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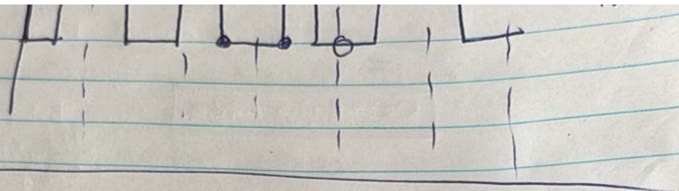

3) IEEE 802.11 Architecture.

* Refers to the design and structure of wireless local area network that operates according to IEEE 802.11 standard.
* IEEE 802.11 standard, popularly known as Wifi, lays down the architecture & specification of wireless LANs.
* Wifi uses high frequency radio waves instead of cables for connecting devices in LAN.

2) Distribut

A
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3) Access

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* users connected by WLANs can move around with in the area of network coverage.

Components :-

1) Station (STA) :-

* A device that contains an IEEE 802.11 interface such as laptop / smartphone.
* There are 2 types:-
  (i) wireless Access Point (WAP).
  * WAPs or simply access points (APs) are generally routers (wireless) that form the base stations or access.

  (ii) Clients :-
  clients are workstations, computers, laptops, printers, smartphones, etc;

2) Distribution System (DS) :-

A system that connects multiple APs together allowing them to communicate with each other & with stations.

3) Access Point :-

A device that connects wireless stations to a wired network, providing access to internet & other network.

4) Basic service set (BSS):-

* A basic service set is a group of stations communicating at physical layer level.

Two categories depending upon mode of operation.

i) Infrastructure BSS:-

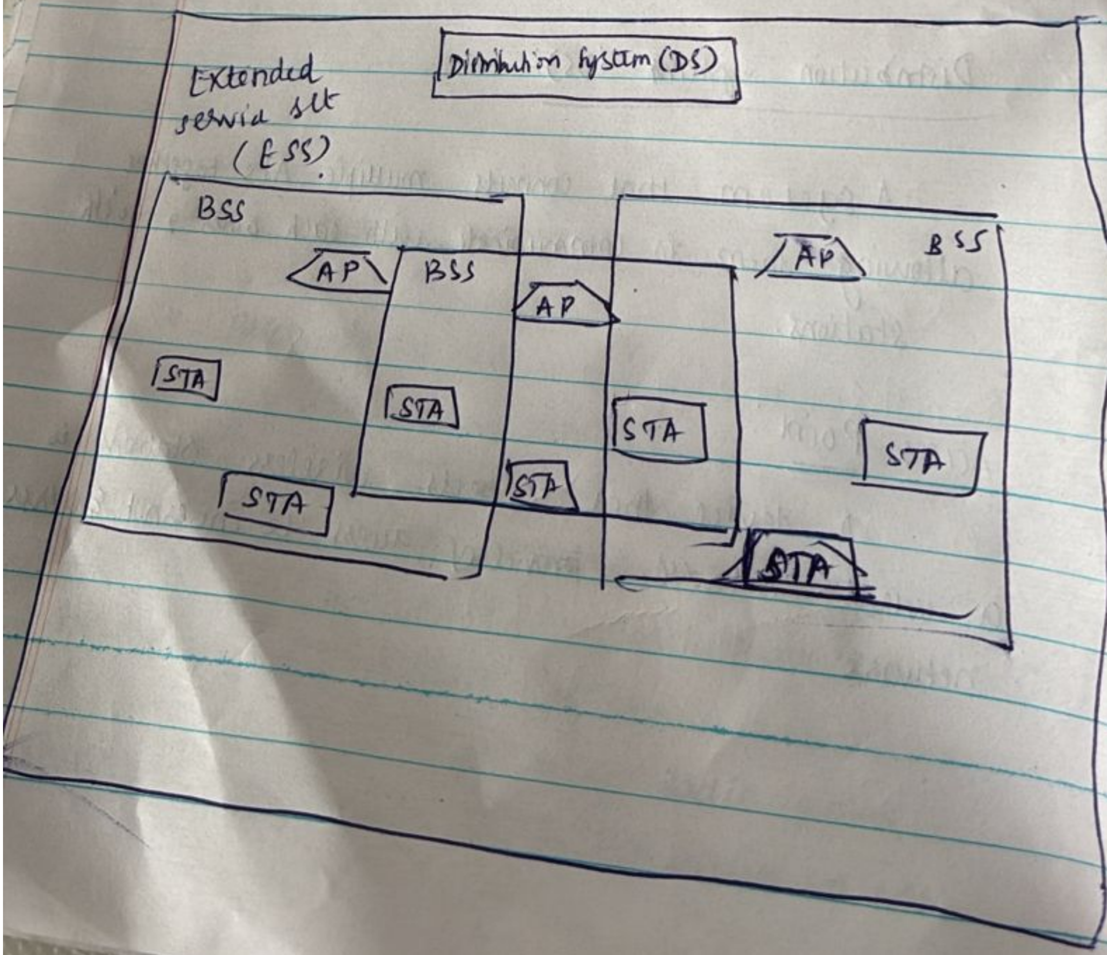
* devices communicate with other devices through access points.

ii) Independent BSS:-

* devices communicate in a peer-to peer basis in an ad hoc manner.

5) Extended service set (ESS)

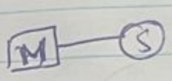
A collection of multiple BSSs that are connected through a DS.

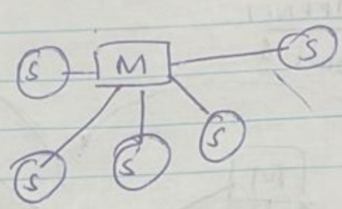


1) <u>Bluetooth Topology</u> :

* Bluetooth wireless technology is a short-range radio technology, developed for PAN.

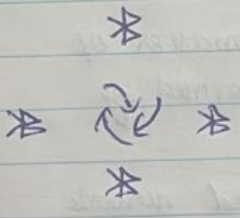
* Bluetooth devices in a network have the function of a master or a slave.
* All communication is between a master and one or more slaves, never directly between slaves.
* It has one master & from one to 7 slaves.



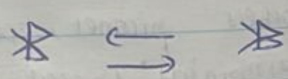


* <u>Two types</u> :-

1) piconet
2) Scatternet

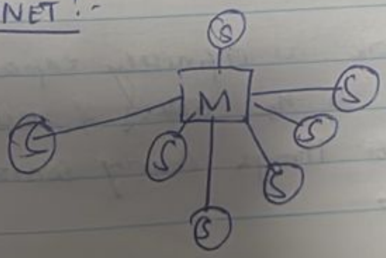


Piconet



Scatternet

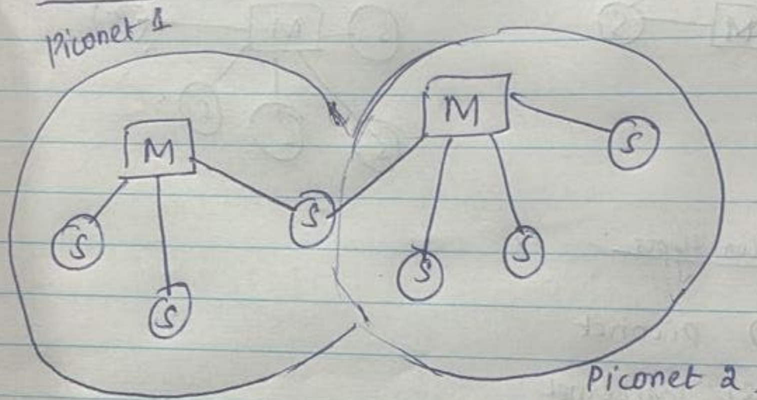
<u>PICONET</u> :-



Features

* One is called master and others are called slaves
* All slaves stations synchronizes their clocks with the master.
* Possible communication : One to one & One to many
* There may be one station in parked state.
* Each piconet has a unique hopping pattern/ID
* Each master can connect to 7 simultaneous or 200+ inactive (parked) slaves per piconet.

SCATTERNET :-



* By making one slave as master of another piconet, scatternet is formed by combining several piconets.
* A scatternet is an interrelated network of piconets where any member of a piconet may also belong to an adjacent piconet.
* Bluetooth network is infinitely expandable.
* A scatternet is the linking of multiple co-located piconets through sharing common master/slave devices

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iconet.

