J.S. Stalings
Foragen

DCCN

17/08/22
L-2

Module - 1

AR: Basic Communication Model

Source → T_x → Transmission System → R_x → Destination

eg. → Work St.ⁿ (S) → Modem → Telephone N/W → Modem → W.S. (D)

→ Commⁿ system has 5 components:
1. Message
2. Sender
3. Receiver
4. Protocol
5. Transmission Medium.

→ The effectiveness of data communication system depends on 3 fundamental characteristics:-
1. Delivery – Whether the receiver has successfully received mssg or not.
2. Accuracy – ~~[illegible]~~ The transmitted mssg must be received exactly.
3. Timeliness – Mssg must be received within a given time.

AR: Communication Task

1. Tr. System Utilization
2. Interfacing
3. Signal Generation.
4. Exchange Management
5. Error Detection & Correction
6. Flow Control
7. Addressing
8. Synchronization
9. Routing
10. Recovery

11. Message Formatting
12. Security
13. Network Management.

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L-3 AR: Key elements of a Protocol

1. Syntax - The str. or format of data.
2. Semantics - Refers to the meaning of each section of bits.
3. Timing - When to transmit data and how fast it can be transmitted.

AR: Protocol Characteristics

1. Direct & Indirect - In direct; the entities are connected directly. In indirect they use shared n/w.
2. Monolithic & Structured - The protocols used in intercom can be monolithic.
3. Symmetric & Assymmetric - Protocols b/w same kind of entities are symmetric (b/w peers).
4. Standard & Non-standard - Protocol made for specific situations is called non-standard.
   Eg. → Rules for online exams → non-standard.

AR: Protocol Func^n Categories:

1. Segmentation & Assembly: Breaking a single mssg into smaller units and then assembling those units ~~into~~ to generate the mssg.
2. Encapsulation: Adding control information to each chunk of data ~~packet~~ is called enc., ~~B~~ Chunk + CI = Protocol Data Unit

CI = Address + Error Detection Code + Protocol Control

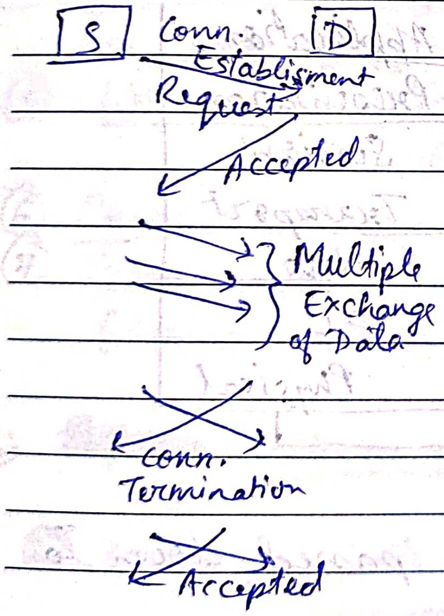
~~(2) Connection Control~~

~~Adv. of Reassembly: • The comm. N/w may only accept~~

Adv. of Seg. & Reass.: • Diff. comm. N/w has a limitation of carrying the data that means it can accept only a certain block of data.
• Easy to detect the error.
• In case of error, only a small part of data needs to be retransmitted.
• The buffer size of the source & dest. is reduced.

Disadv: • Overhead (CI) will be more if the PDU size is smaller.
• Arrival of PDU at dest. causes interrupt. More the no. of PDUs, more is the no. of interrupts.
• Smaller the size, more will be the time taken for segm. & reass.

(3) Connection Control: Connection Oriented and Connection less.



Conn. Oriented

In conn. less: • Delivery not guaranteed
• Ordered delivery " "
• Retransmission of data packet " ".

23/08/22 Tue L-4 C-O mode, C-L mode

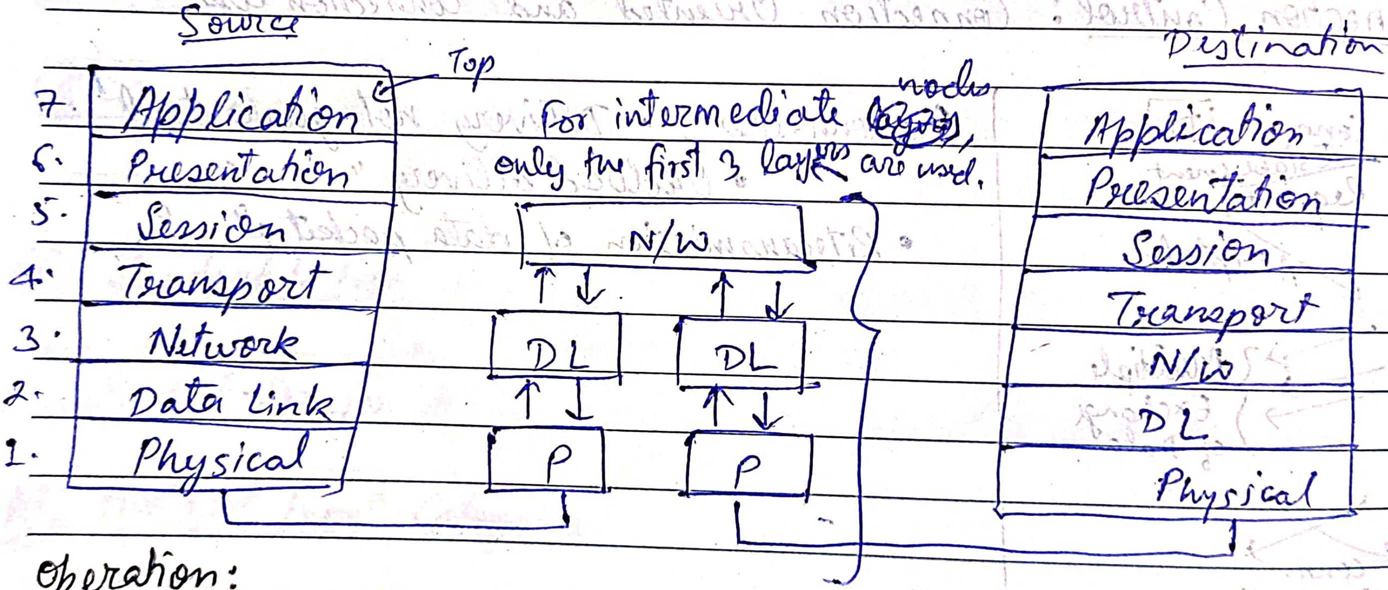
(4) Ordered Delivery: Unique seq. no. is assigned to each and every PDU in both, connection-oriented and connectionless modes.

(5) Flow Control: Acknowledgement (Mechanism to check)
(6) Error Control: error detection code.
(7) Addressing: For C-O mode, network/connection address.
For C-L mode, global add.

(*) Connⁿ identifier: In CO mode, a particular path is chosen and a no. is assigned to that path, called connⁿ identifier. Whenever the same source and destⁿ are there, the same connection identifier is used. It reduces the overhead.

(From Forogen Book)

AR: OSI Model (Open-System Interconnection) (ISO Model)



Operation:
Message is generated at app. layer and the passed down to the layer below it.
Presentation layer appends the CI.

Peer-to-Peer process :- Equivalent

Headers & trailers: If the CI is appended at the beginning then it's called header.

Layer → 2 to 6 append headers
Layer 2 → Trailer and header.

