7/1/2020.

- MC can use any device/ compute the mobile (moving) devices.
  e.g. phone, laptop.
- In MC, atleast one device must be in movement.
  e.g. wifi, Bluetooth, Infrared, Internet, (applications of MC)
  Satellite, GPS, GSM, GPRS.

Applications of MC

- Horizontal
- Vertical

vhf : very high frequency.
uhf : ultra high frequency.
hf : high frequency

Def^n of MC

- Mobile Computing is the ability to use technology while moving.
- It is a term used to describe technologies that enable people to access network services any place, any time and anywhere.
- MC is to work from a non-fixed location using portable computing or communication devices such as laptops, notebooks, PDAs, smart cell phones etc.
- This technology enables the mobile workers to create, access, process, store and communicate information without being constrained to a single location.

→ Technologies that enable MC

* Wireless LAN (WLAN)
* Satellite.
* Cellular Digital Packet Data (CDPD)
* Personal Communication System (PCS)
* Global System for Mobile Communication (GSM).
* Specialised Mobile Radio Service (SMR)
* One and two-way paging handover.
* Plane old telephone system (POTS)
* Internet.
* Infrared.
* Docking (serial, parallel or LAN).
* Disk Swapping.

→ Applications of MC

MC applications are divided into two categories.

i) Horizontal : It is broad based application and includes S/W.
e.g. email, web browsing, word processing, scheduling, messaging, to-do list, presentation.

ii) Vertical : It is industry-specified.
e.g retailing, utilities, warehousing, shipping, law enforcement and public safety.

• Mobile Communication :

- Mobile communication entails transmission of data to and from handheld devices.
- Out of two or more communication devices, at least one is handheld / mobile.

- The location of device can vary either locally/globally and communication takes place through a wireless, distributed, diversified network.

- Communication can be
  i) guided
  ii) unguided.

Guided transmission:

	Optical Fibre	Coaxial Cable	Twisted-pair cable
Range:	10^3 km	40 m	2 km, 100 m
Max frequency:	2×10^4 Hz	500 MHz	100 KHz, 200 MHz

Power line
Below 525 KHz

Adv:

Multiple sources can transmit simultaneously. (using multiplexing and coding)

Directed Path (point-to-point)
very little interference between the cables.

Disadvantages of transmission through cables:

* Signal transmitter and receiver are fixed (immobile). Hence, there is no mobility of transmission and reception points.

* No transmitter and receiver systems limit the total no. of interconnection possible.

Scanned by CamScanner

Unguided Transmission / Wireless.

It is carried out through radiated electromagnetic energy.

Signal Propagation.

- Electrical signal are transmitted by converting them into electromagnetic ~~signals~~ radiation. This radiation is transmitted via antenna that radiates electromagnetic signals.
- There are various frequency bands within electromagnetic spectrum and all have different transmission requirement.
- We consider two frequency range for wireless transmission:
  - i) vhf : Very High Frequency.
  - ii) uhf : Ultra High Frequency → $\lambda/4$ length.

$$\boxed{f = \frac{c}{\lambda}}$$

f in Hz
λ in m.
For air, $c = 3 \times 10^8$ m/s

** Remember Frequencies of VHF, TVVHF, UHF.

VHF
R ~ 50 km.
f ~ 50-250 MHz.

TV. VHF.
f ~ 174-230 MHz

Advantages

* Frequency modulation & multiple frequency band transmission is possible.
* Transmitting antenna length is 3m to 60 cm (due to small $\frac{\lambda}{2}$ length)

Disadvantages.

* Mobility is not practical as transmitting and receiving antenna length is 3m to 60 cm and a directed multi-dipole or disk antenna is required at its receiving end.

UHF
f : 200 - 2000 MHz

GSM
f : 890 - 960 MHz

DECT & 3G.
f : 1880 - 2890 MHz

Digital Audio Broadcasting

Advantages

* Multiple frequency bands, modulation methods, multiplexing and coding are feasible due to the availability of greater bandwidth.
* Mobility is quite practical.