* A device can be a both master and a slave.
* A device cannot act as a MASTER for two piconets.
* A slave in one piconet is a master in another.
* device can be a master only in one piconet.

* Point to point or point to multipoint links.

Q.3 widespread use of wireless Applications :-

1) Use of higher Frequencies :-

* Advances in solid-state devices now allow amplification at millimeter wavelengths.
* These freq bands were previously too costly or impractical.

2) Efficient, Compact antennas are available.

3) Digital Modulation Techniques:-

* digital methods have replaced older analog systems, allow better spectrum efficiency.

* Multiple communication channels can now fit within the same bandwidth, supporting more users.

4) <u>Circuit Miniaturization :-</u>

* development of integrated circuits that combine analog and digital functions on a single chip has made wireless devices extremely compact & power-efficient.

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Q(4) → SRR :-

* RF power o/p :- Varies from a few microwatts to 100 milliwatts

* Communication Range : Can Cover distances from a few Centimeters to several 100 meters

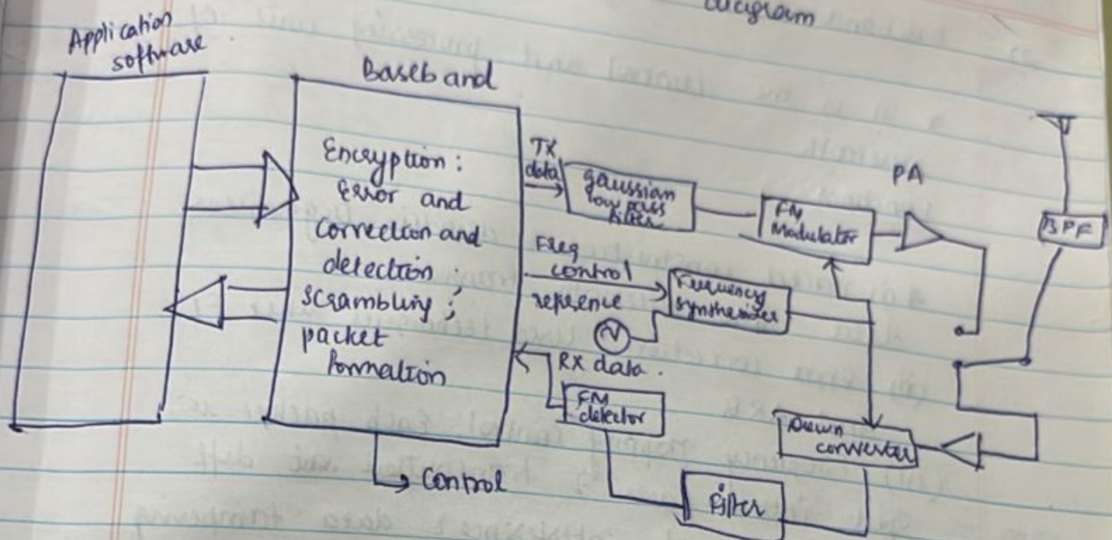
* Mainly designed for Indoor applications.

* Uses Omnidirectional - built - in antennas.

* Simple In design
* Relatively Low Cost
* Suitable for Consumer appliances

* Can operate with battery powered transmitters & Receivers (Low power Consumption)
* Supports Low → Medium data rates
* Works well for portable & mobile Consumer devices
* Commonly used in wireless keyboards, toys, remotes, sensors, smart home appliances.

5) Bluetooth Transceiver with diagram



* A bluetooth Transceiver is the heart of ~~the~~ a bluetooth enabled system enabling short range wireless communication.
* Three parts :-
  (i) RF section (Radio Frequency)
  (ii) Baseband section
  (iii) Application software.

1) Application software :-

* User data stream originates and terminates here.
* It resides in system controller (PC, smartphone, etc).
* Handles higher level communication tasks like pairing, data requests & user commands.
* Works through the bluetooth protocol stack providing services like audio streaming, file transfer or IoT data exchange.

2) Baseband Section (Digital Engine)

* It is the control and processing unit of bluetooth.

Functions:

(i) Packet construction & decoding: Organizes data into bluetooth frames.

(ii) Error correction: Uses techniques like FEC and ARQ.

(iii) Frequency Hopping control: Each packet is split into parts & transmitted at diff freq to avoid interference & data tampering.

(iv) Synchronization: Maintains timing b/wn master and slave devices in a piconet.

(v) Radio control: Directly manages frequency synthesizer for hopping b/wn channels.

3) RF - Radio ~~Front~~ Front-End Section:

* Deals with transmission & reception of signals over the air.

* Gaussian Filter: Smooths digital data before modulation to limit bandwidth.

* Modulator / Demodulator:- Converts digital signals to RF for transmission & extracts data during reception

* Frequency Synthesizer/VCO: Provides carrier signal & supports rapid FH.

* Receiver design: A superheterodyne receiver uses frequency mixing to convert signals into intermediate frequency. A direct conversion receiver directly converts RF signals to baseband using I/Q outputs & low pass filters.

=) Bluetooth protocol Timing :-

* BT uses time slots of 625 μs
* Transmission may occupy 1, 3 or 5 slots
* Communication always b/wn master & one or many slave.
* Point to point or point to multipoint links.

6) Compare and explain NRZ, RZ and Manchester encoding schemas (with diagram)

* NRZ (Non Return to Zero):

→ All signal levels remain on one side of the time axes (either above or below) and do not return to zero during a symbol transmission.

→ Types of NRZ:

- NRL - Level (NRZ-L):
  - → Voltage directly represents the bit value (+V → 1, −V → 0)
  - → Voltage level stays constant during the symbol period.
- NRZ - Inversion (NRZ-I):
  - → A transition or no transition determines the bit value
  - → '0' → maintains same polarity, '1' → Invert polarity from prev level.

→ Avg signal rate : N/2 Baud (Bd)

→ Simple to implement

→ Costly in power consumption } → disadvantages.

→ Poor performance in long sequences

(*) Diagram from ppt (*)

* RZ (Return to Zero):

→ Uses three voltage levels (+v, 0 & -v)

→ Each symbol has a transition in the middle of bit period.

→ Requires a wider bandwidth compared to NRZ

→ No DC component or baseline wandering

→ Self synchronization: the mid symbol transition helps the receiver synchronize with the signal.

→ More complex than NRZ (due to 3 voltage levels)

→ Still has no error detection mechanism.

* (*) Diagram from ppt (*)

* Manchester Encoding:

→ Uses two voltage levels (+V and -V)

→ Every symbol has transition in the middle of the bit period.

→ '1' → High to low transition.

'0' → low to high transition.

→ No DC component or Baseline Wandering

→ Self synchronization : the mid bit transition helps the receiver know exactly where the bit boundaries are.

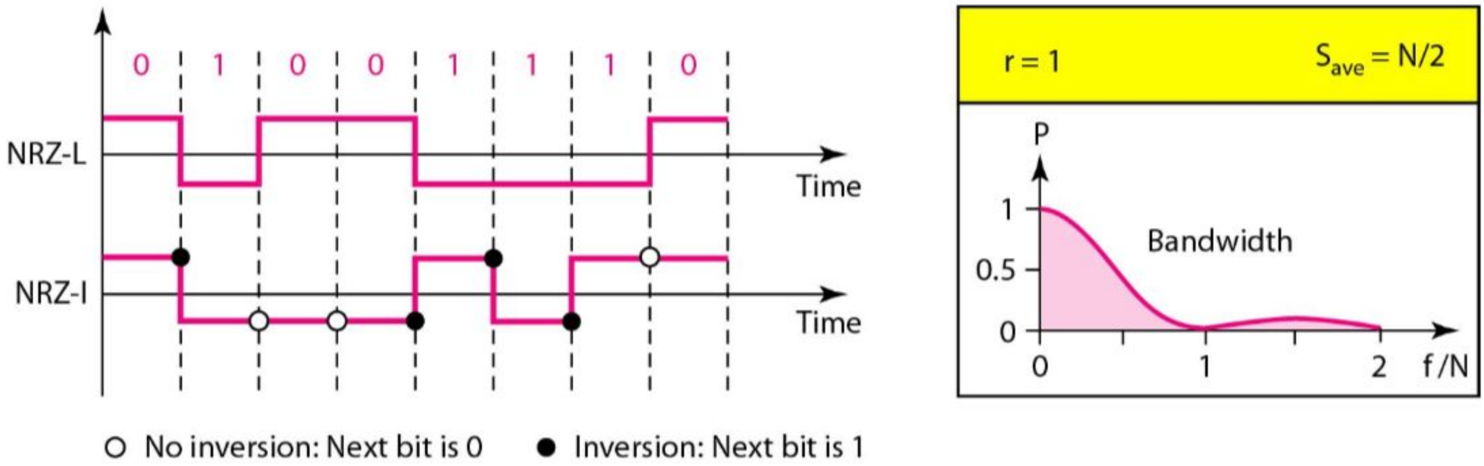
→ Minimum Bandwidth is twice that of NRZ due to guaranteed transition every bit.

