiver to distinguish higher no of levels.

Also, more levels reduces the reliability of the system.

NOISY CHANNEL : SHANNON CAPACITY

In reality, channel is always noisy. In 1944, Claude Shannon introduced a formula called Shannon capacity, to determine the theoretical highest data rate for a noisy channel:

$$\text{Capacity} = \text{bandwidth} \times \log_2 (1 + SNR)$$

Capacity is in bits/second.

No matter how many levels we have, we cannot achieve data rate higher than the capacity of the channel.

Formula defines characteristic of the channel, not the method of transmission.

For practical purposes, when SNR is very high we assume $1 + SNR = SNR$. Then theoretical channel capacity $C = B \times \frac{SNR_{dB}}{3}$.

PERFORMANCE

Throughput how fast we can actually send data thro' a network.

Bandwidth is potential measurement of a link

Throughput is actual measurement of how fast we can send data.

Latency (Delay) how long it takes for entire message to completely arrive at the destination from the time the first bit is sent out from the source.

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

Propagation time measures the time required for a bit to travel from source to destination.

$$\text{Propagation time} = \frac{\text{Distance}}{\text{Propagation speed}}$$

Propagation speed depends upon medium and frequency of signal.

Transmission Time Time between 1st bit leaving the sender & last bit arriving at the receiver.

$$\text{Transmission Time} = \frac{\text{Message size}}{\text{Bandwidth}}$$

Queuing Time Time needed for each intermediate device or end device to hold the message before it can be processed.

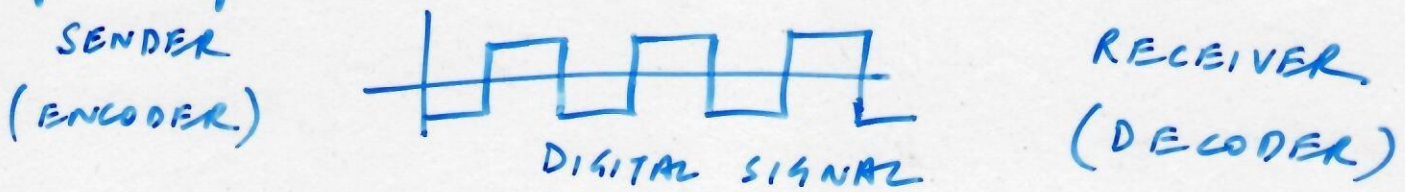
Bandwidth - Delay Product defines the no of bits that can fill the link.

Sender should send burst of (2 x bandwidth x delay) bits
Sender then waits for ACK for part of burst before sending other burst.

2 x bandwidth x delay is the no of bits that can be in transition at any time.

Jitter If different packets encounter different delays & the application using the data at the receiver site is time-sensitive (audio & video data).

LINE CODING process of converting digital data to digital signals.



Data Rate versus Signal Rate

Formula for relationship b/w data rate & signal rate should consider 3 cases : worst, best & average.

Worst case → max signal rate
Best case → min signal rate

In data communications, we are usually interested in average case.

$$S = c \times N \times \frac{1}{r} \text{ baud}$$

N → data rate in bps
c → case factor, which varies for each case
S → No of signal elements
r = $\frac{\text{No of data elements}}{\text{No of signal elements}}$

Baud rate determines the required bandwidth for a digital signal.

Minimum bandwidth can be given as

$$B_{min} = c \times N \times \frac{1}{r}$$

$$N_{max} = \frac{1}{c} \times B \times r$$

<u>Baseline Wandering</u> In decoding a digital signal, the receiver calculates a running average of the received signal power. This average is called the baseline. The incoming signal power is evaluated against this baseline to determine the value of the data element. A long string of 0s or 1s can cause a drift in the baseline (baseline wandering) & make it difficult for the receiver to decode correctly. A good line coding scheme needs to prevent baseline wandering.

<u>DC Components</u> when voltage level in a digital signal is constant for a while, the spectrum creates very low frequencies. These frequencies around zero called DC (direct current) components, present problems for a system that cannot pass low frequencies. For e.g a telephone line can't pass frequencies below 200 Hz.

<u>Self Synchronization</u> To correctly interpret the signals received from the sender, the receiver's bit intervals must correspond exactly to the sender's bit intervals. If receiver clock is faster or slower, the bit intervals are not matched & the receiver might misinterpret the signals.

Sender sends 10110001, receiver receives 11011100011

A self synchronizing digital signal includes timing information in the data being transmitted. This can be achieved if there are transitions in the signal that alert the receiver to the beginning, middle, or end of the pulse.