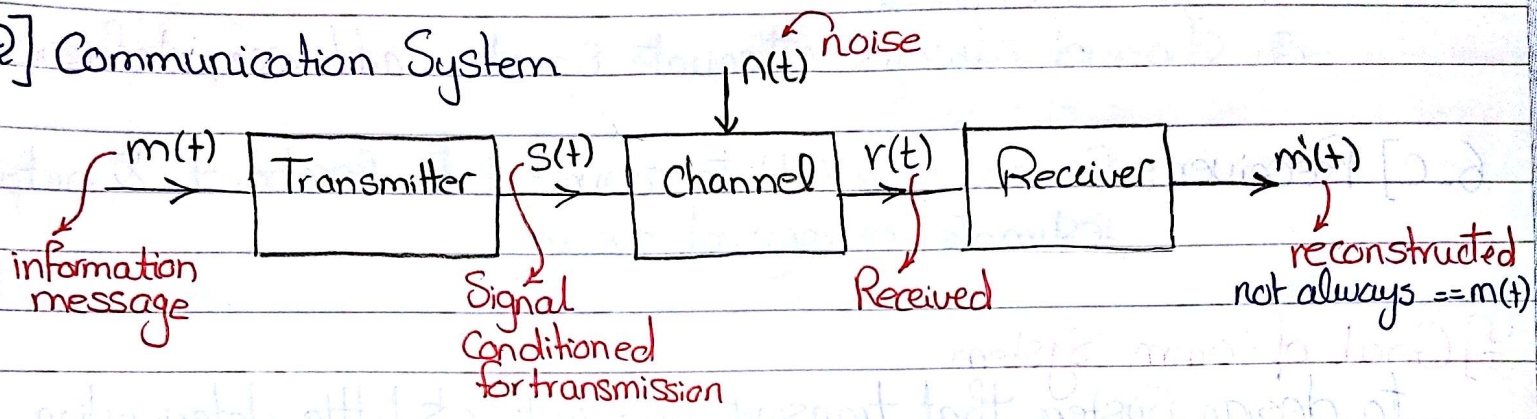
Unit (1) - Basics of Comm. Systems.

1] Communication : Describes general information exchange
Telecommunication : communication with electronic systems (TV, radio, ...)

2] Communication System



3]

-	Comm. Systems	Electrical Energy Systems
waveforms	unknown	Known
Design for	Efficient information transmission	minimum energy loss

4] We have 4 main concerns for comm. System design :
- → Selection of the information bearing waveform "Symbol waveform"
- → Bandwidth & Power of the waveform.
- → Effect of noise on Receiver side
- → Cost of System

5] Resources to transfer info : Time, frequency Band (Spectrum), Money (technology)

* We have 3 main Components of Comm System :

6.a] Transmitter : mainly transform signal to a more appropriate form for channel $m(t) \dashrightarrow s(t)$

Ex: LPF, ADC

6_b] Channel: * Wired : twisted pair copper lines, Fiber optic cable
* Wireless : air, Vaccum

Note that:
(1) General principles of Communication apply Regardless of type of channel
(2) Channel always attenuate Signals (add noise, interference..

6_c] Receiver: Demodulate r(t) to convert it to Baseband & output estimate of original message

7] Goal of Comm. System
to design System that transmit info with as little deterioration as possible with → allowable transmittion energy
→ " Channel Bandwidth.

* How To measure deterioration?
1) Digital System → Bit Error Rate (BER)
2) Analog " → Signal to Noise Ratio (SNR) @Receiver

8] frequency Spectrum:
↳ Available range of frequencies for Communication
* From low freq. (voice) to high freq. (Satellite)

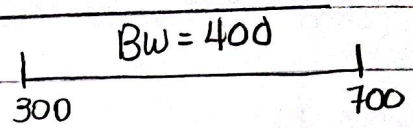
a) Radio frequency (RF) [30 HZ - 300 GHZ]