The 7 layers can be divided into 3 layers:-
1. User support layer. → Layer 5-7
2. N/w Support layer → 1 to 3
3. Transport layer → 4

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1. Responsibilities of Physical Layer:

1. Physical characteristics of interfaces & media.
2. Representation of bits.
3. Data Rate
4. Synchronization of bits → Both the transmitter and the receiver are equipped with a ~~synchroniser~~ timer.
5. Line configuration. → Point to point (dedicated) or multi-point.
6. Physical Topology
7. Transmission mode → Simplex (FM Radio), Half-duplex (Walkie-Talkie), Duplex (Mobile Phones).

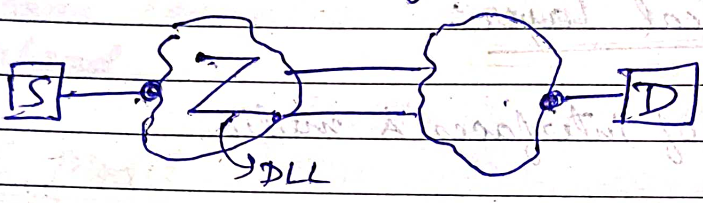
2. Functions of DL Layer :

1. Framing → Data received by the N/w layer is further divided into managable parts.
2. Physical addressing →

* **DL Layer** is responsible to carry the packet from one node to another node within the same N/w. It is called Physical Addressing.

* **N/w Layer** is responsible to carry the ~~message~~ packet from the source node to the destⁿ node without establishing any relationship b/w the packets of the same msg. Logical Add.

* **Transport Layer** is responsible to carry the entire msg. from the source entity to the destⁿ entity. It ~~maintains~~ establishes a relation b/w the diff. packets of the same msg. This is called Service-Point Addressing.



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3. Flow Control
4. Error Control
5. Access Control.

3. **Funcⁿ of N/w Layer:**

1. Logical Addressing
2. Routing

4. **Funcⁿ of Transport Layer:**

1. Service-Point Addressing. – It carries the msg to the particular port or application for which it is sent.

(2) Segmentation & Reassembly – This layer reassembles the packets ~~and delivers the msg to the particular port at~~ at the destn & divides the msg into packets at the source.

(3) Connection Control – Decides whether the connection will be CO or CL.

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(4) Flow Control – End to end flow control.

(5) Error Control.

5. Session Layer : Used to establish, sychronize, maintain the connection b/w the entities.

1. (Network Dialogue Controller) : Allows S & D entities to enter into a dialogue, either in half-duplex, simplex or full duplex mode of commn.

2. Synchronization : It allows a process to add checkpoints (synchronisation points).

6. Presentation Layer : Related to syntax & semantics of the info exchanged b/w ~~the~~ S & D.

1. Translation :

2. Encryption : It encrypts the data for security purposes.

3. Compression : It reduces the size of the msg.

7. Application Layer :

1. Network Virtual Terminal : Software version of the physical terminal. Makes us feel as if we are using a very high speed computer.

UDP → User Defined Protocol
FCS → Frame Check Seq.

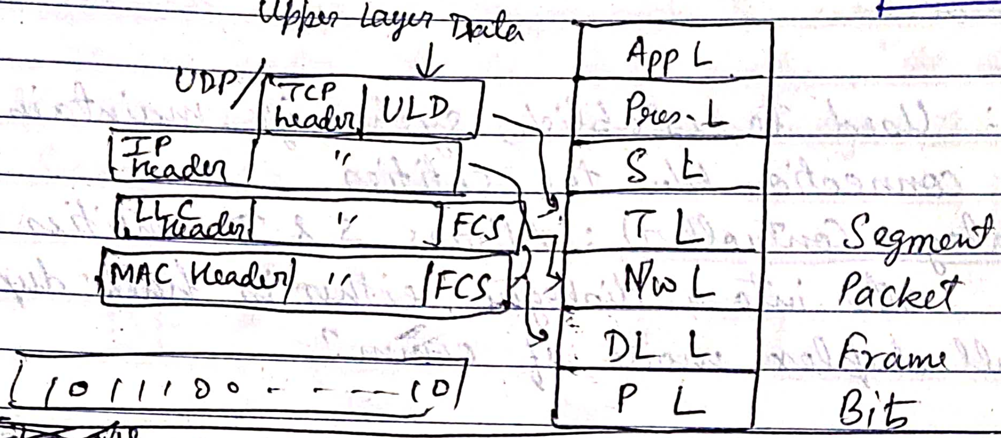
2. File Transfer Access and Management (FTAM)

3. Mail services : Mail forwarding & storage.

4. ~~Directory~~ Directory service - Contains the metadata,

AR: Data Encapsulation

Top-Down approach at S.
Bottom-Up " " D



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AR. TCP/IP

App. L	App. L
Pres. L	
S L	
T L	T L
N/w L	Internet
DL L	N/w Access
Phy L	~~Interface~~ Physical

} or just N/w Interface layer

1. Roles of Transport Layer

TCP :

1. Connection-oriented protocol
2. Flow control → Reliable data transfer
3. Error Control
4.

UDP:
① Connection less protocol
② Provides unreliable data service, bcoz if any packet is lost
③ during the Transmission, it won't be retransmitted.

2. Roles of Internet Layer : Same as N/w layer of OSI.

AR: Data Transmission

1.) Guided Media : The path is fixed, and the packets are transmitted along a physical media called guided media (within bandwidth of the guided media)
Eg. → Optical Fibre, Twisted Pair cables, Co-axial Cables.

2.) Unguided Media : Transmitted with electromagnetic waves without guided media.
Eg. → Satellites, Line of sight.

3.) Direct Link : The signals travel directly from the sender to the receiver without any intervening agents, other than amplifiers and repeaters.

4) Point-to-Point : (Direct link) ~~Direct Links~~ Only 2 devices share the link.

5) Multipoint : More than 2 stations share the link.

6 → 8) Simplex, half-duplex, Duplex.

For periodic signals, $\boxed{s(t+T) = s(t)}$

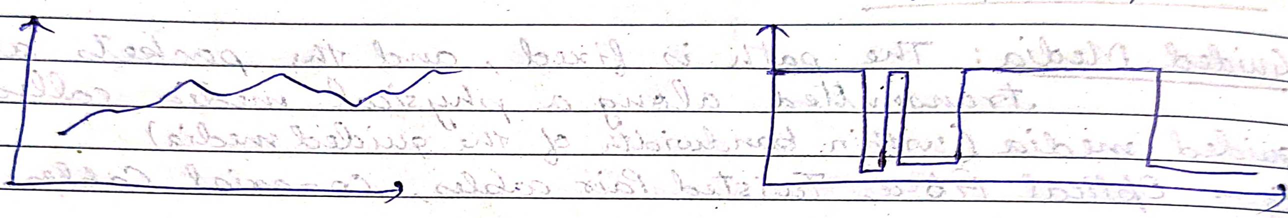
Frequency / Spectrum / Bandwidth

EM

Time Domain Concept: Viewed as a fn of time, any signal can be continuous or discrete.

In continuous, the signal strength varies continuously in a smooth fashion w.r.t. time without any break or discontinuity.

In discrete, the signal intensity is maintained for some time, then varies, and the interval may or may not be fixed.



Periodic: If the same signal pattern repeats over time.