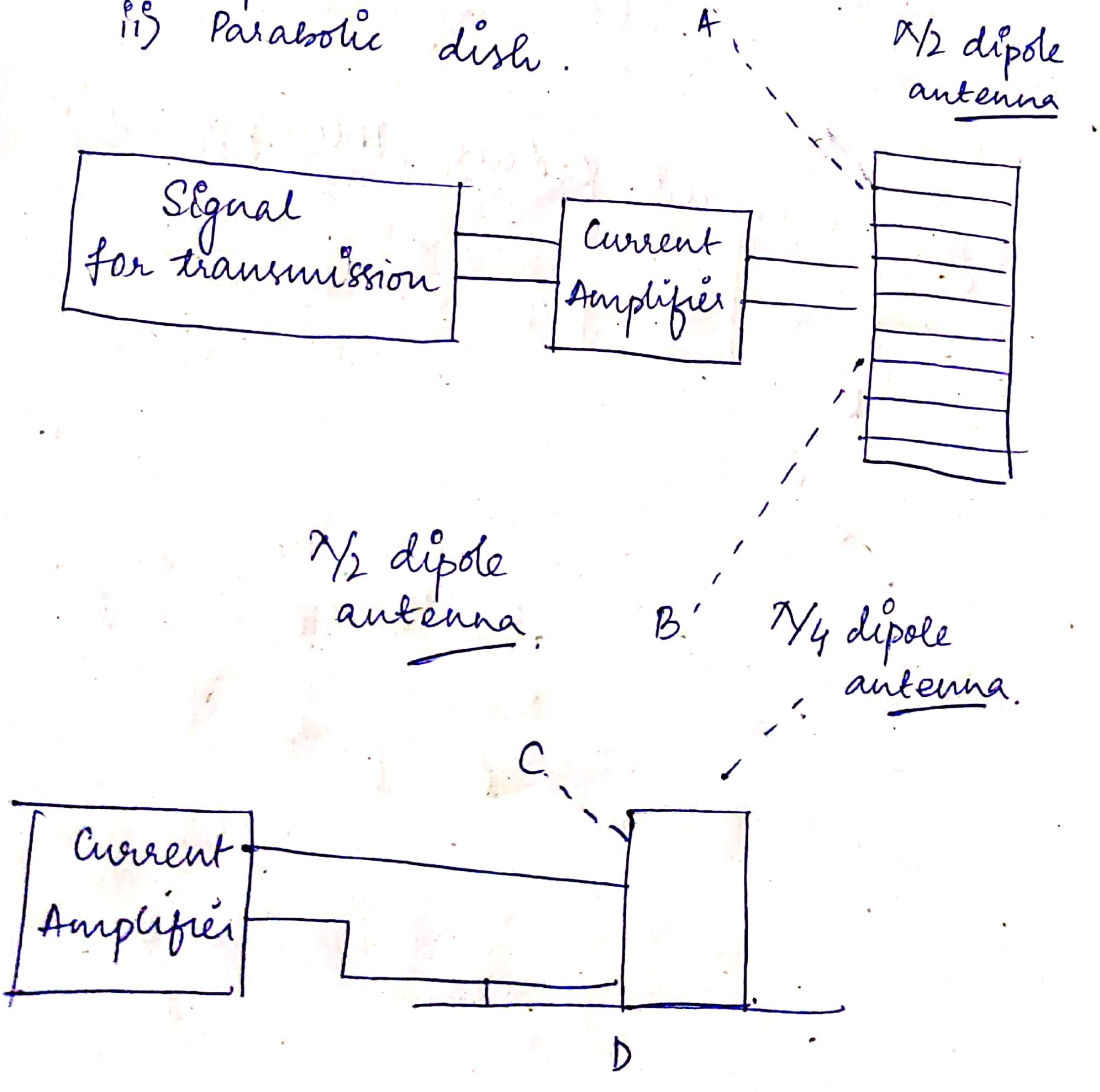
Disadvantages

* Signal quality degrades due to loss within buildings and reflection from large buildings.
* A large no. of base stations are required at separation of about 1 to 5 km each.

DECT : Digital Enhanced Cordless Telecommunication.

14/1/2020

- Antenna is a device that transmits and receives electromagnetic signals.
- Normally, antenna functions properly for narrow frequency range.
- If an antenna is not properly tuned to the frequency band in which transmitting system connected to it operates, the transmitted / received signal may be impaired.
- The types of antenna based on the frequency range on which they operate. It can be:
  i) Dipole antenna.
  ii) Parabolic dish.



$\lambda/2$ and $\lambda/4$ antenna are called dipole antenna as at any given instant, both ends A and B are 180° out of phase.

Q) A 200 MHz to 2000 MHz UHF signal is to be transmitted wirelessly. Calculate the length of dipole antenna required for the transmission.

Sol) length $= \frac{\lambda}{2}$.

$c = f\lambda$

$\Rightarrow \lambda_1 = \frac{c}{f} = \frac{3 \times \cancel{10^8}}{2\cancel{00} \times \cancel{10^6}} = 1.5\ m$.

$\therefore$ length$_1 = \frac{1.5}{2} m = 0.75\ m = 75\ cm$.

$\lambda_2 = \frac{c}{f} = \frac{3 \times \cancel{10^8}}{2\cancel{000} \times \cancel{10^6}} = \frac{3}{20}\ m$.

$\therefore$ length$_2 = \frac{\lambda}{2} = \frac{3}{20 \times 2} = \frac{3}{40} = 0.075\ m = 7.5\ cm$

So, Range of antenna = 7.5 cm to 75 cm

Basically $\lambda/4$ dipole antenna is mounted on a long conducting surface.

e.g. roof of a car, moist ground surface.

At any time, the end C and surface D are 180° out of phase.

The original and the reflected waves then superimpose and create the same electrical effects as in $\lambda/2$ antenna.

** In general,

Length of antenna $\propto$ wavelength

$$\propto \frac{1}{\text{frequency of transmitted signal}}.$$

Assignment

Q) A dipole antenna is to be mounted on a conducting surface ($\lambda/4$). Calculate the length of the required antenna to transmit the GSM signal of 900 MHz.

Sol)

$$L = \frac{\lambda}{4}$$

$$c = f\lambda.$$

$$\Rightarrow \lambda = \frac{c}{f} = \frac{3\times 10^8}{900\times 10^6} = \frac{1}{3}\,m = 0.333m = 33.3cm.$$

$$L = \frac{1}{12}\,m = 8.32\ cm.$$

- The radiation pattern of a given antenna defines a path on which each point will have identical signal strength at any given instant.

- A circular pattern means the radiated energy and thus the signal strength is equally distributed in all dir^a on the plane. and the radiated enery

→ Propagation of signal :

- Wireless propagation of signal faces many complications as the antenna height and size at mobile terminals are very small.
- In order to minimise the significant influence of obstacles, propagation routes have to be specially designed and calculated taking into account of various types of propagation loss.
- Also, the propagation properties vary with place and time for a mobile terminal. So, generally, statistical propagation model are used whereby no specific data paths are considered, rather the channel parameters are modelled as stochastic variables. (Probability-based random variables)

Parameters which affect the propagation of a signal :-

i) Line of sight

↳ It is the transmission of signals without diffraction, refraction or scattering in between the transmitter and the receiver.

↳ Signal strength in free space decreases as the square of the distance from the transmitter because at larger distances, the radiated power is distributed over a larger spherical surface area.

imp Q) A transmitter sends a signal which has a strength of $9 \mu w / cm^2$ at a distance of 500 m. Assuming free space propagation in line of sight, calculate the signal strength at 1500 m.

iv)

ii) Attenuation

↳ Signal strength also decrease due to attenuation when obstacles in the path ~~are~~ of signal are greater in size than the wavelength of the signal.

e.g. (imp) * If an FM Radio transmitter sends out 90 MHz FM band signal ($\lambda = 3.3$ m), then the signal will be attenuated by an object of the size 10m and above.

* If a transmitter sends a GSM signal of 900 MHz ($\lambda = 0.33$ m), then it will face attenuation in objects of size > 1m.

iii) Scattering of signal.