1- ELF	extremly low freq.	3-30 HZ	Metal Detector
2- SLF	Super low freq	30-300 HZ	Submarine Communications
3- ULF/ VF	Ultra low freq / Voice freq	300-3000 HZ	Audio/Telephone
4- VLF	very low freq	3-30 KHZ	Navigation - Sonar
5- LF	low freq	30-300 KHZ	→ 9-190 KHZ: Radio nav & Maritime ↘ 190- KHZ: Aeronautical & Radio Beacons

6. MF	Medium freq. (AM Radio)	300 KHZ _ 3MHZ	• 535 _ 1705 KHZ police, Fire • 2000 - 2187 KHZ Maritime radio, Direction finding • 457 KHZ Avalanche Beacon • 1800 - 2000 KHZ 160 m amateur Radio • 2300 - 2500 KHZ 120 m Shortwave international Radio
7. HF	High freq (ITU Band 7)	3 _ 30 MHZ	• Marine Search & Rescue • Shortwave Radio • 75/80 amateur Radio
8. VHF	Very high freq. (ITU Band 8)	30 - 300 MHZ	• Public Service • Mobile phone - Base to car • Garage door openers • Alarm Systems • TV channels 2 to 6 • Radio controlled airplanes في حاجات تانية كتير ، للكورية 28
9. UHF	ultra high freq (ITU Band 9)	300 MHZ _ 3GHZ	• Aeronautical Radio nav. • GPS • LEO • Global Star Satellite Phones • S-Band
10. SHF	Super high Freq. (ITU Band 10)	3 _ 30 GHZ	• MDS • WLL • C_band (WLAN) • X_band (Satellite to earth comm) • Ku_band (police Radar) • K_band (Nasa)
11. EHF	extremly high freq	30 - 300 GHZ	• Ka-band (mm wave freq) • LMDS • Winstar • V-band • W-band.

9] Signal propagation
- Low freq → Omni-directional
- High freq → Unidirectional

10] Bandwidth : represent range of frequencies



↳ we use it to specify communication capacity & indicate BW of technology.

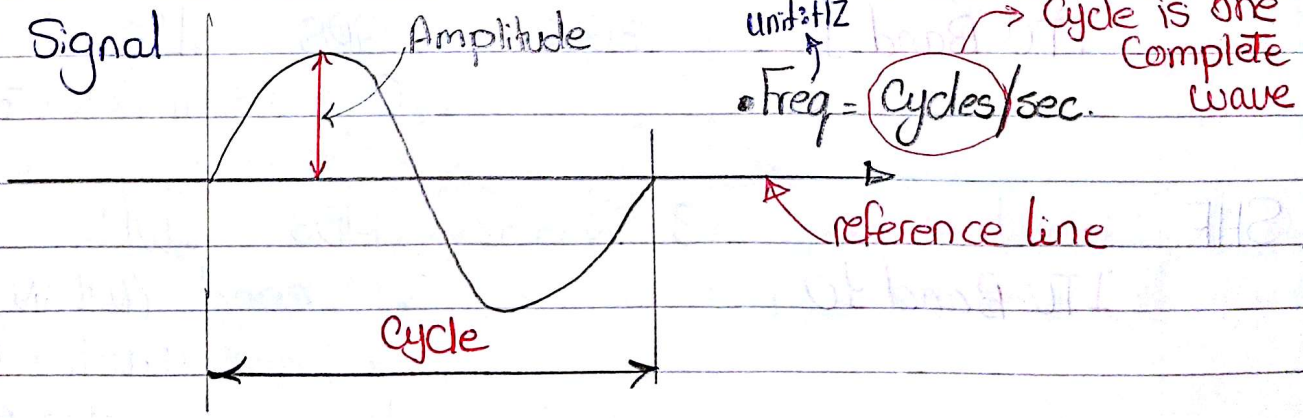
Mod(3) : Analog & Digital Systems

1] Specify type of system by → Reference to the possible amplitudes of voltage (and/or current) waveforms.