A sine wave is a fundamental periodic signal. It is represented by 3 parameters:
- Amplitude (Strength of signal)
- Frequency (Cycles per unit time)
- Phase

$$\boxed{s(t) = A \cdot \sin(2\pi f t + \phi)}$$

$$\boxed{s(t) = \frac{4}{\pi}\left(\sum_{k=1,\text{odd}}^{\infty} \frac{\sin 2\pi k f t}{k}\right)}$$

Frequency Domain Concept:

$$\boxed{s(f) = \frac{4}{\pi}\left(\sin(2\pi f t) + \frac{1}{3}\sin(2\pi(3f)t) + \frac{1}{5}\sin(2\pi(5f)t) + \cdots\right)}$$

Any signal is made up of many frequencies.

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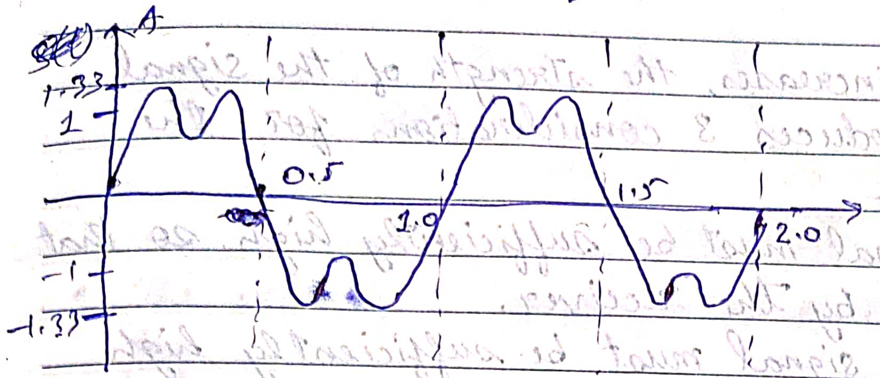
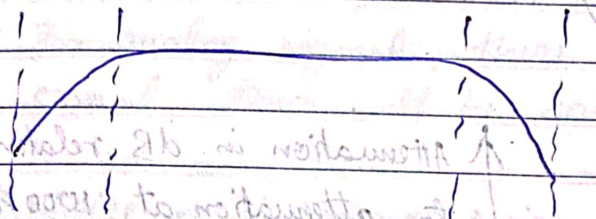
⊛ The second frequency is the integral multiple of the 1st freq. and the 1st freq. is called the fundamental freq.



Spectrum of a Signal:



$\boxed{\text{Absolute B.W.} = \text{Max}^m f - \text{Min}^m f}$
↳ also called width

→ ABW = 13 − 1 = 12f
→ E.BW = 11 − 3 = 8f

Sometimes, most of the energy of a signal lies within a certain range of spectrum. This B.W. is called effective spectrum.

AS ⟷ AD
DS ⟷ DD

AS AD ⟶ Amplifiers used
AS DD ⟶ Repeaters used
DS AD
DS DD

Amplifiers ~~also~~ amplify the noise also along with the signal.

Repeaters don't amplify the noise, instead they generate a new signal (noise-free).

→ The signal transmitted is not received exactly as it is due to Transmission impairements.

AR: Transmission Impairments

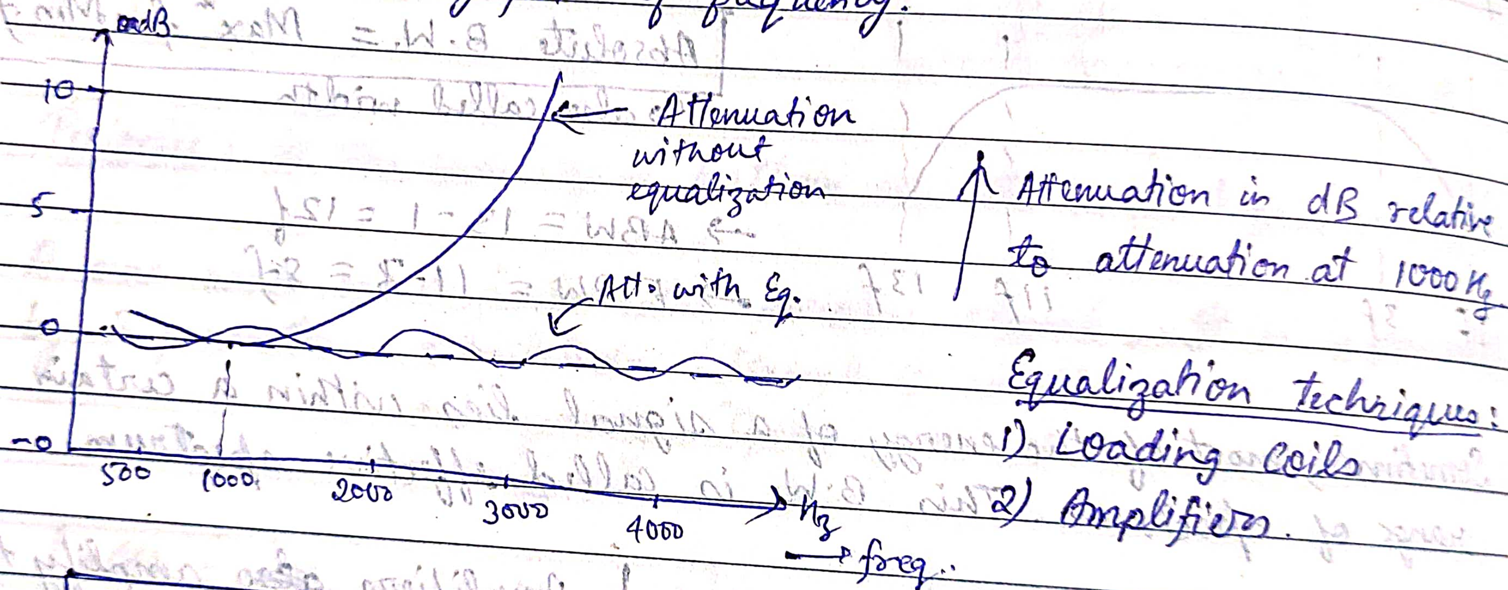
1.) Attenuation 2.) Delay Distortion 3.) Noise

1.) **Attenuation**: As the dist. increases, the strength of the signal decreases. It introduces 3 considerations for the transmission engineers:-

a) The strength of the signal must be sufficiently high so that it can be easily detected by the receiver.

b) The strength of the actual signal must be sufficiently high w.r.t. noise so that the signal can be received by the receiver without any error.

c) It is an increasing fun. of frequency.



Equalization techniques:
1) Loading Coils
2) Amplifiers.

$$\boxed{N_f = -10 \log_{10} \frac{P_f}{P_{1000}}}$$

P_f → Power level at f Hz

N_f = Attenuation at f Hz rel. to attenuation at 1000 Hz.