↳ A signal scatters when it encounters an obstacle of size equal to or less than the wavelength

e.g. A GSM signal about 33 cm in wavelength is scattered by an object of 33 cm or less.

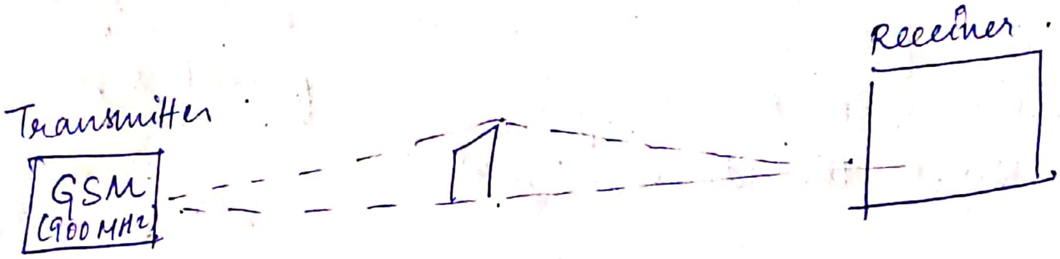
Only a small part of scattered signal reaches the receiver.

iv) Diffraction of signal.

↳ A signal bends as a result of diffraction from the edge of an obstacle of size equal to or less than the wavelength.

e.g. A GSM signal ($\lambda = 33$ cm) is diffracted from an object of 33 cm or less.

↳ A diffracted signal may or may not reach at the receiver depending on the geometry of obstacles and the separation between the object receiver and the transmitter.



v) Reflection of signal..

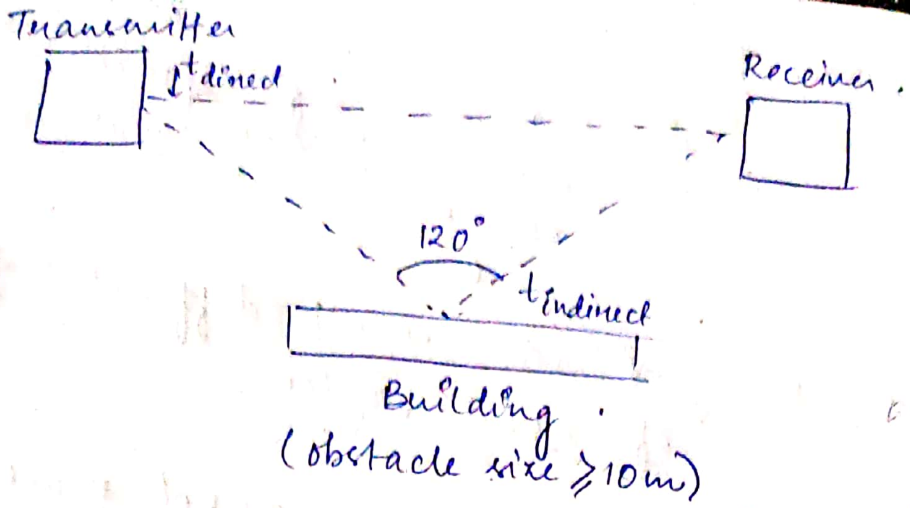
↳ A signal may get reflected from the surface of the obstacle when its ~~wavel~~ size is greater than the wavelength of the signal.

e.g. GSM signal (900 MHz) reflects when obstacle size ≥ 10 m.

↳ Reflected signal suffers a delay in reaching its destination.

$$\text{Delay} = t_{indirect} - t_{direct}.$$

$$= \frac{\text{additional path travelled in meters.}}{3 \times 10^8 \text{ m/s}}.$$



Assignment

Q) A receiver receives two signals - one directly in line of sight and other after a reflection at 120° from a transmitter at a distance of 1000m. Calculate the delay in the reflected signal w.r.t the direct signal.

Sol) $$\text{Delay} = t_{direct} - t_{indirect}$$

$$= \frac{1000}{3\times10^8} - \frac{1000}{\sin(120°)\times3\times10^8}$$

$$= 3.33\,\mu s - 2.85\,\mu s$$

$$= 0.52\,\mu s.$$

Module-1

Overview of Wireless Technologies

→ Frequencies for radio transmission.

- Radio transmission can take place using many different frequency bands. Each frequency band exhibits certain advantages and disadvantages.

VLF (Very Low Frequency)
LF (Low Frequency)
→ Long waves.
→ submarines.
(these waves penetrate water and can follow the earth's surface).

MF (Medium Frequency), HF (High Frequency)
→ Short wave.
(AM or FM).
Amateur radio transmission.
↳ enabled by reflection at the ionosphere.

VHF (Very HF), UHF (Ultra HF)
→ TV stations, DAB (Digital Audio Broadcasting),
Mobile phones. etc.

SHF (Super HF), EHF (Extremely HF)
close to InfraRed.

Signals :

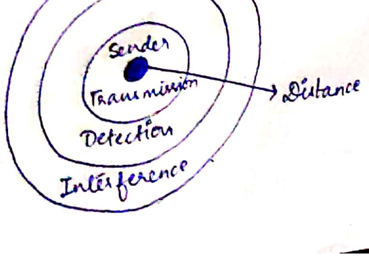
- **Signals** : Physical representation of data.
Users of a communication system can only exchange data through the transmission of signals.
(Layer 1 of ISO/OSI : bits ↔ signal)
(data)

- Signals are funcⁿ of time and location and signal parameters represent the data value.
↳ amplitude (A), frequency (f), phase shift (ϕ).

Signal Propagation :

- Wireless communication networks also have senders and receivers of signals.
- In wireless network, the signal has no wire to determine the direction of propagation unlike in wired network.
- One can precisely determine the behaviour of a signal travelling in a wire (wired n/w) as long as the wire is not interrupted or damaged as it exhibits the same characteristics at each point.

For wireless communication, this predictable behaviour is only valid in vacuum.



simple and ideal scheme for wireless commⁿ (in vacuum)

Transmission range
Within certain radius of the sender, transmission is possible i.e. a receiver receives the signals with an error rate low enough to be able to communicate and can also act as sender.