2] Information Sources
- Analog : produce values defined on a continuum (voice)
- Digital : produce finite set of possible symbols (computer keyboard)

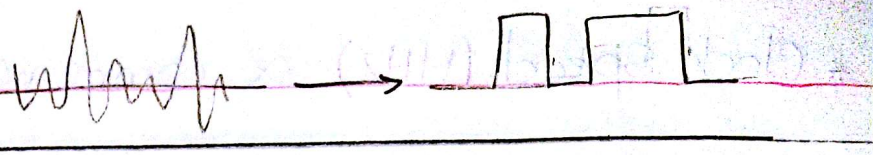
3] Apps : old telephone networks - Radio broadcasting
Most analog Tv broadcast turning into digital

4] Analog Signal

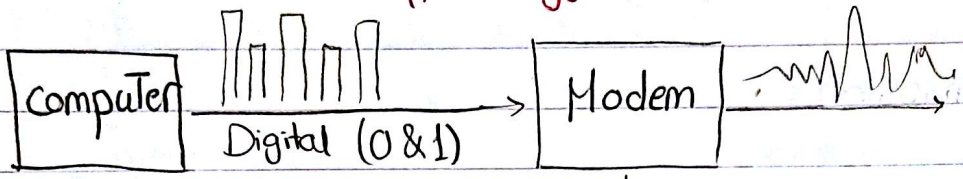


Notes :
- information can be represented using analog signals
- Analog Signal can't be manipulated easily
- " " must be digitized for computer processing.

5] Analog to Digital (DSP)



6] Data Transmission (Analog)



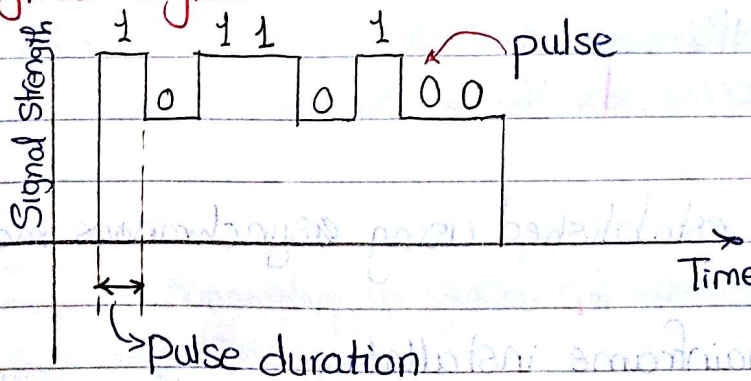
↑
Digital to Analog Modulation & Viceversa

* Voice transmission (Analog_to_Analog Modulation)

7] Digital Comm.

Advantages	Disadvantages
• Better quality due to being able to reconstruct exact digital pattern at Receiver end • Faster Comm. Speeds • Privacy & Security (encryption) • Common channel for different data Sources • Better imunity to noise.	• greater BW requirements • Synchronization required

8] Digital Signal :



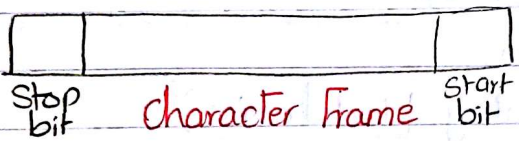
- pulse duration $\propto \frac{1}{\text{clock freq.}}$
- pulse duration ↓ execution ↑
- pulse duration ∝ time taken to transmit one bit

* Clock Speed (MHz) ∝ Communication Speed (Mbps)

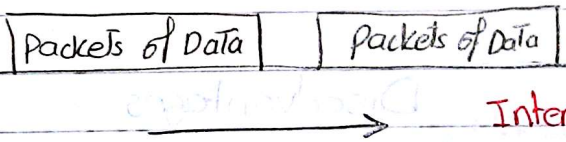
Mod(4) : Synchronous & Asynchronous Transmission

1] Asynchronous Transmission :