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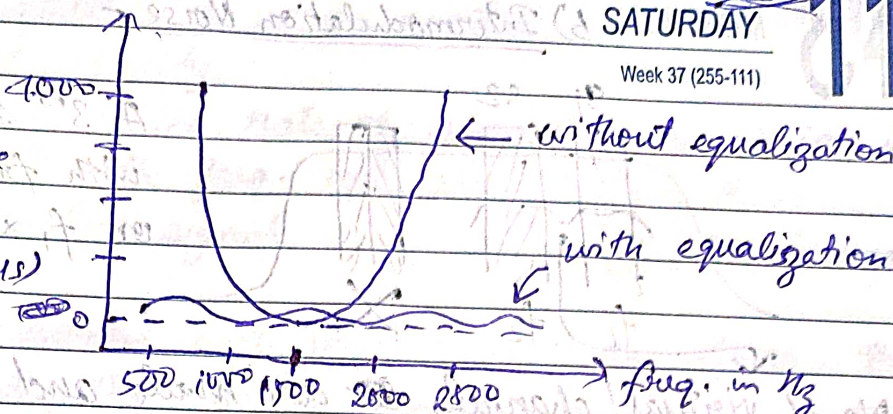
2.) Delay Distortion:



- The velocity of propagation of EM waves varies with the freq.
- The velocity is max^m at the centre and it reduces towards the edge.
- This is more prevalent in guided media.
- For analog signal, there will be phase shift & for digital signal, there will be spilling of one bit over another.

3.) Noise :- a) Thermal Noise b) Intermodulation Noise
c) Cross talk d) Impulse Noise.

➤ Any unwanted signal mixed with the actual signal.

a) Thermal Noise - Also known as white noise. It is due to thermal agitation of e^- (heat generated by the e^-s). It can't be eliminated. Hence called white noise. It is uniformly distributed throughout the spectrum.

The amount of thermal noise in a bandwidth of 1Hz in any device or conductor is $\boxed{N_0 = kT}$ watts/Hz, where N_0 = noise power density per Hz of the bandwidth,

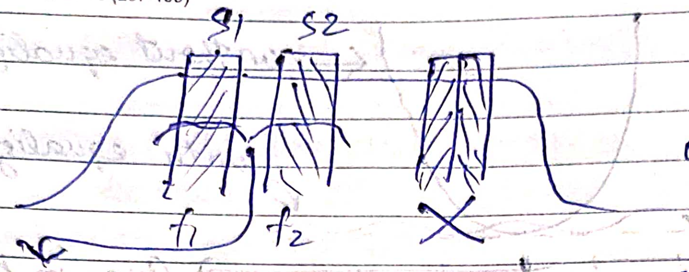
k = Boltzmann Constant = 1.3803×10^{-23} J/K, T = Temp. in K

The thermal noise present in a bandwidth of b Hz is $\boxed{N_b = bKT}$ watts

or $\boxed{N = 10 \log_{10} (bKT)}$ dB

Talk about Analog signals → Bandwidth
Digital signals → Data Rate

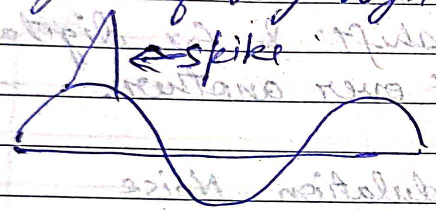
b) Intermodulation Noise –



A 3rd signal is generated with freq: $f_1 + f_2$ or $f_1 - f_2$ or $f_1 \times f_2$.

No. of virtual channels are made and safeguard is maintain (Gaps), thus avoiding the noise.

d) Impulse Noise – Due to EM disturbances like thundering. The actual signal may picks up a very high energy signal of very high intensity for a very short duration.



It mainly affects conductors like twisted pair, co-axial cable & not the insulators like fibre optic cables.

c) Cross Talk: ~~Coupl~~ Coupling of Paths

AR. Channel Capacity

→ The max^m data rate that can be transmitted over a given path in a given condition.

1) Data Rate : How fast the data can be transmitted (bits per s)
2) Bandwidth : Higher is the data rate, higher is B.W.
3) Noise : It is always considered avg. lvl of noise
4) Error Rate : Higher is the data rate, higher is the error rate

Bandwidth of transmission media is fixed.

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~~Shannon had assumed~~

Nyquist Channel Capacity:-

→ Nyquist states that if the rate of signal transmission is 2B, then a signal with freq. not greater than B is sufficient to carry the signal. $\boxed{C = 2B}$ bits/sec.

~~or, for a given Bandwi~~ with multi-level signalling, the Nyquist formula for the channel capacity is

$$\boxed{C = 2B \log_2 M} \text{ bps}$$

Shannon Channel Capacity:-

→ Shannon has considered data rate, noise & error rate. If the data rate is high, the duration of the bits (life of bit) will be short, or, higher the data rate, higher will be the error rate.

$$\boxed{\underset{\text{(Signal to Noise Ratio)}}{(SNR)_{dB}} = 10 \log_{10}\left(\frac{\text{Signal Power}}{\text{Noise Power}}\right)}$$

$$\boxed{C = B \cdot \log_2 (1 + SNR)} \text{ bps}$$

Q Calculate the channel capacity & no. of signalling levels req. if the spectrum of a channel is b/w 3 MHz & 4 MHz & SNR is 24 dB.

→ ~~Bandwidth B=~~ $SNR_{dB} = 24 = 10 \log_{10} SNR$

$\Rightarrow SNR = 251$

$\therefore C = 10^6 \times \log_2 (252) = 8 \text{ Mbps} \Rightarrow 2 \times 10^6 \log_2 M = 10^6 \log_2 252$

$\Rightarrow M = (252)^{1/2} \approx 16$

Expression of E_b/N_o :

Ratio of signal energy per bit to the noise power density per Hz determines the digital data rate & error rate.

Consider a signal, either digital or analog, carrying digital data, transmitted at a bit rate 'R'. The energy per bit in a signal is given by: $\boxed{E_b = S \cdot T_b}$

where, S = Signal Power, T_b = Time req. to send 1 bit. $\Rightarrow R = 1/T_b$

$$\therefore \boxed{\frac{E_b}{N_o} = \frac{S/R}{k \cdot T} = \frac{S}{k \cdot T \cdot R}}$$

$$\boxed{\left(\frac{E_b}{N_o}\right)_{dB} = 10 \log_{10}\left(\frac{S}{k \cdot T \cdot R}\right)}$$

As the data rate 'R' increases, the transmitted signal power relative to noise must be increased to maintain the required ~~data rate~~ E_b/N_o.

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Module - 2

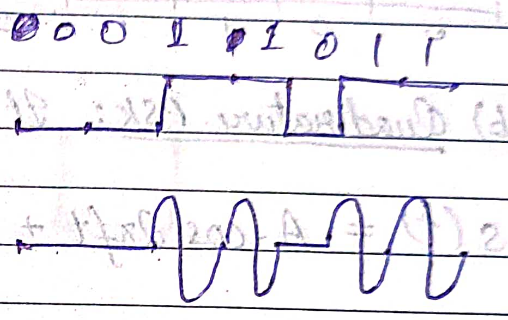
AR: Data Encoding

1.) Digital Data, Analog Signals

→ ASK (Amplitude Shift Keying): The 2 binary values 0 & 1 are represented by 2 different amplitudes of the carrier freq^n keeping freq. & phase constant. Commonly, 1 amplitude is 0.

$$s(t) = \begin{cases} A \cdot \cos 2\pi f_c t & \rightarrow \text{binary } 1 \\ 0 & \rightarrow \text{binary } 0 \end{cases}$$

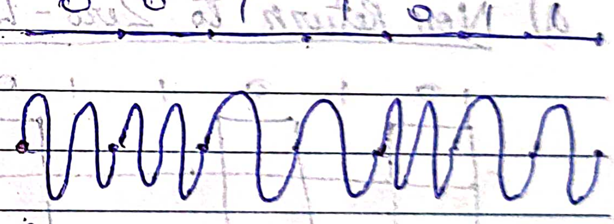
= AS =



→ Frequency Shift Keying (FSK): The 2 diff. binary values 0 & 1 are represented by 2 diff. frequencies near the centre frequency by equal and opposite amount, keeping phase & amplitude as constant.