Detection range
Within a second radius, detection of the transmission is possible, i.e. the transmitted power is large enough to differ from background noise. However, the error rate is too high to establish communication.

Interference range
Within a third even larger radius, the sender may interfere with other transmission by adding the background noise.
A receiver will not be able to detect the signals, but the signals may disturb other signals.

- In real life, radio transmission has to contend with our atmosphere, mountains, buildings, moving senders and receivers etc.

So, the three circles are actually irregularly-shaped polygons. time & frequency dependent.

Problems in wireless communication :

i) Path loss of radio signals (attenuation)
↳ In free space, radio signals propagate as light does (independently of their frequency).
↳ Even if no matter exists between the sender and the receiver (vacuum), the signal still experiences free space loss.

$$P_R \propto \frac{1}{d^2}$$ (inverse square law)

P_r : received power.
d : distance.

→ The received power also depends on the wavelength and the gain of receiver and transmitter antennas.

↳ Most radio transmission takes place through atmosphere - signals travel through air, rain, snow, fog, dust particles, smog etc.

↳ Attenuation (path loss) does not cause too much trouble for short distances (LANs), but heavily influences transmission over long distances in the atmosphere (satellite transmission).

↳ Mobile phone systems are influenced by weather condition.

↳ Depending on the frequency, radio waves can also penetrate objects.
Generally, the lower the frequency (long waves), the better the penetration.

(Higher frequency of radio waves resembles ⇒ light).

↳ Radio waves can exhibit three fundamental propagation behaviour depending on their frequency:

a) Ground wave (<2MHz).
Waves with low frequencies follow the earth's surface and can propagate long distances.
e.g. Submarine commⁿ, AM radio.

b) Sky wave (2-30 MHz).
Short waves that are reflected at ionosphere.
(The waves can bounce back and forth b/w the ionosphere and the earth's surface, travelling around the world).

c) Line-of-sight (>30MHz)
↳ Very high frequency. The emitted waves follow a straight line of sight.
↳ Direct communication with satellites.
e.g. Mobile phone systems, Satellite systems, cordless telephones etc.

Note : waves are bent by the atmosphere due to refraction.

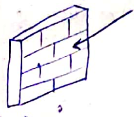
ii) Additional signal propagation effects.
↳ In real life, we rarely have a line-of-sight between the sender and receiver of radio signals (sky scrapers, mountains, buildings etc.)
So, several effects occur in addition to the attenuation caused by the distance b/w sender and receiver, which are frequency dependent.

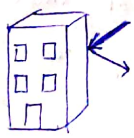
↳ Blocking or Shadowing:
An extreme form of attenuation caused due to large obstacles like a wall, truck or trees.
(Even small obstacles may block a signal) high frequency.

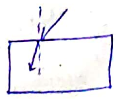
Particle behaviour of radio signals

Reflection.
If an object is large compared to the wavelength of the signal (e.g. huge buildings, mountains; surface of earth), the signal is reflected.
Reflection helps in transmitting signals as soon as no LOS exists.
not as strong as the original as object can absorb some of the signal's power.

Refraction.
This effect occurs because the velocity of the electromagnetic waves depends on the density of the medium through which it travels.
(LOS radio waves are bent towards the earth because the density of the atmosphere is higher closer to the ground).


Shadowing


Reflection


Refraction.

↳ Scattering

wave behaviour of radio signals

If the size of an obstacle is in the order of wavelength or less, then waves can be scattered. (An incoming signal is scattered into several weaker outgoing signals)

Diffraction

Radio waves ~~are~~ will be deflected at an edge and propagate in different directions.

The result of scattering and diffractions are patterns with varying signal strength depending on the location of the receiver.

↳ Effects like attenuation, scattering, diffraction and refraction all happen simultaneously and are frequency and time dependent.

∴ It is very difficult to predict the precise strength of signals at certain point in space.

Scattering Diffraction.

iii) Multipath propagation

↳ Radio waves emitted by a sender can either

a) travel along a straight line

b) reflected at a large building

c) scattered at smaller obstacles.

In reality, many paths are possible from sender to receiver.

↳ Due to finite speed of light, signals travelling along different paths with different lengths arrive at the receiver at different times. This effect caused by multi-path propagation is called delay spread.

– the original signal is spread due to different delays of parts of the signal.

Multiplexing – A technique that allows simultaneous transmission of multiple signals across a single data link.

✓ Multiplexing describes how several users can share a medium with minimum or no interference.

Multiplexing

- wave~~space~~length Division multiplexing
- Time Division multiplexing
- Frequency Division multiplexing
- ~~Code Division multiplexing~~

~~Space Division Multiplexing (SDM)~~

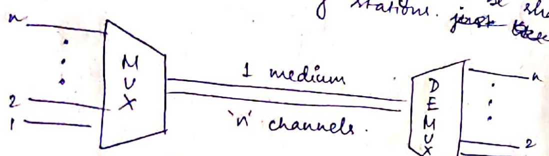
✓ Two communicating stations do not utilize the full capacity of a data link.

Moreover, when many nodes compete to access the network, some efficient techniques for utilising the data link are very essential.

✓ When the bandwidth of a medium is greater than individual signals to be transmitted through the channel, a medium can be shared by more than one channel of signals.

The process of making the most effective use of the available channel capacity is called multiplexing.

For efficiency, the channel capacity can be shared among no. of communicating stations. ~~just like~~



The MUX combines (multiplexes) data from these 'n' input lines and transmits them through the high capacity data link, which is being demultiplexed at the other end and is delivered to appropriate output lines.

① Frequency division multiplexing (FDM)

- Frequency spectrum is divided into several logical channels, giving each user exclusive possession of a particular frequency band.

Sender
- Independent message signals are translated into different frequency bands using modulation techniques, which are combined by a linear summing circuit in the multiplexer, to a composite signal.
- The resulting signal is then transmitted along the single channel by electromagnetic means.