- Burst mode transmission
- Sender & Receiver are not Synchronized w.r.t the flow of info.
- " " " " Synchronized w.r.t timing of chars transmitted

Chars: 

→ each char. is individually timed

Packets: 

→ Intermittent transmission of Packets of data

* Speed variations in Asynchronous transmission :
  - Low speed : Almost all modem based comm. fall into this Categorey
  - High speed : Asynchronous transfer mode (ATM)
    "Internet is good Example"

2] Synchronous Transmission :

- Sender & Receiver are Synchronized w.r.t Sending & receiving of info
- Don't need start/stop bit as they are both Synchronized
- Require more Hw & Sw resources
- High Speed Comm is the norm.

Examples :

→ High-Speed Comm. links established using @synchronous modems
  * It's possible to establish it using asynchronous.

→ Used in a number of mainframe installation.
  * Collective Exchange of info between mainframe & peripheral Devices.

Mod(5) : Access Networks and Transmission Media.

1) Design factors :
- BW : Higher BW gives higher data Rate
- Transmission impairments → Attenuation
- Interference
- Number of receivers (in guided media, more receivers more attenuation)

2) Transmission Media → Guided : Twisted pair - Coaxial Cable - optical fiber
→ Unguided : Wireless . Wireless LAN
. Digital Satellite channel.

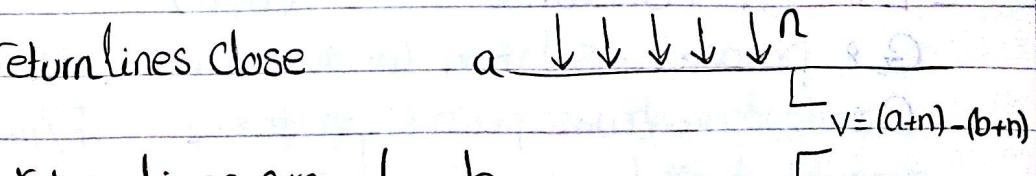
2-a-1) Twisted Pair Wire :
- Twisting : to minimize effect of electromagnetic interference
- Shielding : Conductive material
- Insulation : non-conductive material (casing [plastic])

Types :

I) Shielded Twisted pair (STP)
- Metal braid or sheathing that reduces interference
- More expensive . Harder to handle (thick, heavy)

II) Unshielded twisted pair (UTP)
- Ordinary telephone wire . cheapest . easy To install
- Suffers from external EM interference

Why twisted ?
- To place the direct & return lines close together
- To twist the direct & return lines around one another so that they should be absloutly equidistant from disturbing wires.



* For low frequencies : Don't need shielding
  For high " : UTP has cross talk " due to capacitive/inductive mismatch"

Charactristics:
Compared to coaxial cables, twisted pair have lower BW
↳ Recent improvement increase BW so speed increased.

Apps:
1) Telephone network (Between house and local exchange)
2) within Buildings (to private branch exchange PBX)
3) Local area network (LAN) 10 Mbps or 100 Mbps.

UTP Categories:

Category	Description	BW/Data rate
Category 3 (CAT3)	Telephone installation class C	up to 16 Mbps.
CAT 5	Computer Networks	up to 100 MHz/100 Mbps - 100 m length
CAT5e		100 MHZ/1000 Mbps. Applications with improved noise performance.
CAT 6	Higher speed computer Networks	up to 200 MHZ
CAT 7	STP, More expensive, Harder to deal with	up to 600 MHZ/data up To 10 Gbps.