$$s(t) = \begin{cases} A \cos 2\pi f_1 t & \rightarrow \text{binary } 1 \\ A \cos 2\pi f_2 t & \rightarrow \text{binary } 0 \end{cases}$$

AS =



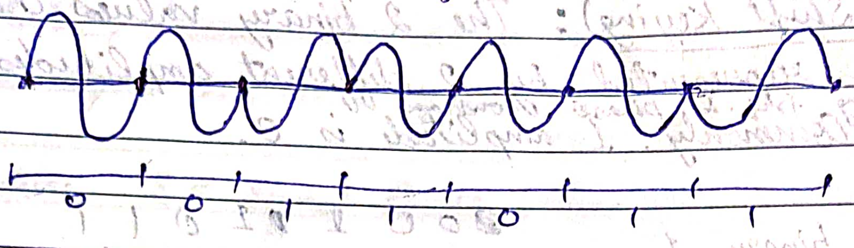
$f_1 = 1f$, $f_2 = 2f$, $f_c = 1.5f$

→ Phase Shift Keying (PSK): The phase of the carrier is shifted to represent data. In this system, a binary 0 is represented by sending a signal burst of the same phase as the previous signal burst sent. A binary 1 is represented by sending a signal burst of opposite phase to the preceding one. The freq. & amplitude are kept constant.

a) <u>Differential PSK</u> : It is so called bcoz the phase shift is with reference to the previous bit transmitted rather than some constant reference signal.

$s(t) = A\cdot\cos 2\pi f t + \pi \rightarrow$ binary 1

$\quad\;\; = A\cdot\cos 2\pi f t \rightarrow$ binary 0



b) <u>Quadrature PSK</u>: It uses the phase shift of multiples of $\pi/2$.

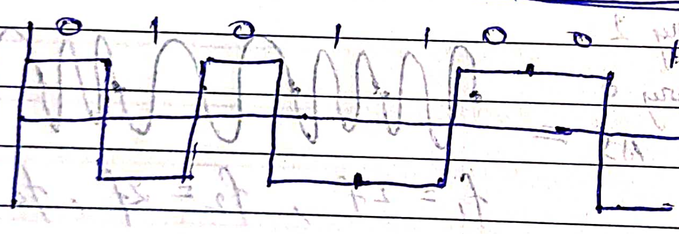
$s(t) = A\cdot\cos 2\pi f t + \pi/4 \rightarrow$ binary 1

$\quad\;\; = A\cdot\cos 2\pi f t + 3\pi/4 \rightarrow$ binary 0.

2) <u>Digital Data, Digital Signals</u>

a) <u>Non Return to Zero - Level (NRZ-L)</u>

0 → high level
1 → low level

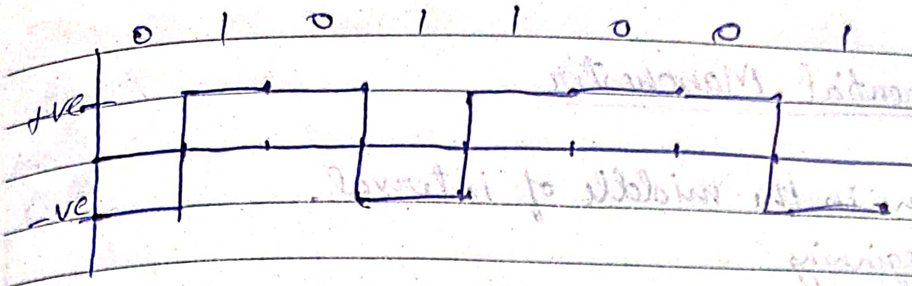


~~We assume the~~

If we assume that the bit prior to 1st bit is 1, then there will be a vertical line (in this case) else not.

b) <u>Non Return to Zero - Inverted (NRZ-I)</u>

0 → No transition at the beginning of interval.
1 → Transition " " "



I've assumed here that the previous bit was -ve.

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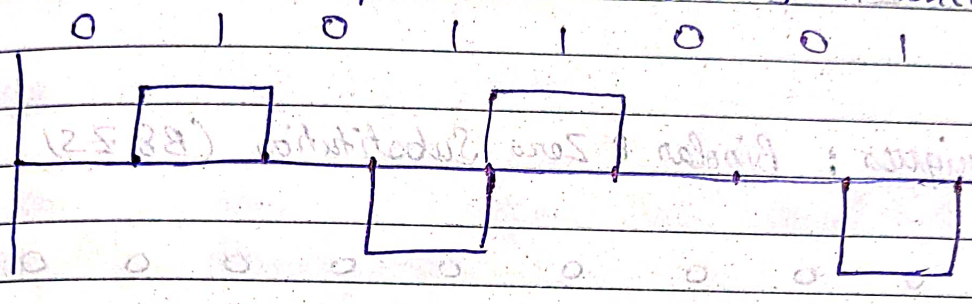
c) Bipolar-AMI

0 → no line signal
1 → +ve or -ve pulse that alternates on successive 1's.

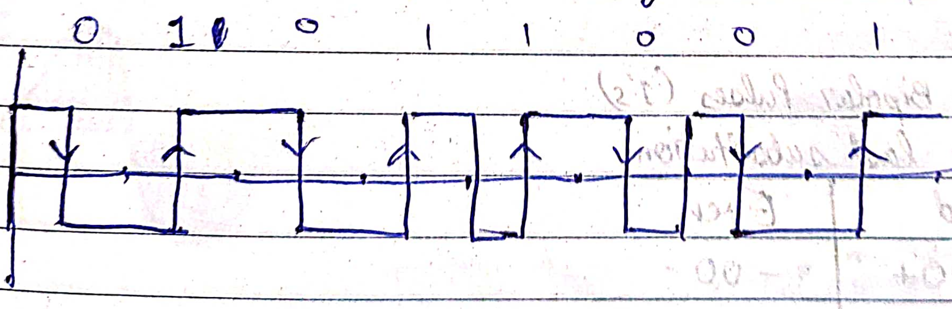


d) Pseudoternary (Opp. of biopolar)

1 → no line signal
0 → +ve or -ve pulse that alternates on successive 0's.

e) Manchester

0 → Transition from high to low in the middle of interval.
1 → " low to high "



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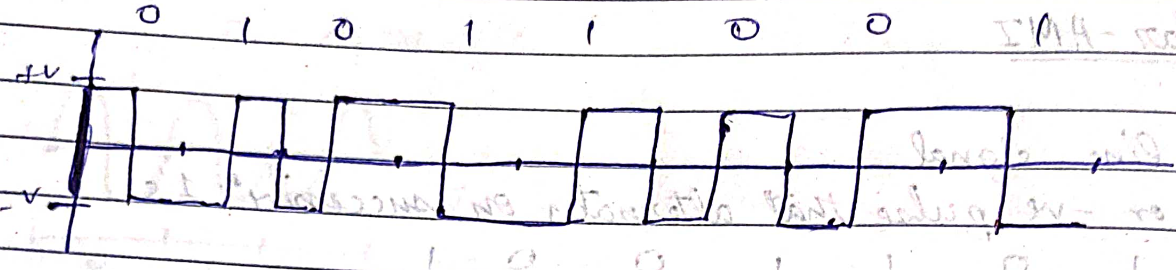
Easy method, first draw all the middle lines along with arrows, then start joining them.