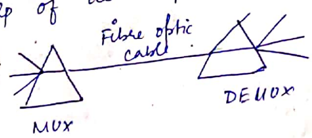
Receiver
- At the receiving end, the signal is applied to a bank of band-pass filters, which separates individual frequency channels.
- The band pass filter outputs are then demodulated and distributed to different out channels.

- If the channels are very close to one another, it leads to inter-channel cross talk.
So, channels must be separated by strips of unused bandwidth to prevent inter-channel cross talk.
↳ unused channel between each successive channel are known as guard bands.

- Applications : Radio broadcasts, TV networks

② Wavelength Division Multiplexing (WDM)

- conceptually same as FDM, except that the multiplexing and demultiplexing involves light signals transmitted through fibre-optic channels.
↳ Different frequency signals are combined but here, the frequencies are very high.
- Designed to utilize the high data rate capability of fibre-optic cable.
- Very narrow band of light signal from different source are combined to make a wider band of light.
At the receiver, the signals are separated with the help of demultiplexer.
- Prism



③ Time Division Multiplexing (TDM)

- In FDM, all signals operate at the same time with different frequencies, but in TDM, all signals operate with same frequency at different times.
- This is a base-band transmission system, where an electronic commutator sequentially samples all data source and combines them to form a composite base band signal, which travels through the media and is being demultiplexed into appropriate independent message signals by the corresponding commutator at the receiving end.
- The incoming data from each source are briefly buffered.
  The buffers are scanned sequentially to form a composite data stream.
  (Each buffer is emptied before more data can arrive).

  composite data rate $\geq$ sum of individual data rates.

- Composite signal can be transmitted directly or through a modem.

"Synchronous" TDM : Each time slot is preassigned to a fixed slot. ~~[illegible]~~
Time slots are transmitted irrespective of whether the sources have any data to send or not.
(∴ Channel capacity is wasted)

Solⁿ: Statistical TDM / Asynchronous TDM / Intelligent TDM.

* "Devices can handle sources of different data rates
  ↳ Fewer slots per cycle to slower I/P device than faster devices.

Statistical TDM :
↳ Dynamically allocates the time slots on demand to separate I/P channels, thus saving the channel capacity.
↳ I/O lines with buffers in statistical MUX.
↳ During the I/P, the MUX scans the I/P buffers, collecting data until the frame is filled and send the frame.
At receiving end, the DEMUX receives the frame and distributes the data to appropriate buffers.
↳ Fully utilized slots ⇒ Smaller transmission time
⇒ Better utilisation of bandwidth of the medium.
↳ The data in each slot must have an address part which identifies the source of data for proper delivery.

---

* Multiplexing is used:
  i) to send large no. of signals simultaneously.
  ii) to reduce the cost of transmission.
  iii) to make effective use of available bandwidth.

* FDM can be used with analog signals.
  ↳ A no. of signals are carried simultaneously on the same medium by allocating to each signal a different frequency band.

* TDM can be used with digital or analog signals (carrying digital data).
  ↳ Data from various sources are carried in respective frames. Each frame consists of a set of time slots and each source is assigned a time slot per frame.

* Sync pulse is required in TDM to identify the beginning of each frame.

Baseband transmission : A (digital) signalling technology that sends digital signals over a single frequency as discrete electrical pulses. (FDM not possible). – TDM.

Entire bandwidth of a baseband system carries only one signal.

Broadband transmission : Uses analog signalling which involves optical signals or EMW signals. The signals are sent into multiple frequencies permitting multiple signals to be sent simultaneously (FDM is possible).

Modulation

- Digital modulation : Digital data (0 and 1) is translated into an analog signal (baseband signal).

Digital modulation is required if digital data has to be transmitted over a medium that only allows for analog transmission.

- In wireless networks, digital transmission cannot be used. Here, the binary bit-stream has to be translated into an analog signal first.

Digital-to-Analog

↳ Amplitude Shift Keying (ASK)

↳ Frequency Shift Keying (FSK)

↳ Phase Shift Keying (PSK).

- Apart from digital modulation, wireless transmission requires an analog modulation that shifts the centre frequency of the baseband signal generated by digital modulation upto the radio carrier.

Why baseband signal cannot be directly transmitted in a wireless system?

i) Antennas' size : An antenna must be the order of magnitude of the signal's wavelength in size to be effective

ii) FDM : using only baseband transmission, FDM could not be applied. Analog modulation shifts the baseband signals to different carrier frequencies.

iii) Medium characteristics : Path-loss, penetration of obstacles, reflection, scattering, ~~refract~~ diffraction etc.

Depending on the application, the right carrier frequency with the desired characteristics has to be chosen.

Submarine – Long waves.

Handheld devices – short waves.

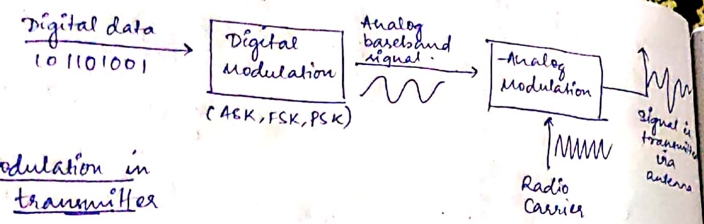
Directed microwave transmission – very short waves.

- Analog modulation (Analog-to-Analog).

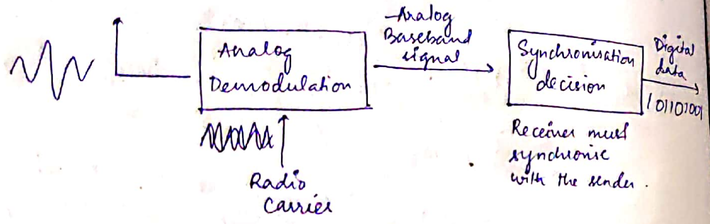
↳ Amplitude Modulation (AM)

↳ Frequency Modulation (FM)

↳ Phase Modulation (PM).