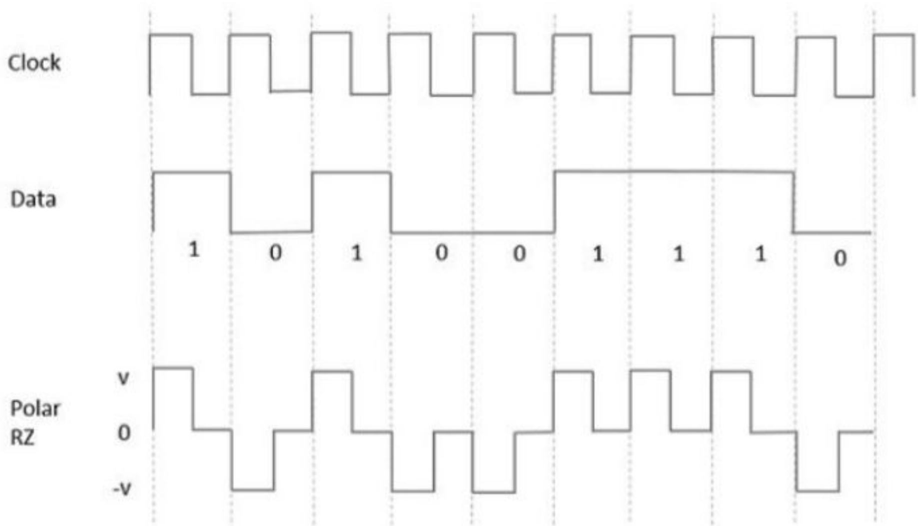
→ Simpler than RZ in terms of voltage levels (uses only 2 levels)

→ No error detection mechanism.

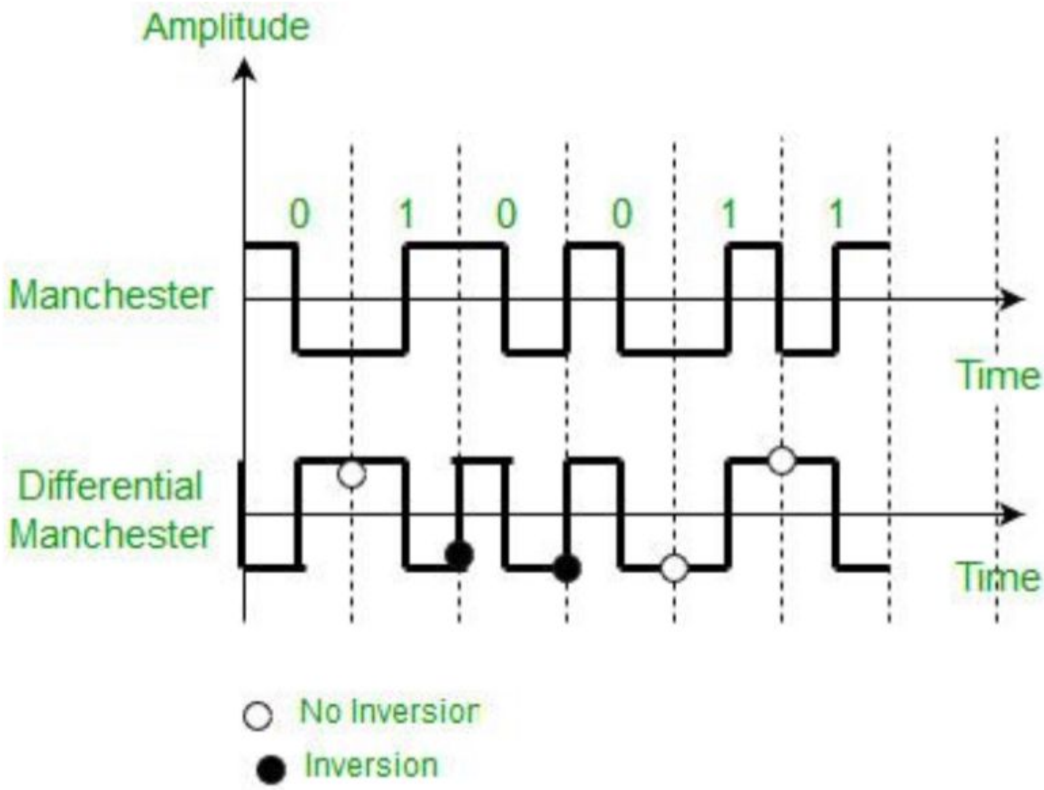
(*) Diagrams in PPT (*)

Figure 4.6 *Polar NRZ-L and NRZ-I schemes*




Clock
Data
1 0 1 0 0 1 1 1 0
Polar
RZ
v
0
-v

Manchester and Differential Manchester



→ Dynamic Mic:

* Durable, no external power needed.
* Ideal for field reporting.

→ Condenser Mic:

* High audio quality but needs power.
* used in studios and broad casts.

7) DIPOLE ANTENNA:

→ consists of 2 wires or rods, each about $\lambda/4$ long, making the total length $\lambda/2$. It is fed at center.

→ Radiation Resistance : 73 Ω in free space.

→ Mounting: Usually horizontal; if vertical, feeder cable extends at right angle by at least $\lambda/4$

→ Radiation Pattern: Broadside pattern with directivity 1.64 (2.15 dB). Indoors, reflections enable good omnidirectional behaviour

→ Advantages:

* Easy impedence matching.
* No ground plane needed
* Small devices can feed directly
* High efficiency.

→ Disadvantages:

* Too large for short ranges
* Less effective as a single element.

Types:

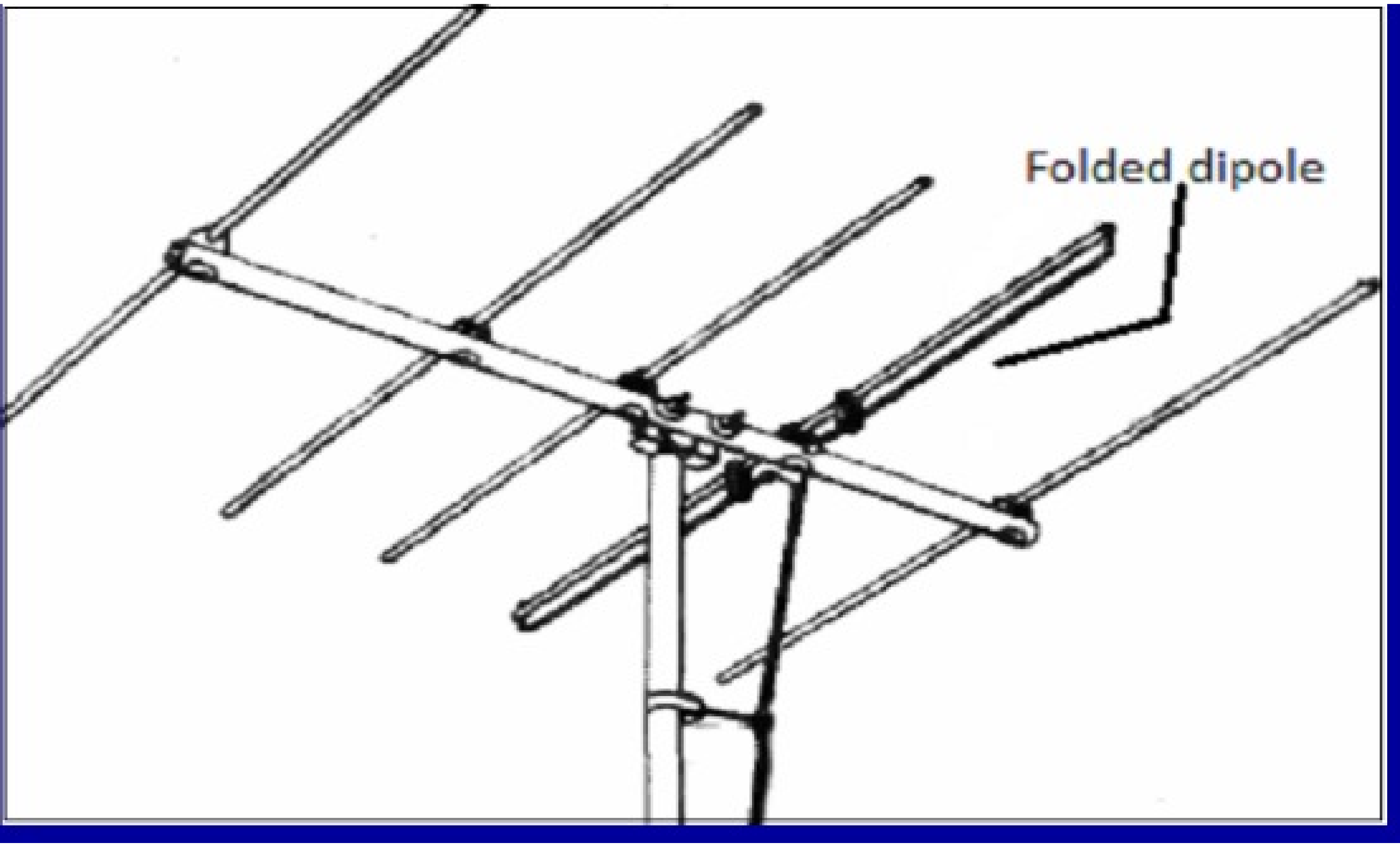
→ Half wave dipole antenna:

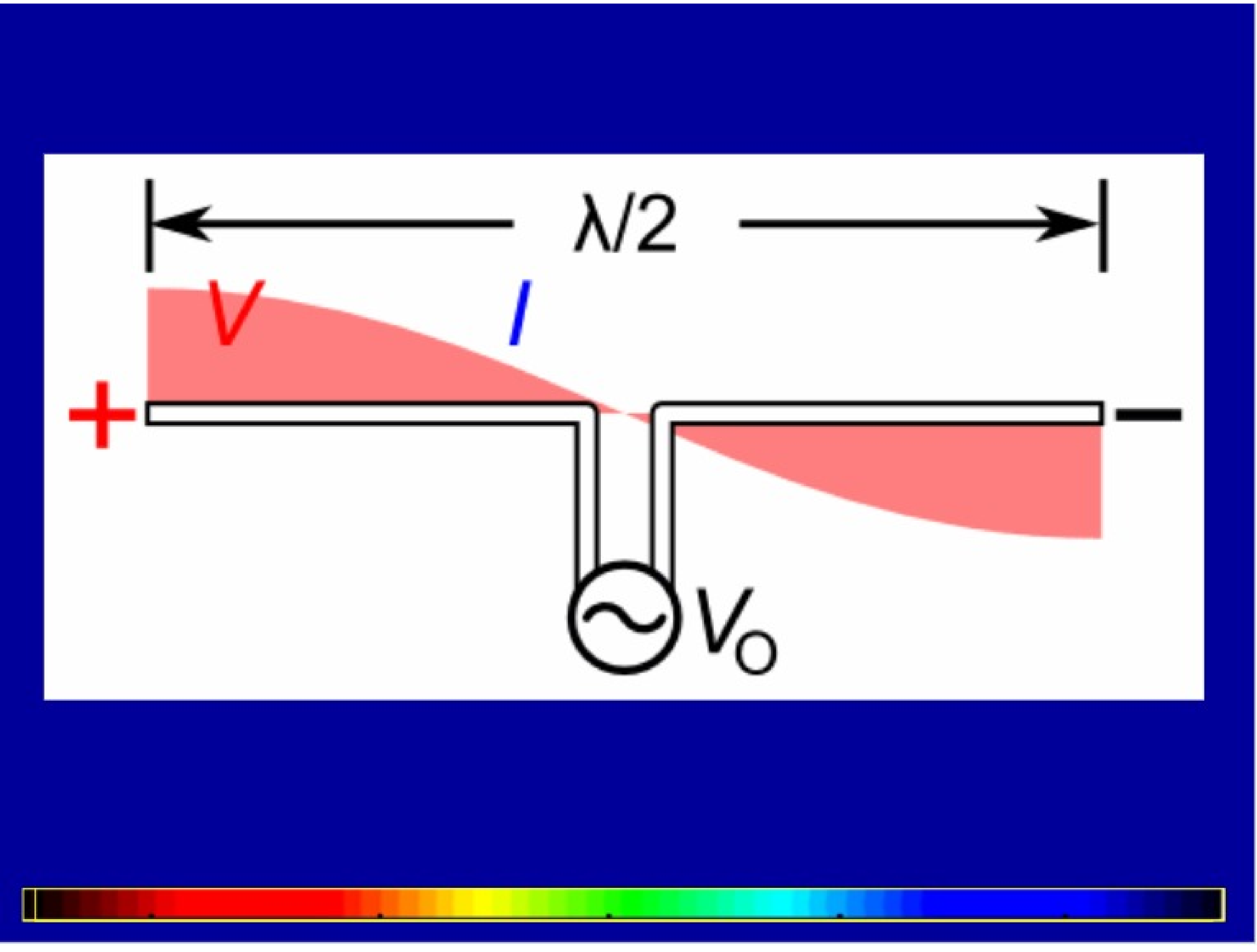
* Most common type
* Total length $\approx \lambda/2$
* Easy to match impedence ($\approx 73\,\Omega$)
* Not suitable for short range portable devices.

→ Folded Dipole Antenna:

* Consists 2 parallel conductors connected at ends.
* Main element in Yagi_Uda antennas (Used in TV reception)
* Stable input impedence.
* Matches well with transmission lines.

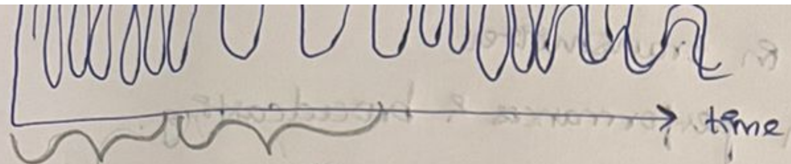
※ Diagram from PPT ※


Folded dipole



λ/2
V
I
+
−
V0

carrier frequency set)



2 different frequencies

(1 - 1st freq
0 - 2nd freq)

8) Working principle of a wireless microphone & its types.

Ans A wireless microphone operates by converting sound waves into an electrical signal and transmitting it wirelessly to a receiver.

Working principle:

→ Microphone : Converts soundwaves into electrical audio signal.

→ Transmitter : * Applies preemphasis and compression

* Modulates the audio signal onto a RF carrier (AM, FM or PM)

* Sends the RF wirelessly

→ Receiver : * De Modulates the RF signal to Retrive audio

* Applies de-emphasis and expansion

* Outputs the clean audio to speakers.

Diagram from PPT

Types :

→ Hand held :

* Built in transmitter

* used in performances & broadcasting.

→ Body pack :

* Seperate transmitter

* connects lavalier, headset or instrument mics.

* Ideal for mobility

→ Omnidirectional mic :

* Picks sound equally from all directions

* Ideal for ambient sound.

→ Cardioid Mic :

* Picks sound mainly from the front.

* Rejects ambient noise.

→ Hyper cardioid mic :

* Very directional.

* Used on boom poles in controlled settings

→ Dynamic

→ Conde

→ Dynamic Mic:

* Durable, no external power needed.