Transmission Line Parameters : (Lumped)
- R : longitudinal resistance (Ω/m)
- L : loop inductance (H/m)
- G : parallel insulation conductance (S/m or 1/Ω·m)
- C : " wire pair capacitance (F/m)

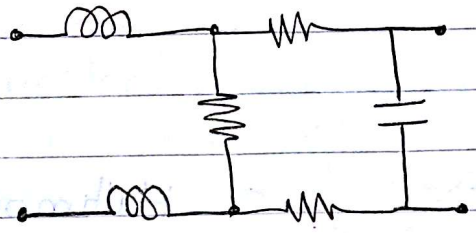
* Charactristic impedance or Surge impedance Z_o:

$$Z_o = \sqrt{(R+jL2\pi f)/(G+jC2\pi f)}$$

* Wave Speed (Phase velocity)

$$C_m = 1/\sqrt{(R+jL2\pi f)\cdot(G+jC2\pi f)}$$

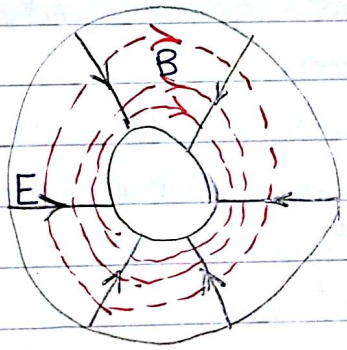
Lumped element Model for transmission Line:

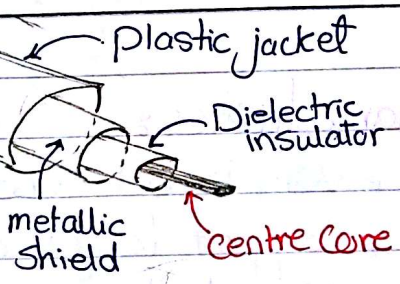


في جدول في سلايد 16 فيه السلك والـ diameter بتاعه لو سألنا في الكلام دا وضرب نفسنا بالنار اسهل ما نحفظه!

2-a-2) Coaxial Cable

Electromagnetic waves in the Cable





Types:
- thin
  - lighter version
  - Thin ethernet Cable
- thick
  - Original version
  - Standard ethernet Cable

Apps:
Ethernet bus LANs - Telephone trunk
Mainframe Networks - Cable TVs

Examples of thin & thick usage in LAN:

- Standardized → 10Base2 Cable, 10 Mbps over baseband Ethernet, thin, Bus Topology
- Standardized 10Base5

Charactristics:

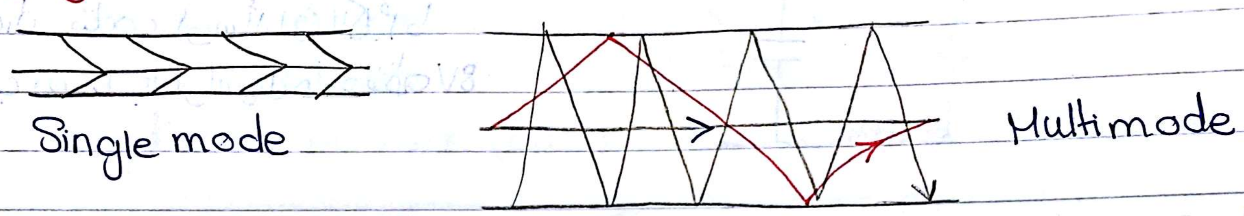
- Cost < fiber optics
- Bw > twisted pair
- good transmission charactristics
- used in high speed synch. transmissior

- Supports broadband Communication
- Can be tapped for multi-drop Connection.

2-a-3) Optical fibers:

Light travels along the path of the fiber by bouncing around its edges. شكل الـ Cable ومش في الـ Slides و Google it :D

* Propagation methods



Charactristics:

- Very broad Bandwidth, So higher transmission Speeds are possible
- Support longer distance (low attenuation)
- No electromagnetic field → no interference
- Smaller size → n-fiber strands in a cable (diameter ↓)

Apps:

* Long-haul trunks, Metropolitan-trunks, Rural-exchange trunks
* Subscriber Loops, LANs.