Modulation in transmitter



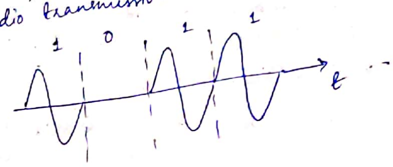
Demodulation and data reconstruction in a receiver

✓ The digital modulation schemes (ASK, FSK, PSK) differ in spectral efficiency, power efficiency and robustness.

- spectral efficiency: how efficiently the modulation scheme utilises the available frequency spectrum.
- power efficiency: how much power is needed to transfer bits [Important for portable devices that are battery dependent].
- robustness: Robustness to multi-path propagation, noise and interference.

ASK:

↳ Susceptible to interference.
↳ multipath propagation, noise, path loss heavily influence the amplitude.
↳ In wireless environment, a constant amplitude cannot be guaranteed, so ASK is typically not used for wireless radio transmission.



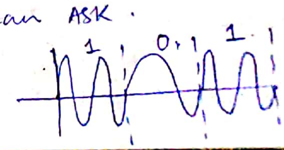
FSK:

↳ Used for wireless transmission.
↳ Implementation: To switch between two oscillators, one with frequency f_1 and the other with f_2 depending on the I/P.

↳ To avoid sudden changes in phase, special frequency modulators with Continuous Phase Modulation (CPM) can be used.
(sudden changes in phase cause high frequencies, which is an undesired side effect).

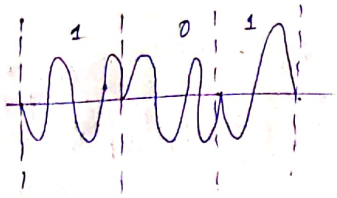
↳ Demodulation: Using 2 bandpass filters, one for f_1 and other for f_2.
A comparator can then compare the signal levels of the filter outputs to decide which of them is stronger.

↳ Needs larger bandwidth than ASK.
↳ Less susceptible to errors.



PSK :

- ↳ uses shifts in phase of a signal to represent data.
- ↳ Implementation : Multiply a frequency f with +1 if data is '1' and with −1 if data is '0'.
  (BPSK)
- ↳ To receive the signal correctly, the receiver must synchronize in frequency and phase with the transmitter.
  - ↳ PLL (Phase Lock Loop).
- ↳ PSK is more resistant to interference than FSK but receiver & transmitter are also more complex.



Spread Spectrum

- ✓ Spread spectrum techniques involve spreading the bandwidth needed to transmit data.
- ✓ Advantages of spreading bandwidth :
  - ↳ Resistance to narrowband interference.
  - ↳ Security effect
- ✓ Spreading of a narrowband signal is achieved using a special code.
  Each channel is allotted its own code, which the receivers have to apply to recover the signal. without knowing the code, the signal cannot be recovered and behaves like background noise.

(Security effect : If a secret code is used for spreading)

- ✓ Applications of (CDM + spread spectrum) :
  Military uses, US mobile phone systems

[Frequencies are a scarce resource around the world, particularly license free bands.
Solⁿ: Spread spectrum allows an overlay of new transmission technology at exactly the same frequency at which current narrowband systems are already operating]

- ✓ Disadvantages of spread spectrum :
  - ↳ Increased complexity of receivers — receivers despread a signal
  - ↳ Large frequency band is needed due to the spreading of the signal.
  - ↳ Although spread signals appear more like noise, they still raise the background noise level and may interfere with other transmission if no special precautions are taken.

Spread spectrum
- Direct Sequence Spread Spectrum (DSSS).
- Frequency Hopping Spread Spectrum (FHSS).

DSSS :

- DSSS systems take a user bit stream and perform an XOR with a so-called chipping sequence
- * Each user bit has a duration t_b.
- * Chipping sequence consists of smaller pulses, called chips, with duration t_c.

* If the chipping sequence is generated properly, it appears as random noise, sometimes called pseudo-noise sequence

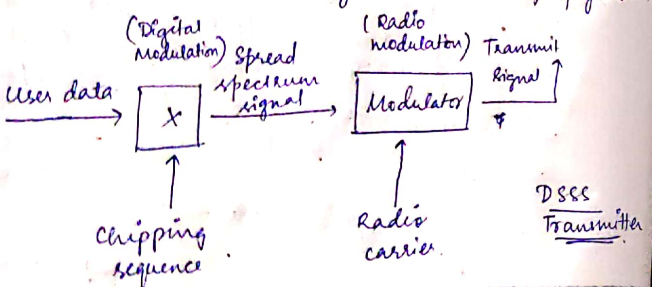
* Spreading factor,

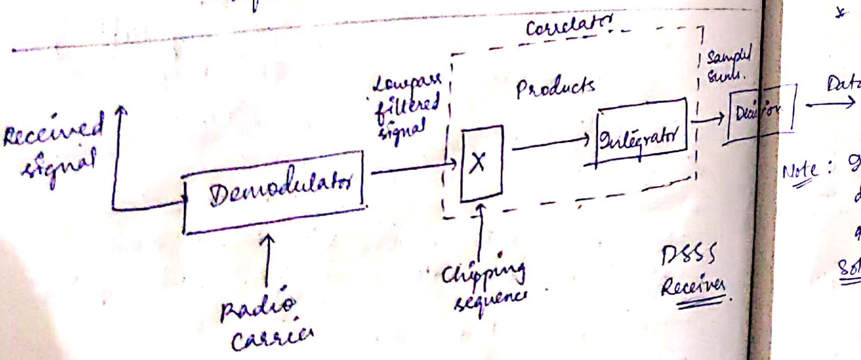
$$s = \frac{t_b}{t_c}$$

's' determines the bandwidth of the resulting signal.

If original signal needs a bandwidth 'w', the resulting signal needs 's-w' after spreading.

Note : Barker Codes (Chipping sequence - 11, 110, 1110, 11101, 1110010, 11111001101 01) exhibit a good robustness against interference and insensitivity to multipath propagation.





* DSSS receiver is more complex than the transmitter.
  1. Demodulating the received signal.
     ↳ using same carrier as the transmitter reversing the modulation and results in a signal with approximately the same bandwidth as the original spread spectrum signal.
  II. The receiver has to know the chipping sequence i.e. receiver generates the same pseudo random sequence as the transmitter.