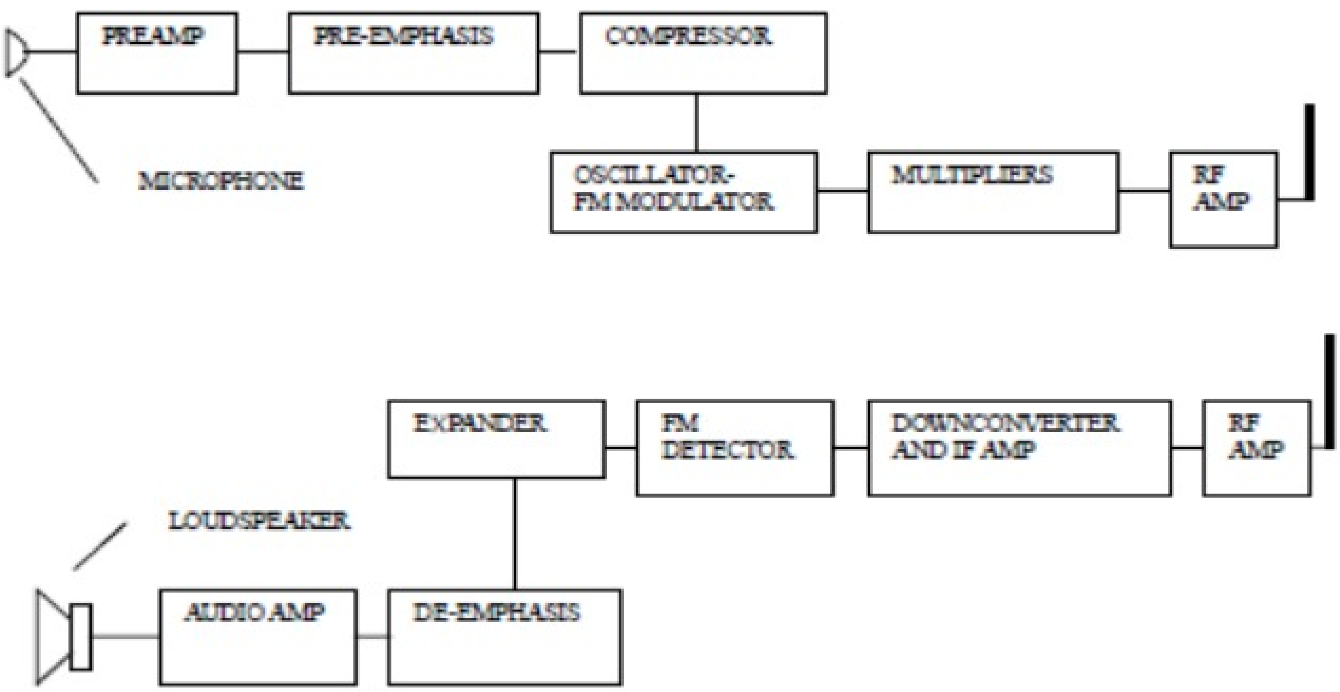
* Ideal for field reporting.

→ Condenser Mic:

* High audio quality but needs power.

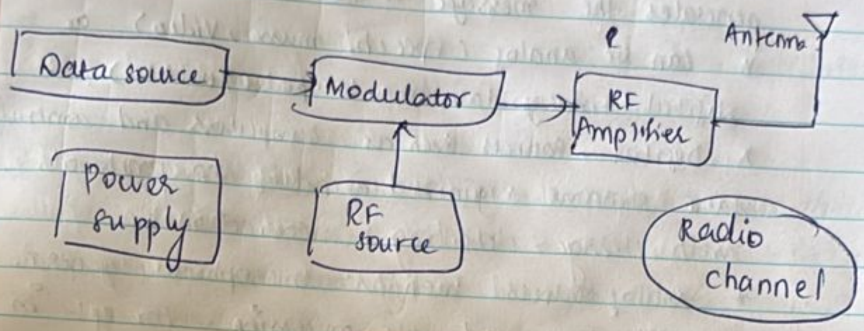
* used in studios and broadcasts.

Wireless Microphone System

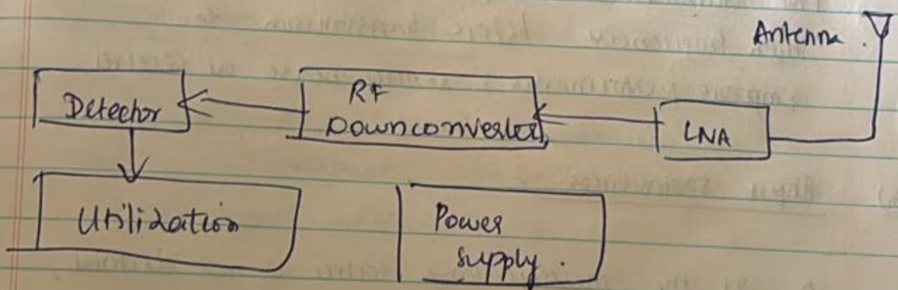


4) wireless communication systems :-

TRANSMITTER



Receiver



Components :-

1) Data source
2) Input Transducer
3) Transmitter.
4) Communication Channel.
5) Receiver.
6) Destination.

* A wireless communication system allows transmission of information from one point to another w/o any physical connections by using electromagnetic waves.

1) <u>Data Source :-</u>

* System begins with information source which generates the message to be communicated.
* Can be analog (speech, music, video) or digital (binary data from computer, WLANs).
* Digital sources such as computers and continuous data streams organized according to protocols with error detection & correction.
* Analog sources such as microphones generate signals that need pre-processing. For eg:- in FM transmission, a pre-emphasis filter boosts high frequencies before transmission to improve performance & reduce noise at receiver.

2) <u>Input Transducer :-</u>

* If the message from source is not electrical, it must be converted into electrical form.
* It is done using an input transducer.
Eg:- A microphone converts sound into electrical signal. This ensures that the message can be processed by the transmitter.

3) <u>Transmitter :-</u>

<u>Functions :-</u>

* <u>Amplification</u> :- Increases signal strength before Modulation.

* **Modulation** - Superimposes the message signal onto a high-frequency carrier wave for efficient transmission.

* **RF Generation** - Involves oscillators, modulators & amplifiers.

* **Antenna and Radiation** :- antennas radiate the modulated signal into space. For short-range devices, antennas are usually small, omni-directional & often build into devices.

4) Communication Channel :-

* The radio channel is a medium through which electromagnetic waves propagate. For short-range wireless systems :-

* Range is limited, often indoors.
* Transmission power is regulated by telecom authorities.
* The human body or environment can affect signal quality.
* Propagation is less predictable compared to wired channels.

Thus, channel effects are attenuation, interferance and fading must be considered in system design.

5) Receiver :-

* Receiver works opposite to the transmitter

Functions:-

* Demodulation:- Extracts the original message signal from distorted carrier.
* Amplification & Filtering : Improves signal quality
* Selectivity & Sensitivity: Ensures receiver captures only desired signal while minimizing interference

6) Destination :-

* It is the end-user's o/p stage.
* Converts ~~the~~ received electrical message into its original form.
* Eg:- Loudspeaker in radio broadcasting converts electrical signal into audible sound.

7) Power supplies:

* Wireless systems require reliable power.
* Transmitters often operate intermittently to save energy (Eg:- security system).
* Receivers usually consume more power since they must always be active to detect incoming signals.
* Techniques like standby modes & duty cycle reduction are used to extend battery life.

Q.10 Power conservation in wireless devices :-

(Same as the "power supplies" part from Q.9 ("wireless communication system" question)

VARIOUS POWER MODES IN BT technology :

Bluetooth has 3 modes for achieving different degrees of power consumption during operation:-

1) sniff
2) hold
3) park.

Even in normal active mode, power saving can be achieved.

1) Active mode :-

* Normal operating state where slave communicates with master.
* Slave transmits only if addressed by master in the previous slot.
* If not addressed, slaves enter a temporary low-power "sleep" until the next master transmission.
* saves power by avoiding unnecessary listening.

2) Sniff mode :-

* Slave listens ~~at~~ at pre-defined intervals instead of every slot.
* If not addressed in the sniff slot, it goes back to sleep until next sniff interval.
* Extends sleep time & reduces power consumption further when compared to active state.

3) Hold Mode :-

* Master can suspend data transfer with slave for a specific time.
* During this period, the slave can :-
  (i) enter low-power sleep (or)
  (ii) Join another piconet while still keeping membership in the original one.
* After the hold time, the slave resynchronizes with the master.