Visible light Spectrum:

↳ El-Sora mawgoda fy nafs folder el file da

← آخر ورقة في الـ pdf دا اللي هي صفحة 5 فيها شوية رسومات كدا اتفرجوا عليهم :D

3-b) Wireless Transmission

* Transmission and reception are achieved by means of an antenna
* Antenna → Directional: freq ↑ & transmitting antenna puts out focused beam (Transmitter & Receiver must be aligned)
  → Omnidirectional: freq ↓ & Signal spreads out in all directions (can be received by many antennas)

3-b-1) Wireless Examples

(1) Terrestrial microwave transmission → when microwaves are used to transmit data, used for TV & Radio
- → Use Spectrum of radio 2-40 GHZ
- → Use parabolic dish transmitter, mounted as high as possible
- → Used by common carriers & private networks
- → Require unobstructed line of sight between Sender & Receiver and repeater to be ≈ 50 km because of earth's curvature

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1-a) Apps of Microwave:
i. long-haul telecommunication service for voice & TV transmission
ii. Short point-to-point links between buildings for closed-circuit TV or link between LANs.
iii. Bypass apps → Ex: bypass local telephone company to reach long distance carrier.

"Microwaves BW & Data rate Slide 39"

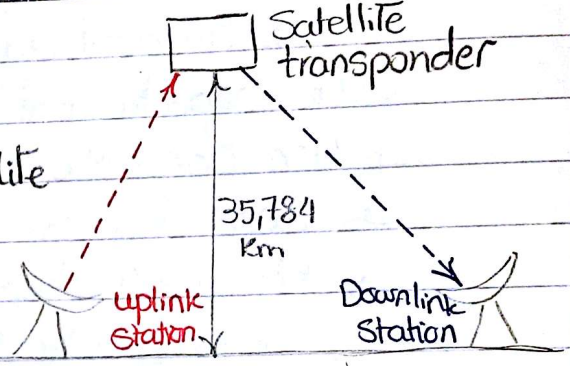
1-b)

Adv.	Disadv.
• No cables needed • Wide BW • Multichannel transmission	• Line of Sight needed • expensive towers & repeaters • Subject to interference

(2) Satellite Transmission → a microwave relay station in space, can relay signals over long distance.

2-a) Geostationary Satellites
- remain above the equator at height of 35,863 km (geosynchronous orbit)
- travel around the earth in exactly the time the earth takes to rotate

2-b) Satellite Transmission Links
- earth station send signals to satellite on an uplink, then satellite repeats those signals on downlink



→ Broadcast Nature of downlink make it attractive for services such as: Distribution of TV programming.

2-c) Satellite Apps:
- television distribution
  - → A network provides programming from central loc.
  - → Direct broadcast satellite
- long-distance telephone transmission
  - → high-usage international trunks
- private business networks
- Internet connectivity
- global positioning

2-d) Satellite Bands
i. C Band: 4 downlink - 6 uplink GHz (first one)
ii. Ku Band: 12 " - 14 " "
- → Small cheap earth stations
- → problem: rain interference.

iii. Ka band: 20 (downlink) - 30 (uplink) GHz
→ Smaller cheaper receivers → Even greater attenuation

2-e)

Adv.	Disadv.
• Can reach larger geograph. area • Bw ↑↑ • Cheaper over long. distance	• Cost ↑↑ (initially) • Susceptible to noise & interference • propagation delay (1/4 sec)

3) Radio → Omnidirectional and easily received

Broadcast Radio
• 30 MHZ - 1GHZ - FM, UHF, VHF TV

Mobile telephony
• Bands below 1 GHZ & in 2GHZ band

Wireless LAN
• 2.4 GHZ range for 11 MB up to 200 m

3-a) Wireless LANs
→ IEEE 802.11 Standard - WiFi
• Operates in unlicensed freq. bands, permitted if limited transmissa power [902-928 MHZ, 2.4-2.5 GHZ, 5.7-5.8 GHZ]

→ Several variations
• LAN extension → access points (Base Stations) Connected via wired LAN
→ Cross-building interconnect
→ Ad-hoc network - peer-to-peer without access point

→ Initial 802.11 Standards
• Operate at 1 Mbps // 2 Mbps & by hopping between frequencies or Spreading Signal accross allowable spectrum
* instantly declared by users as too slow.