Sequences at transmitter and receiver have to be precisely synchronised because the receiver calculates the product of a chip with the incoming signal.
↳ XOR operation + Medium Access Mechanism.

* During a bit period, which also has to be derived via synchronisation, an integrator adds all these product.

* Calculating the products of chips and signal, and adding the products in an Integrator is also called correlation, the device is called a correlator.

* Finally, in each bit period, a decision unit samples the sums generated by the integrator and decides if this sum represents a binary 1 or a 0.

Note : In multipath propagation, several paths with different delays exist between a transmitter and a receiver.

Sol^n : Rake receivers
↳ uses 'n' correlators for 'n' strongest paths. Each correlator is synchronised to the transmitter plus the delay on that specific path.

As soon as the receiver detects a new path which is stronger than the currently weakest path, it assigns this new path ~~which is stronger than the curr~~ to the correlator with the weakest path.

The O/P of the correlators are then combined and fed into the decision unit.

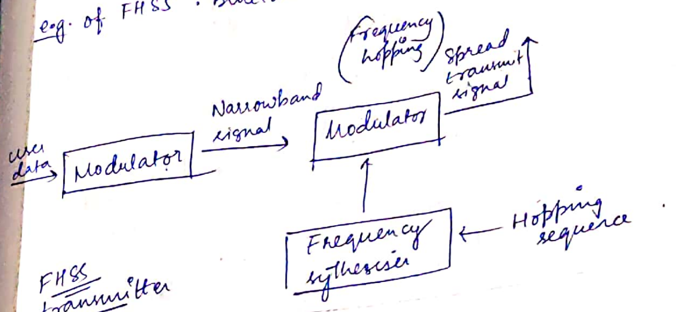
FHSS :

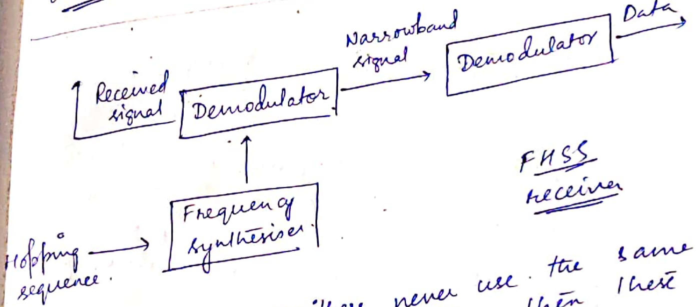
- The total available bandwidth is split into many channels of smaller bandwidth plus guard spaces between the channels.
- Transmitter and receiver stay on one of these channels for a certain time and then hop to another channel.
- This system implements FDM and TDM.
- The pattern of channel usage is called the hopping sequence.

The time spend on a channel with a certain frequency is called the dwell time.

FHSS
- Slow hopping — GSM
  * The transmitter uses one frequency for several bit periods (t_b) (bits/hop)
  * Cheaper
  * have relaxed tolerances
  * Not as immune to narrowband interference as fast hopping
- Fast hopping
  * The transmitter changes the frequency several times during the transmission of a single bit (hops/bit)
  * More complex to implement because transmitter & receiver have to stay synchronized within smaller tolerances to perform hopping

e.g. of FHSS : Bluetooth (1600 hops per second).





Note: If two transmitters never use the same frequency at the same time, then these two transmissions do not interfere.
↳ required coordination of all transmitters and their hopping sequence, at more or less at the same points in time.

- Spreading is simpler in FHSS than DSSS. FHSS systems use only a portion of the total band at any time, while DSSS systems always use the total bandwidth available.

Media Access Control (MAC)

- MAC belongs to layer 2 of ISO/OSI reference model
  ↳ Data Control Layer (DLC).

- DLC : To establish a reliable point-to-point or point-to-multipoint connection between different devices over a wired or wireless medium.

- Special MACs are needed in the wireless domain.

→ Motivation for a Specialised MAC :

* CSMA/CD fails for wireless medium.
  ↳ CSMA/CD is not really interested in collisions at the sender, but rather those at the receiver.
  The signal should reach the receiver without collisions but the sender is the one detecting collisions
  ↳ Wired medium : Same signal strength (almost) all over the wire. So, if a collision occurs in the wire, everybody will notice it.

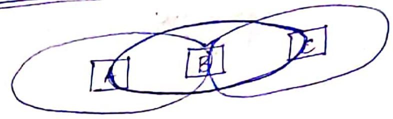
  Wireless medium : The strength of signal decreases proportionally to the square of the distance to the sender. Obstacles attenuate even further.
  ↳ Hidden terminal problem (Carrier sense)
  ↳ Problem in collision detection.

  Collision detection is very difficult in wireless scenarios as the transmission power in the area of the transmitting antenna is several magnitudes higher than the receiving power.

Some scenarios where schemes known from wired networks fail in wireless network for medium access control :

i) Hidden and exposed terminal

Transmission range of B reaches A and C.

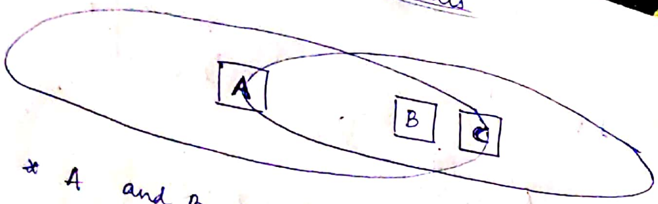


Transmission range of A reaches B but not C.
Detection range of A reaches B but not C.
(Same for C).
∴ A cannot detect C and vice-versa.

Hidden terminal
A starts sending to B, C does not receive the transmission. C also wants to send something to B and senses the medium which appears to be free. So, C also starts sending to B causing a collision at B.
But, A can not detect this collision at B and continues its transmission.
∴ A is hidden for C and vice-versa.
(Hidden terminal may cause collisions).