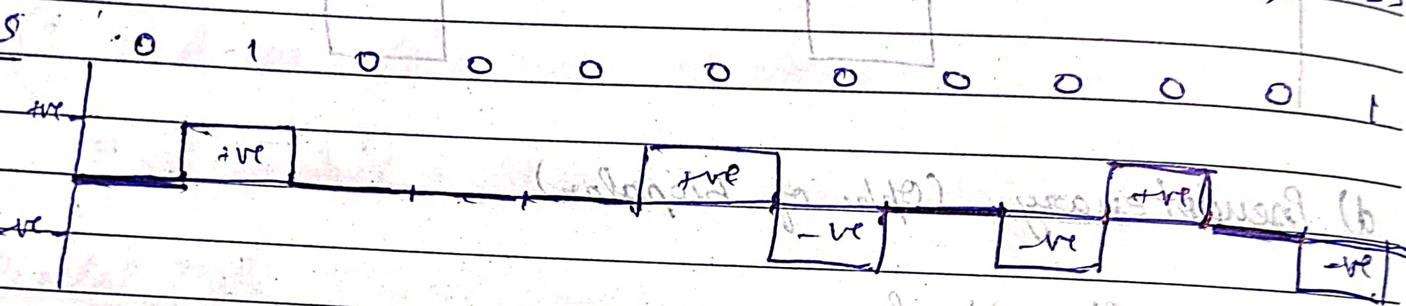
f) Differential Manchester

→ Always a transition in the middle of interval.
0 → trans. at the beginning
1 → no trans.



Scrambling Techniques : Bipolar 8 Zero Substitution (B8ZS), HDB3

① B8ZS



Code Violation : depends on the preceding pulse.

+ve → 000+-0-+
-ve → 000-+0+-

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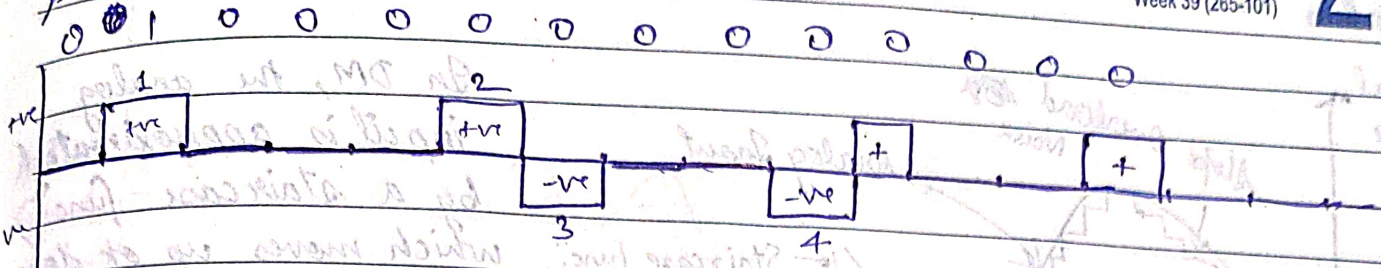
② HDB3 (High density Bipolar with 3-Zero Substitution)

Polarity of Proceeding Pulse \ No. of Bipolar Pulses (1's) since last substitution	Odd	Even
+ve	000+	-00-
-ve	000-	+00+

There can be 4 possible waveforms in HDB3.
In this example we assume that the preceding pulse is -ve and even no.



3.) Analog Data, Digital Signals

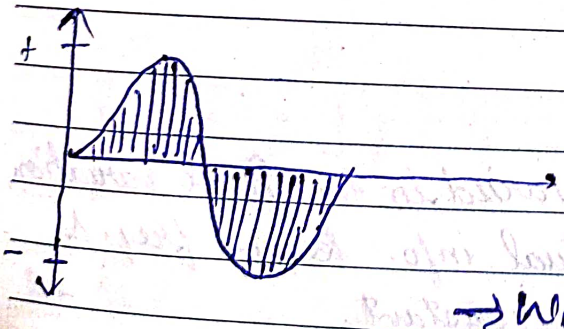
a) Pulse Code Modulation (PCM)

It can be done in 3 ways: Pulse Amplitude Modulation (PAM), Sampling, Quantization.

(ii) Sampling: ~~The~~ Measuring the amplitude of the ~~wave~~ signal at a regular interval of time.

(iii) Quantization: Assigning integral values to the samples.

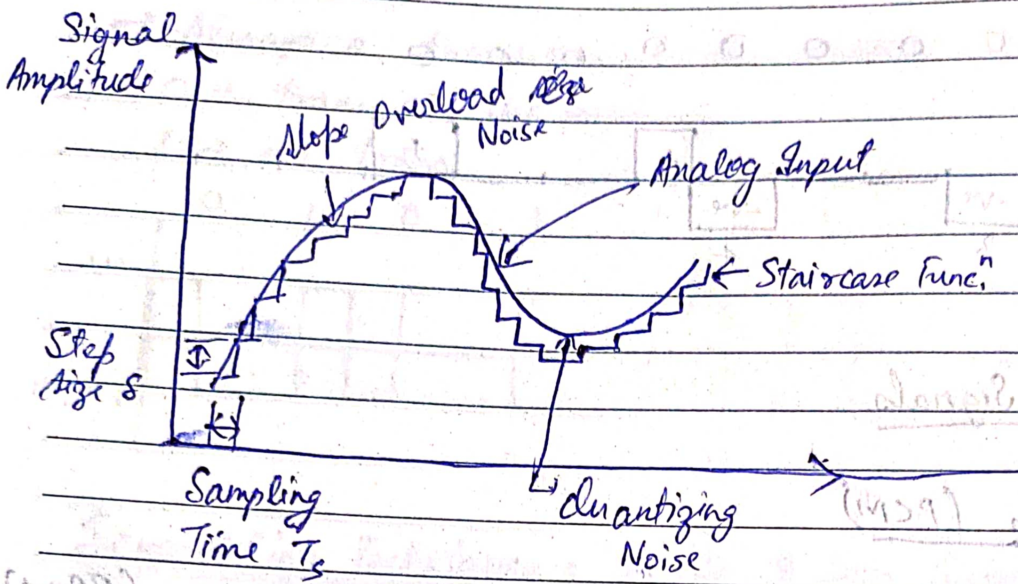
According to ~~the~~ Nyquist, the sampling rate must be at least twice as high as the maximum frequency of the signal, only then will we get all the data about the signal.



(i) PAM: Generation of ~~digital signal~~ ~~using~~ analog ~~signal~~ data into digital data.