4) **Park Mode :-**

* Provides maximum power saving among all modes.
* Slave gives up its active address and receives a parked member access.
* Cannot communicate directly but remains synchronized with piconet through periodic beacon signals from master.
* Park mode also increases network capacity, allowing upto 255 parked devices in addition to 7 active ones.
* A parked device can rejoin active network when invited or on its own request.

12) ~~DIRECT SEQUENCE~~

11)

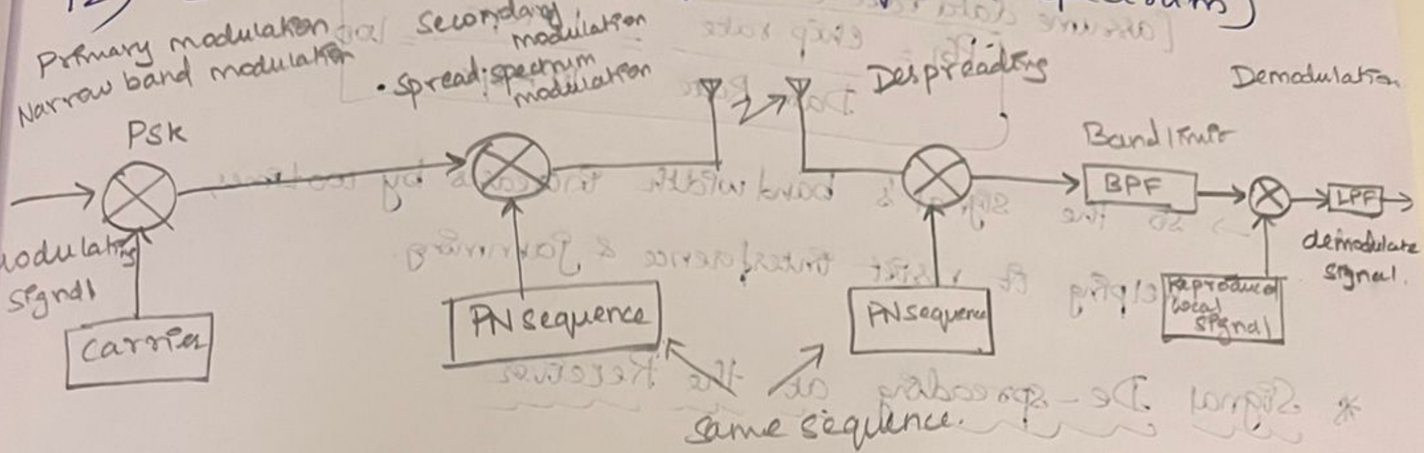
Modulation

- Analog
  - Amplitude
  - Frequency
  - Phase
- Digital.
  - Amplitude shift keying
  - Frequency shift keying
  - Phase shift keying

Analog modulation	Digital modulation
→ Continuous wave form	→ Descrete levels
→ Low Noise Immunity	→ High Noise Immunity
→ Less Bandwidth efficiency	→ More Bandwidth efficient
→ Higher Power requirement	→ Lower power requirement.
→ Simpler hardware	→ complex hardware.
→ Difficult error detection	→ Easier to implement
→ Applications: AM/FM radio, radar, seismic monitoring	→ Applications: WIFI, Bluetooth, optical communication

$\boxed{S = 50k \text{ baud.}}$

12) DSSS (Direct Sequence Spread spectrum)



→ Direct Sequence Spread spectrum is widely used Spread spectrum communication technique where the data signal is multiplied by a pseudo random high rate code sequence known as spreading code or chipping code, before transmission.

* Signal spreading in DSSS:
  → In DSSS, the original data signal m(t) is combined with a high speed pseudo random spreading code c(t) running at, say 1 MCps.

→ The combination is done by XOR.

$$\boxed{d(t) = m(t) \oplus c(t)}$$

→ This spreads the signal across a much wider bandwidth – making it look like random noise.

→ The spreading Gain (Process Gain):
[assume data rate (m(t)) = 10kbps]

$$\boxed{PG = \frac{\text{Chip rate}}{\text{Data Rate}} = \frac{1\ \text{Mcps}}{10\ \text{kbps}} = 100}$$

→ So the signal's bandwidth increases by 100 times, helping it resist interference & jamming.

* Signal De-spreading at the Receiver

→ The receiver generates the same spreading code c(t) in perfect synchronization with incoming signal.

→ It then applies XOR again:

$$\boxed{m'(t) = d(t) \oplus c(t) = (m(t) \oplus c(t)) \oplus c(t) = m(t)}$$

→ This removes the spreading effect and recovers the original data m(t).

* Role and Effect of the chipping code:

→ The chipping code spreads the signal, making it appear as noise & improving security.

→ It protects against narrowband interference & jamming.

→ It also allows multiple users to transmit in the same frequency band using different spreading codes.

→ The higher the chip rate compared to data rate, the wider the signal's bandwidth.

14). Patch Antenna:

Construction:

A microstrip patch antenna consists of :

1. Patch (Radiating element):

* Geometric plated shape. (rectangular or circular)
* Mounted on one side of a dielectric substrate

2) Dielectric substrate:

* Separates the patch and the grounded plane.
* Its effective dielectric constant influences the resonance.

3) Ground plane:

* A conducting plane opposite the patch.

4) Feed Mechanism:

* Feeds RF power to the patch
* Methods:
  - → contacting feed: Microstrip line feed or coaxial probe.
  - → Non contacting feed: Aperture coupled or Proximity coupled.

Working principle:

→ The patch behaves like resonant cavity, where the electric field is concentrated between the patch & ground plane.

→ patch Length (L) : $L \approx \frac{\lambda}{2\sqrt{\varepsilon}}$

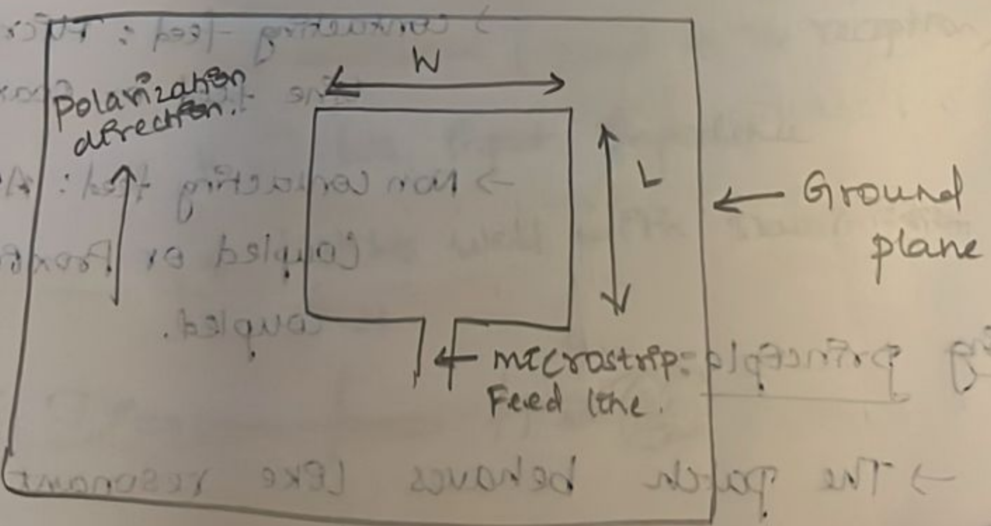
→ maximum radiation occurs perpendicular to the patch plane.

→ Feed impedence depends on patch size & feed position

→ a 50 Ω coaxial line connects ~~via~~ directly with the center conductor going through a via to the feed point and the shield connected to the ground plane.

→ Feed methods :

* Microstrip Line Feed.
* Coaxial Probe Feed.
* Aperture coupling.
* Proximity coupling.



→ Bluetooth &
(17) Zigbee Standards :-

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BLUETOOTH	ZIGBEE
(1) Based on IEEE 802.15.1 standard	* Based on IEEE 802.15.4 std.
(2) Follows "FHSS" transmission scheme (freq. hopping spread spectrum)	* Follows "DSSS"
(3) Moderate to High power consumption	* Very low power consumption, ideal for battery powered devices
(4) Cost is higher due to complex hardware	* Cost is lower due to simple, low-cost chips.
(5) N/K supports piconet & Scatternet	* N/K supports star, Tree & mesh Topologies
(6) Data rate is high : 1-3 Mbps	* Data rate is low: 20-250 Kbps
(7) Latency is very low ; good for real time applications	* Latency is higher, good for periodic data
(8) Used in wireless headsets, speakers, smartwatches, keyboards	* Used in smarthomes, industrial automation, & IoT sensors

→ The higher the chip rate compared to data rate, the wider the signal's bandwidth.