Exposed terminal
B sends something to A and C wants to transmit data to some other mobile phone outside the interference ranges of A and B. C senses the carrier and detects that the carrier is busy (B is sending). C postpones its transmission until it detects the medium as being idle again, but since A is outside the interference range of C, waiting is not required i.e. causing a 'collision' at B does not matter because the collision is too weak to propagate to A
∴ C is exposed to B.

ii) Near and far terminals



* A and B are both sending with the same transmission power. As the signal strength decreases proportionally to the square of the distance, B's signal drowns out A's signal. As a result, C cannot receive A's transmission (∵ A is far than B to C).

* If C is an arbiter for sending rights i.e. C acts as a base station coordinating media access, then terminal B would already drown out terminal A on the physical layer. So, C would have no chance of applying a fair scheme as it would only hear B.

∴ The near/far effect is a severe problem of wireless networks using CDM.
↳ Precise power control is needed to receive all senders with the same strength at a receiver.

MAC techniques for wireless networks:

① FDMA:
- FDMA comprises all algorithms allocating frequencies to transmission channels according to the FDM scheme
- Allocation of frequency can either be fixed (radio stations) or dynamic (demand driven)
- Channels can be assigned to the same frequency all the time (pure FDMA) or change frequencies according to a certain pattern (FDMA + TDMA) wireless systems.

hopping pattern
(sender and receiver have to agree on a hopping pattern, otherwise the receiver could not tune to right frequency).

② TDMA:
- TDMA offers a much more flexible scheme which comprises all technologies that allocate certain time slots for communication (controlling TDM) than FDMA.
- Tuning to a certain frequency is not necessary using only one frequency, very simple transmitters and receivers, ~~[illegible]~~ many different algorithms exist to control medium access.
- Listening to ~~[illegible]~~ different frequencies at the same time is quite difficult, but listening to many channels separated in time at the same frequency is simple.

- Synchronisation between sender and receiver has to be achieved in the <u>time domain</u>.
  - Fixed: Allocating a certain time slot for a channel.
  - Dynamic.
- Dynamic allocation schemes require an identification for each transmission as this is the case for typical wired MAC schemes. (sender address) or the transmission has to be announced beforehand.
- MAC addresses are often used as identification. This enables a receiver in the broadcast medium to recognise if it really is the intended receiver of the message

TDMA:
- Fixed TDM.
- Classical ALOHA.
- Slotted ALOHA
- CSMA.
- DAMA
- PRMA
- Reservation TDMA.
- MACA
- Polling
- ISMA.

i) <u>Fixed TDM</u>: — wireless phone systems.
- ↳ Allocating time slots for channels in a <u>fixed pattern</u> — assigned by base station.
- ↳ Fixed bandwidth, fixed delay.
- ↳ Accessing the reserved time slot at the right moment. (Synchronisation).
- ↳ Each mobile station knows its turn and no interference will happen.

(TDMA schemes with fixed access patterns are used for many digital mobile phone systems)

ii) <u>Classical ALOHA</u> (see notes!).
- ↳ Each station can access the medium at any time. (ALOHA does not coordinate medium access; ALOHA does not resolve contention on the MAC layer).
- ↳ Random access scheme (without a central arbiter).
- ↳ If two or more stations access the medium at the same time, a collision occurs and the transmitted data is destroyed.
  - ↳ Retransmission of data is left ~~for~~ to higher layers. $\boxed{\text{Throughput} = 18\%}$.
- ↳ works fine for light load.

iii) <u>Slotted ALOHA</u>.
- ↳ All senders are synchronised i.e. transmission can only start at the beginning of a time slot.
- ↳ Access is not coordinated. $\boxed{\text{Throughput} = 36\%}$.
- ↳ works fine for light load

iv) <u>CSMA</u>.
- ↳ sensing the carrier and accessing the medium only if the carrier is idle, decreases the probability of a collision.
- ↳ Hidden terminals cannot be detected.

CSMA:
- Non-persistent
- p-persistent
- 1-persistent.

Non-persistent CSMA :

* Sense the carrier and start sending immediately if the medium is idle.
* If the medium is busy, the station pauses a random amount of time before sensing the medium again and repeating this pattern.

p-persistent CSMA

* Sense the medium, but only transmit with a probability of p, with the station deferring to the next slot with the probability 1-p.

1-persistent CSMA

* All stations wishing to transmit access the medium at the same time, as soon as it becomes idle.

This will cause many collisions if many stations wish to send and block each other.

Sol^n^: Backoff algorithm.

↳ CSMA/CA used in wireless LAN.
(Backoff algorithm).

v> **DAMA** (Demand Assigned Multiple Access).

↳ Reservation period followed by transmission period.
  ↳ stations can reserve future slots in the transmission period.

↳ DAMA also called Reservation ALOHA

↳ Satellite systems.

* All stations can try to reserve future slots.
* Collisions during reservation phase do not destroy data transmission.
* If successful, a time slot in the future is reserved, and no other station is allowed to transmit during this slot.

↳ To maintain the fixed TDM pattern of reservation and transmission, the stations have to be synchronised from time-to-time.

↳ Explicit reservation scheme
(Each transmission slot has to be reserved explicitly).

vi> **PRMA** (Packet Reservation Multiple Access)

↳ Implicit reservation scheme.
(slots can be reserved implicitly)

↳ Certain no. of slots form a frame.
The frame is repeated in time.

A base station broadcasts the status of each slot to all mobile stations. All stations receiving this vector will then know which slot is occupied and which slot is currently free.

vii> **Reservation TDMA**

↳ Guarantees each station a certain bandwidth and a fixed delay.

↳ Other stations can send data in unused data slots.

viii) **MACA** (Multiple Access with Collision Avoidance)

ix) **Polling**:

- One master station, several slave station.
- One station is to be heard by all others.
- Master can poll the slaves according to many schemes: Round Robin, Randomly, Reservations.

x) **Inhibit Sense Multiple Access** (ISMA)

- Base station only signals a busy medium via a busy tone. After the busy tone stops, accessing the link is not coordinated any further.
- Base station acknowledges successful transmissions. So, a mobile station detects a collision only via the missing the acknowledgement.
- In case of collisions, additional backoff and retransmission mechanisms are implemented.