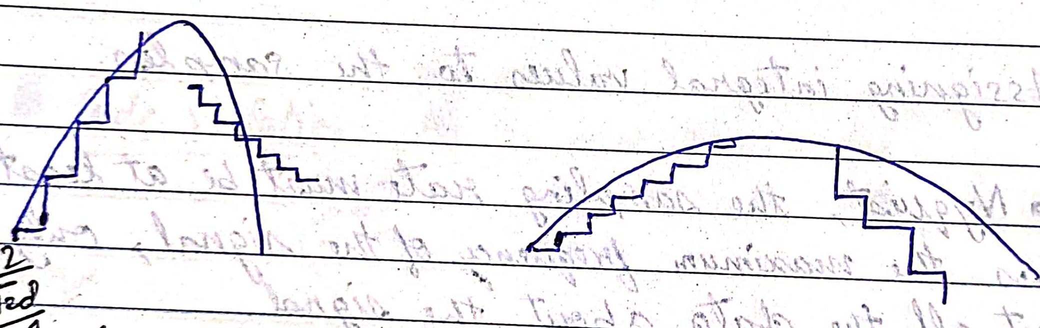
→ We have no direct ~~signal~~ method to send analog data into digital signals. So we convert analog data into digital data & then use ~~either PCM or~~ any one technique from digital data, digital signals.

b) Delta Modulation (DM)



In DM, the analog input is approximated by a staircase func^n which moves up or down by a fixed step size (S) (or Quantization level).

If the analog signal is changing slowly, and the step size is more, then Quantizing Noise is introduced, while if the signal is changing rapidly, and the step size is ~~increas~~ less, ~~the~~ then a Slope Overload Noise is introduced.



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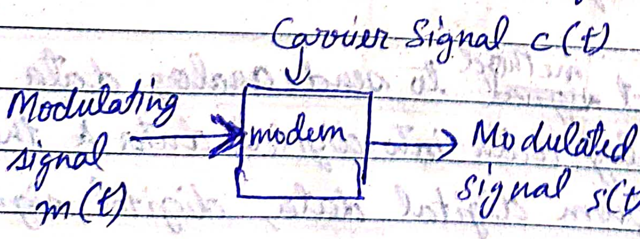
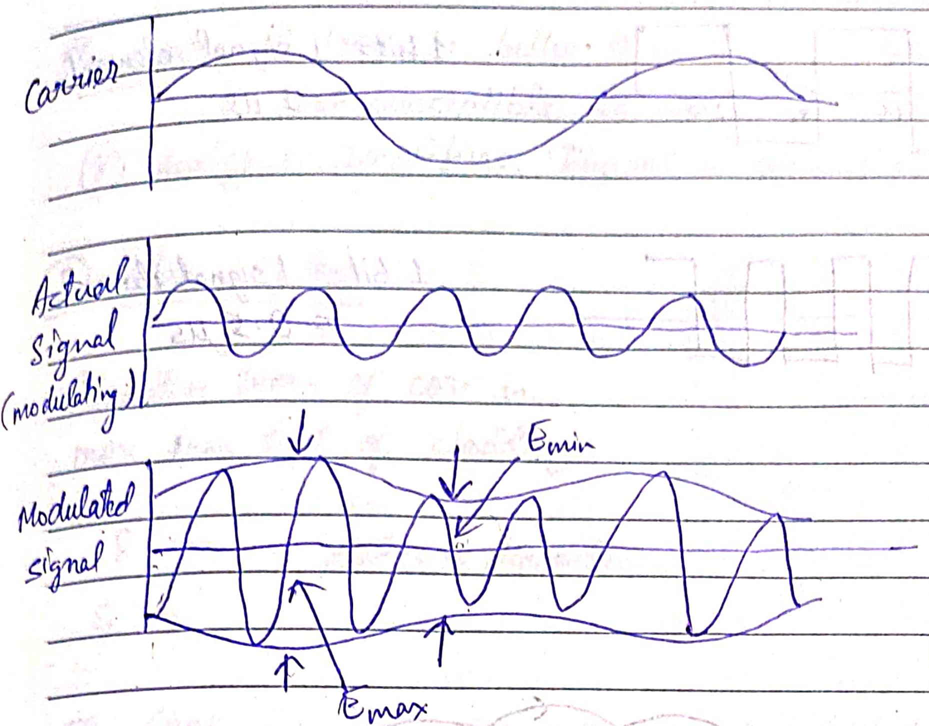
4) Analog Data, Analog Signals

a) Amplitude Modulation

→ The peak amplitude of the carrier is varied to the level variation of the actual info. keeping freq. & phase as constant.





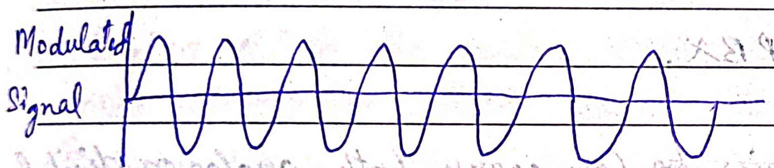
$$\mu = \frac{E_{max} - E_{min}}{E_{max} + E_{min}} = \frac{A_m}{A_c}$$

$$\% \text{ modulation} = \mu \times 100$$

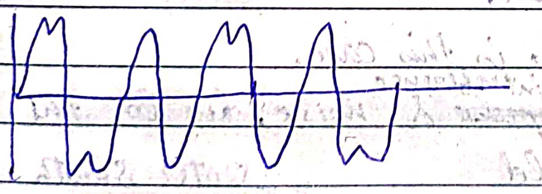
Without modulation, frq. manipulation is not possible.

b) ~~Phase~~ Frequency Variation

→ Carrier signal frq. is ~~...~~ varied.



c) Phase Modulation

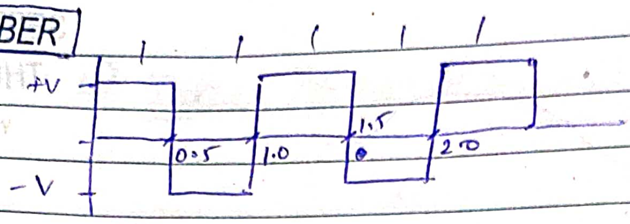


➤ Modulation Rate: The rate at which the signal elements are generated.

$$\boxed{D = \frac{R}{b} \text{ baud}}$$

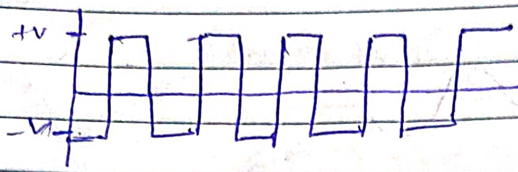
(also called baud rate) R = Data Rate
b = No. of bits per signal element.

NRZ-I



1 bit = 1 signal element
= 1 μs

Manchester



1 bit = 1 signal element
= 0.5 μs

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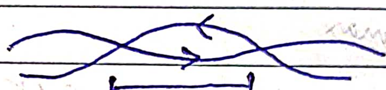
AR: Transmission Media

1: Guided TM

① Twisted Pair Cable

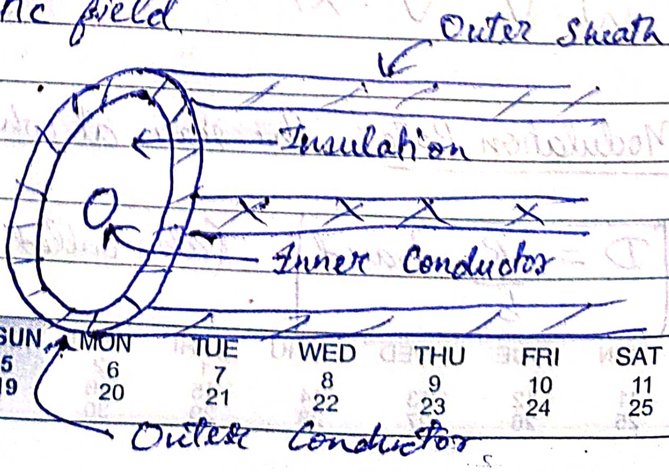


Twist length

→ Twisting is done to reduce the cross-talk interference.
→ Twist lengths for adjacent TPC are diff. to reduce/avoid the cross talk interference.
Uses: Earlier LAN, Telephones, PBX.