18) (i) Impedence:

→ The antenna impedence is the load for the transmitter or the input impendence to the receiver

→ It consists of Radiation Resistance (R_R) and Ohmic Resistance (R_I)

→ Radiation resistance relates to the power radiated or received and depends on antenna environment & height above ground

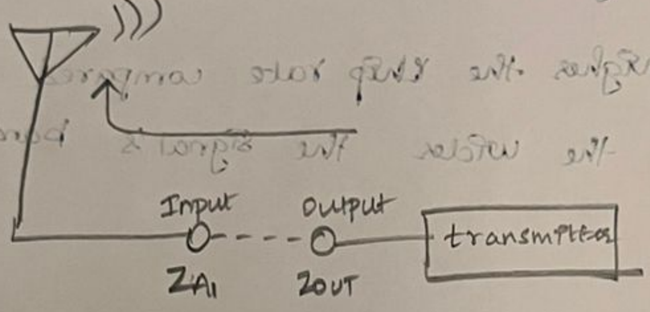
Total power loss = Ohmic loss + Radiation loss

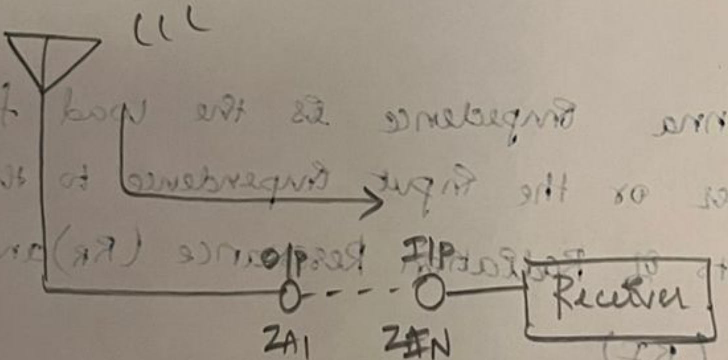
$$W = W' + W''$$
$$= I^2 R_R + I^2 R_l$$
$$= I^2 (R_R + R_l)$$
$$= I^2 R$$

→ Efficiency of Antenna:

Antenna Efficiency (%) = $100 \times \left(\frac{R_r}{R_r + R_L}\right)$

→ Maximum power transfer occurs when the impendence at the antenna terminals matches the complex conjugate of the transmitter/receiver impendence.





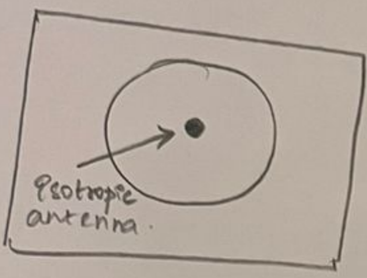
(ii) Directivity:

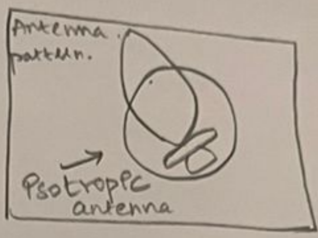
→ Directivity describes the directional radiation pattern of an antenna.

→ Defined as the ratio of power density in the direction of maximum radiation to average ~~to~~ power density.

→ An isotropic antenna radiates equally in all directions.

~~isotropic wave~~





(iii) Gain.

→ Gain = Directivity × Antenna Efficiency.

→ Efficiency depends on power loss

→ When losses are small, Gain ≈ Directivity.

→ Gain is used to calculate the maximum radiated power when the I/P power is known.

(iv) Effective Area (A_e)

→ Effective area relates to the antenna's ability to capture power from an incoming wave.

→ $A_e = \dfrac{G \times \lambda^2}{4\pi}$

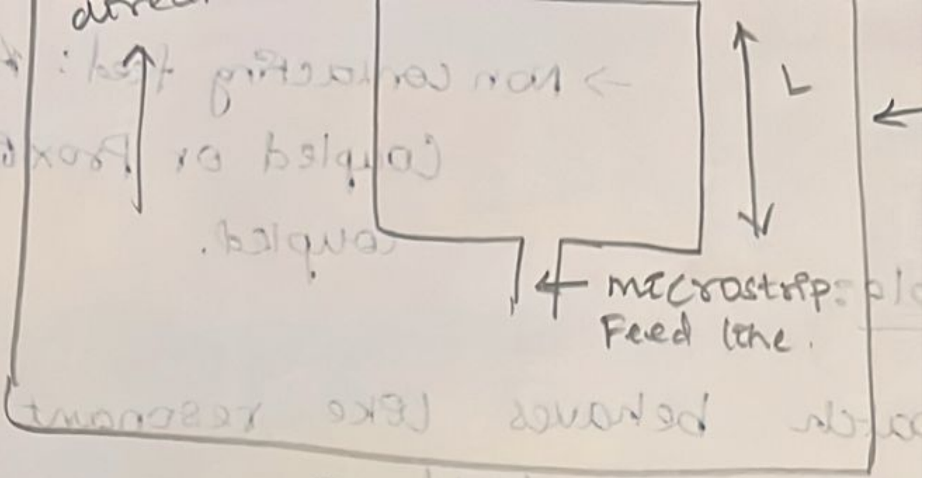
→ Higher frequencies → smaller wavelength → small effective area

→ When Electric field strength is known;

$$P_d = \frac{E^2}{120\pi}$$

→ Received power is $A_e \times P_d = P_r$

$$P_R = \frac{E^2 G \lambda^2}{480\pi^2}$$ //



19) $r = 1$

$N = 100 \text{ kbps} = 100000 \text{ bps}$

$C =$ assume average value is $1/2$

$S =$ baud rate

$$\boxed{S = C \times N \times \frac{1}{r}}$$

$$S = \frac{1}{2} \times 100000 \times \frac{1}{1}$$

$$= \frac{100000}{2} = 50000$$

$$\boxed{S = 50k \text{ baud.}}$$

20) Frequency Hopped Spread Spectrum (FHSS) =

* Frequency Hopped spread spectrum is a technique where the carrier frequency of the transmitted signal is changed systematically over a wide band of frequencies during communication.

* How it works:

→ The transmitter and receiver share a pseudo random hopping sequence and switch frequencies in sync.

→ Data is sent over a seemingly random series of frequencies, making it hard for eavesdroppers to intercept.

→ Jamming one frequency only affects a small part of data, improving resistance to interference.

Types of FHSS:

→ Slow FHSS:

→ Hopping rate is slower than the data symbol rate

→ $T_c \geq T_s$ } → T_c = dwell time, T_s = Symbol duration.

→ Multiple symbol are transmitted during same freq hop.

→ Easier to implement

→ Lower hardware complexity.

→ Less Resistant to fast jamming.

→ Fast FHSS:

→ Hopping rate is faster than the data symbol rate.

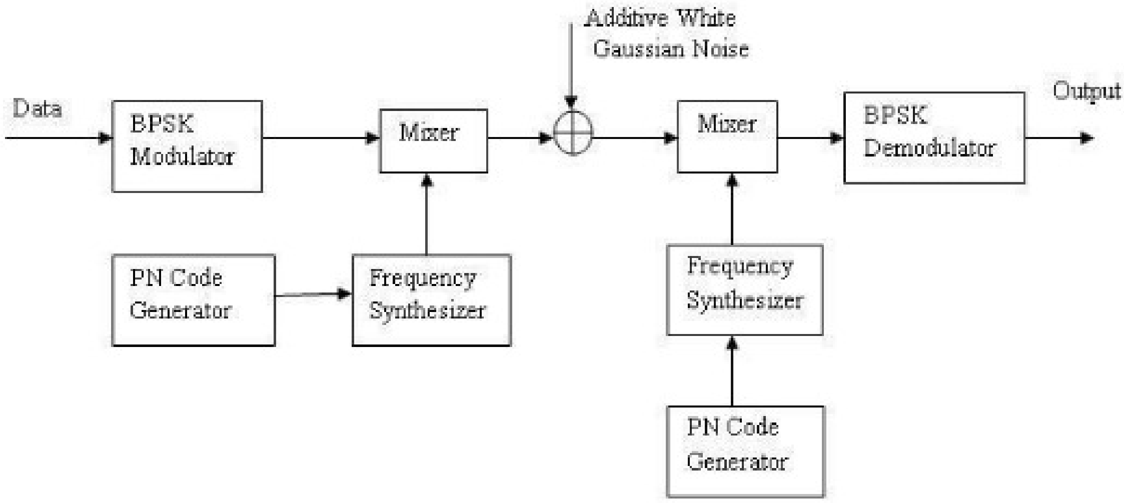
→ $T_c \leq T_s$

→ a single symbol is spread over multiple frequencies.