→ What's transmission technique?

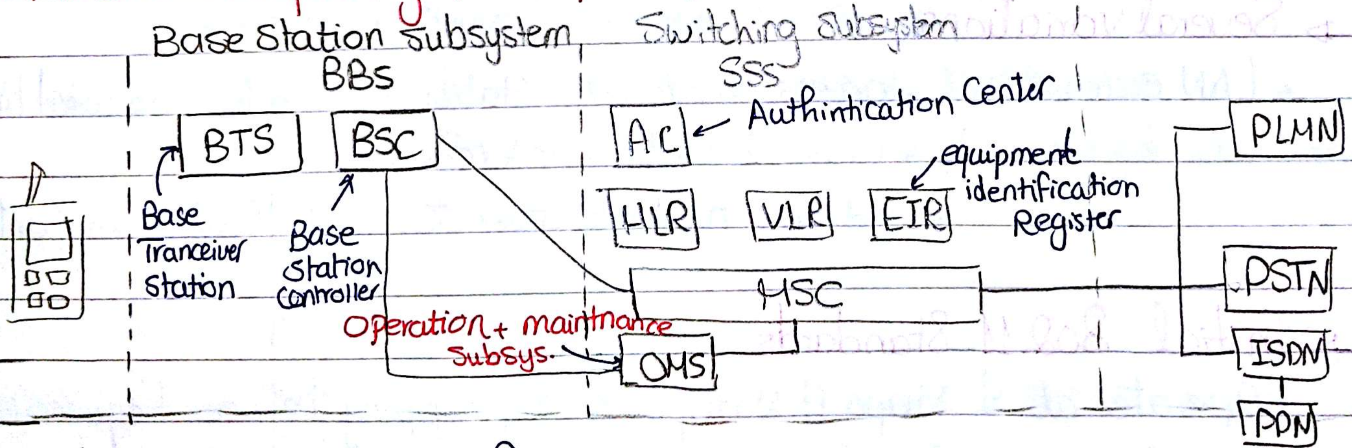
a. Spread-Spectrum LANs → Signal spread across multiple freqs
b. OFDM LANs → use multi carriers for different freqs & Bits spread over signals.

1) Original 802.11	• Direct Sequence spread spectrum. • 2.4 GHz band @ 1 Mbps & 2 Mbps. • Up to 7 Channels _ 5 MHz each • Depend on BW available
2) 802.11 b	→ Extension for previous one • Data rate 5.5 & 11 Mbps • Pros: cost ↓ -

← الـ Slides اللي فيها IEEE Stand دي كلها للعلم بس مش هنتسأل فيها انا سألت الدكتور لحد سلايد 58

→ Concerning interference: كل دولة بتحط قواعد تتحكم بيها الـ Channels المسموحة وعدد الـ users والـ max power levels وأغلب العالم بيسمح بالـ first 13 Channels in spectrum.

* Mobile Telephony (GSM / 2G)



HLR → Home Location Register
MSC → Mobile Service Switching Center
VLR → Visitor Location Reg.

← اللي عايز يفهم الـ Call scenario in 2G بالتفصيل موجودة على google كتير جداً"

Module(6) _ Telephone Channel

1) Telephone transmission:

- Baseband voice signal: freq range optimized for voice signals
- Why direct transmission of digital data is not possible?
  - ↳ Because long sequences of 1's or 0's look like signal freq = 0

- Modulate an audio-frequency carrier signal with digital data
  - ↳ Carrier above low cutoff
  - ↳ to get high data rates we can squeeze multiple bits into a signal element.