Transmission Characteristics: ① ~~Carries bo~~ Can carry both analog or digital.
② If it carries analog signals, amplifiers are used and for digital signals, digital signals are used.
③ Bandwidth and Data Rate are minimum.
④ Attenuation is a strong funcⁿ of freq. in this case.
⑤ The medium is quite susceptible to ~~impulse~~ interference & noise, due to the easy coupling with electromagnetic field.

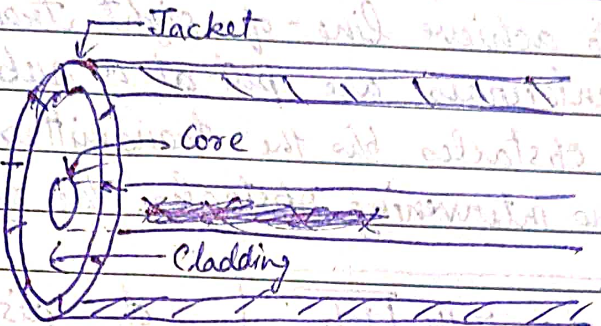
② Co-Axial Cables



Uses: Telephone,

Tr. Char: ① Freq. is better than TPC but less than fibre optics.
② Less susceptible to int. — compared to TPC.
③ Analog → Amplifiers, Digital → Repeaters.

③ Fibre Optics



Refractive Index of core is more than that of cladding.

8-100 mm ~~dia~~ core diameter.

Eg. →

Tr. Char: ① Step index multimode refers variety of angles that it reflects with multimode transmission. Multiple propagation of path exists, each with a different path length and hence different time to traverse the path.
② Graded index and multimode: By varying the R.I. of the core, the graded index multimode transmission is ~~processed~~ possible. The higher RI in the centre makes the light rays moving down the axis more slowly than those near the ~~axis~~. cladding.
③ Single Mode: When the fibre core radius is reduced then only fewer angles reflect. By reducing the radius of the core to the order of a wavelength, only a single ~~ray~~ angle or mode can pass i.e., axial ray.

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~~2. Unguided Media~~
2. Unguided TM (Wireless)

They can be directional or omnidirectional.

① Terrestrial μWave

→ Parabolic disks (0.5m – 3m size) used.

→ Antennaes are fixed rigidly and focus a narrow beam of EM wave to achieve line-of-sight transmission.

→ These antennaes are put at a substantial height so that there are no obstacles b/w the transmitter & receiver.

With no intervening obstacles, the <u>max^m^ dist.</u> b/w ~~anten~~ antennaes is

$$\boxed{d = 7.14\sqrt{kh}}$$

d = dist. b/w antennaes in km
h = height of the antenna in m

k = Adjustment factor = 4/3

Eg. → TV, Telephone transmission.

<u>Transmission Characteristics</u>: ① Freq. Range is 2 – 40 GHz.

② For <u>μwaves and radio freq.</u>, the attenuation loss can be expressed as

$$\boxed{L = 10 \log_2 \left(\frac{4\pi d}{\lambda}\right)^2 dB}$$

where d = dist.
λ = wave length.

③ Amplifiers (more) / Repeaters (less) spacing ranges from 10 to 100 km.

④ Attenuation increases with rainfall (above 10 GHz, it is severe).

⑤ Transmission area may overlap, resulting in interference.

⑦ Common bands for long haul telecommunications. (4–11 GHz)

⑥ Assignment of freq. bands is strictly regulated.

⑧ 12 GHz band for cable TV signals.

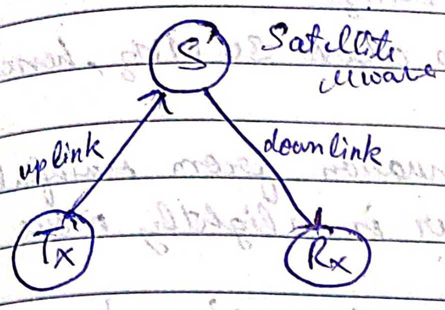
⑨ μwave links are used to ~~provide TV signals~~ local service providers. From there co-axial cables are used.

⑩ Higher ~~μwave~~ freq. μwaves are used for short point to point links (buildings). 22GHz band is preffered.

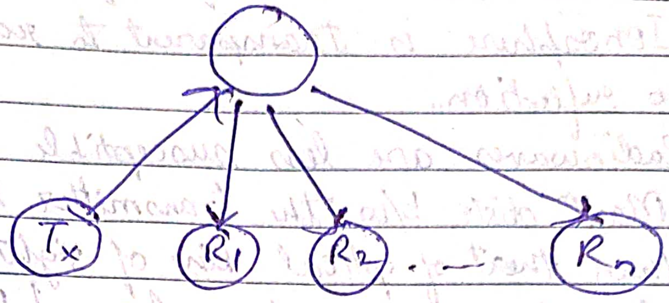
⑪ Higher freq. μwaves are not ~~preff~~ preferred for long range to avoid attenuation.

⑫ ~~Higher~~ ↑ freq., ↓ smaller & cheaper is the antennae.

(2) Satellite μwave



Point to point link via satellite μwave



Broadcast via ---.

$\boxed{\text{uplink freq.} \neq \text{downlink freq.}}$

→ It is μwave relay station.

→ Used to link 2 or more ground-based μwave transceivers. (T_x/R_x).

→ The satellite receives transmission at one freq. band and transmit it to 2 or more Earth stations, at a diff. freq. band after amplifying or repeating it.

→ Single orbit satellite operates on a no. of ~~receiving~~ freq. bands called transpoder ~~ch~~ channels / transponders.

→ To remain stationary, the satellite must have a period of rotation equal to the earth's period. To remain stationary w.r.t. to Earth's position, it is placed at 35784 km.

→ 2 satellites using the same freq. band, if close enough, may interfere with each other. To avoid this, a 4° ~~do~~ spacing (angular displacement as measured from Earth) in 4/6 GHz band and a 3° spacing at 12/14 GHz band.

→ 4/6 GHz band refers to 4 is downlink & 6 GHz is uplink. The 4 GHz downlink varies from 4.2 - 4.7 GHz, and the 6 GHz varies from 5.925 to 6.425

12 from 11.7 to 12.2 and 14 from 14 to 14.5.

19/29 GHz is also in use.

③ Broadcast Radio

→ Freq. Range 30 MHz - 1 GHz.

→ Ionosphere is transparent to radiowaves above 30 MHz, hence no reflection..

→ Radiowaves are less susceptible to attenuation from rainfall.

→ Max^m dist. b/w the transmitter & receiver is slightly more than that of optical line of sight.

→ Amount of attenuation loss $\boxed{L = 10 \log_2 \left(\frac{4\pi d}{\lambda}\right)^2 dB}$

→ Prime source of transmission impairment is multi-path interference. (reflection from land/water/buildings/etc.)

④ Infrared Communication

→ Achieved using transceivers that modulate non-coherent IR light.

→ Tranceivers must be within the line of sight of each other either directly or via reflection.

→ IR does not penetrate walls like μwaves.

→ Security & interference problems are not present as in μwave.

→ No freq. allocation issues with IR bcoz no licensing is req^d.