→ Better resistance to narrowband interference & jamming.

→ Provides better performance in noisy environments

→ More complex to implement.

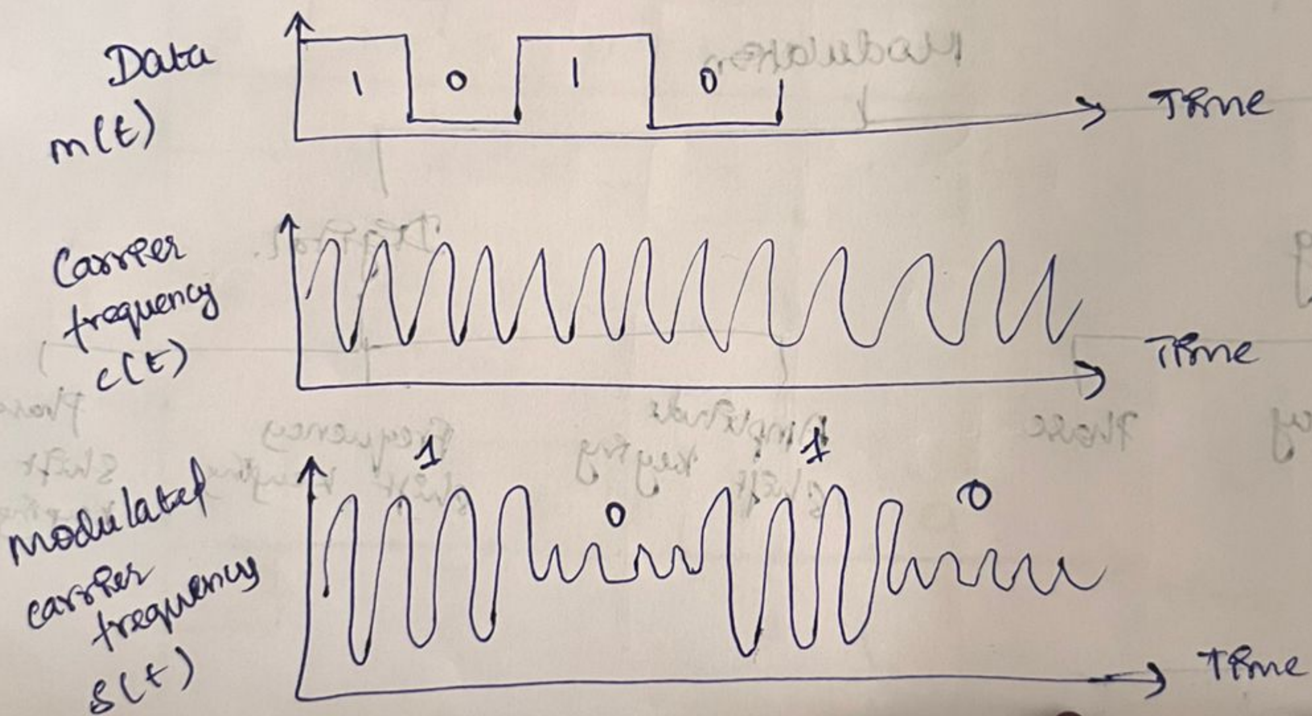

Additive White
Gaussian Noise
Data
BPSK
Modulator
Mixer
Mixer
BPSK
Demodulator
Output
PN Code
Generator
Frequency
Synthesizer
Frequency
Synthesizer
PN Code
Generator

-> Difficult error detection

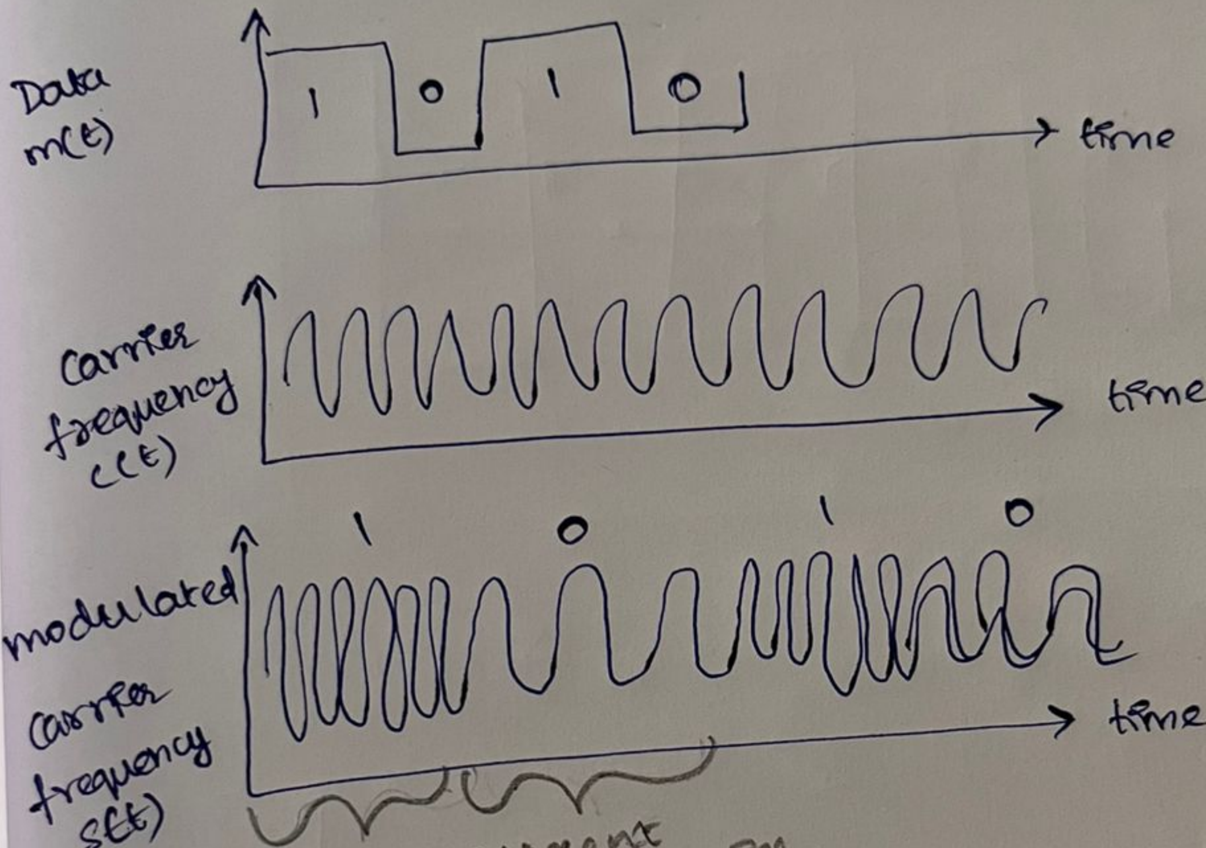
-> Applications: AM/FM radio, radar, seismic monitoring

-> Applications: WIFI, Blue optical communic

21) Waveform of Amplitude shift keying:



Waveform of Frequency shift keying:



2 different
frequencies.

(1 - 1st freq
0 - 2nd freq)

Comparison of DSSS and FHSS

Spreading Method	Merits	Demerits
Direct Sequence	i) Simpler to implement ii) Low probability of interception iii) Can withstand multi-access interference reasonably well	i) Code acquisition may be difficult ii) Susceptible to Near-Far problem iii) Affected by jamming
Frequency Hopping	i) Less affected by Near-Far problem ii) Better for avoiding jamming iii) Less affected by multi-access interference	i) Needs FEC ii) Frequency acquisition may be difficult