1-a) Baud Rate:

↳ Each signal element is baud, no of signal elements / s = Baud rate

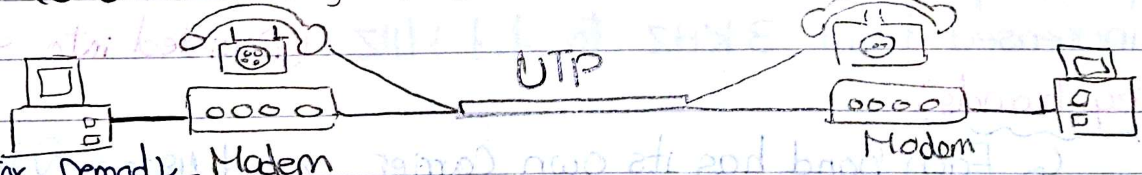
- Limitations on Transmission rate

Nyquist theorem: Max Bit Rate = 2 x Carrier BW x $\log_2\left(\frac{\text{Possible values}}{\text{Signal element}}\right)$ (no of bits encoded by signaling elem.)

Ex (voice) = $2 \times 3000 \times \log_2(8) = 18000$ bps

1-b) Data Supported via voice-grade modems

→ to send Data, it's converted into 4 KHZ audio (modem)



→ Data rate determined by "Shannon's Capacity theroem"

Capacity: Max data rate (bps) that can be sent through channel

↳ Depend on BW & SNR

↳ Signal to noise ratio

زمان كانت 25 kbps
دلوقتي حوالي 33.6

* Shannon _ Hartley law:

$$\text{Max bit rate} = BW \times \log_2\left(1 + \frac{S}{N}\right)$$

↳ SNR ~ 1000

PSTN: public switched Telephone network

→ For analoge PSTN with multiple exchanges S/N ~ 1000
Note that: it depends of connection's complexity
& Max bit rate = $3000 \times \log_2(1000) = 30000$ bps

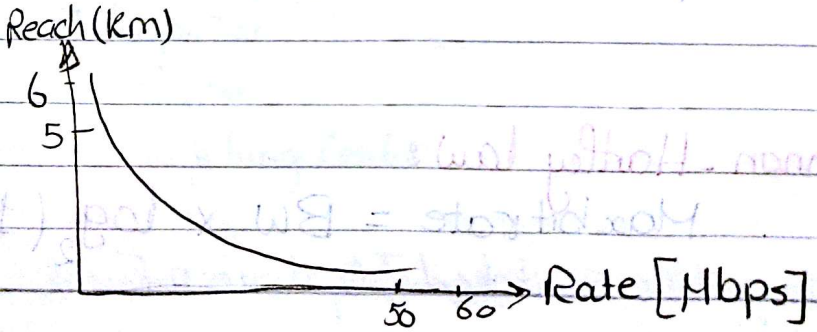
Soal Wagody: How can old Modems Run at 56K?
↳ 56.6 kbps modems expect to be used with digital PSTNs
User's modem to local exchange بس analog link هنا صيغ هو *
↳ S/N better than 1000
الرقم in fact b بس بيوصلوله

(2) Digital Subscriber line (DSL):
→ Why DSL?
- Need higher speed digital connection to subscribers.
- Not feasable to replace UTP in last mile
- DSL modems don't assume either 4 KHZ analog line or 64 kbps digital line. "Use whatever physics of UTP allows"

(A) DSL Asynchronous ↳ download speed & upload speed differ.
Example:
↳ D comm. technology bt. enable faster data transmission using Copper telephone line.
- BW increased from 3 KHZ to 1.1 MHZ (Divided into separate freq. bands)
↳ Each band has its own carrier, coded using QAM

→ System adapts to S/N Ratio across freq range
→ Variable upload/download channel allocation

xDSL max. reach



up stream
& down stream

modem	Speed	reach	main apps
ADSL	6 Mbps (DS) 640 kbps (US)	3.5-5.5 km	• Residential internet • Video-on-Demand
ADSL2	8 Mbps (DS) 800 kbps (US)	> ADSL	• Internet access • VOIP → Voice over IP i.e Viber etc
ADSL2+	16 Mbps (DS) 800 kbps (US)	< 2 km	
VDSL	<= 52 Mbps	300m - 1km	LAN interconnect, HDTV,
VDSL 2	~~1100~~ Mbps	up to 1.8 km	combined services