

# WIRELESS COMMUNICATION

Unit - 1

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Wireless communication :

Wireless communication generally works through EM signals that are broadcast by an enabled device within the air, phy environment or atmosphere.

The communication between two devices occur when the destination or receiving devices capture these signals creating a wireless comm' bridge.

It has various terms like

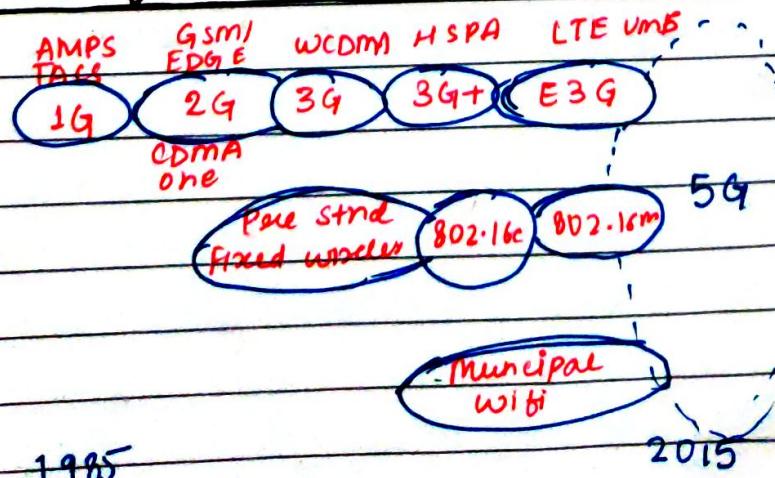
- ① Satellite communication
- ② mobile communication
- ③ Infrared communication
- ④ Bluetooth communication
- ⑤ Wireless N/w communication

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We use wireless communication for

- (i) Increased efficiency : High technology comm' systems leads to faster transfer of info
- (ii) Rarely out of touch : No need to carry cables or adapters in order to access networks.
- (iii) Greater flexibility : Can be networked without sitting at dedicated PC's.
- (iv) Reduced cost : cheaper to install and maintain.

## ① Evolution of mobile communications :



- (i) 1934 : Police radio uses conventional AM mobile comm system
- (ii) 1935 : Edwin Armstrong demonstrated FM
- (iii) 1946 : First mobile telephone service - IMTS - full duplex
  - ↳ (drawback was interruption while comm")
- (iv) 1960 : IMTS (improved) full duplexed
  - ↳ (Bell lab introduce concept of cellular mobile system)
- (v) 1968 : AT&T propose concept of cellular mobile system to FCC.
- (vi) 1976 : Bell mobile phone service, poor service due to cell blocking
- (vii) 1983 : Advanced mobile phone system (AMPS), FDMA, FM use
- (viii) 1991 : US Digital cellular (USDC) IS-54, TDMA, QPSK
- (ix) 1993 : IS-95, CDMA, QPSK, BPSK

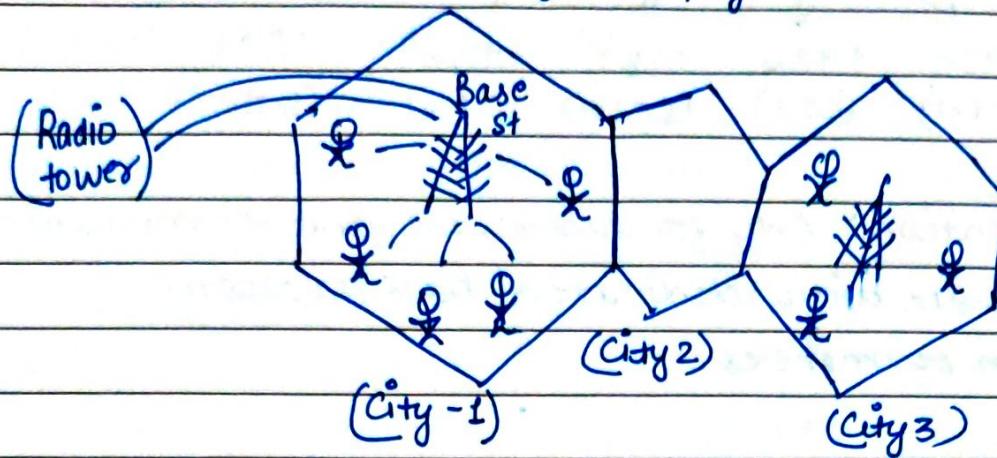
### Examples of wireless communication systems

- (i) Cordless phones
- (ii) Remote controllers (DVD player)
- (iii) Walkie Talkie (certain Range)
- (iv) Pagers (1990 to syn detailed msg)
- (v) Telephones
- (vi) WLAN

### ② Paging Systems:

- (i) Conventional paging system sends brief message to subscribers.
- (ii) modern Paging system → News, headline, stock quotation fax may be sent.

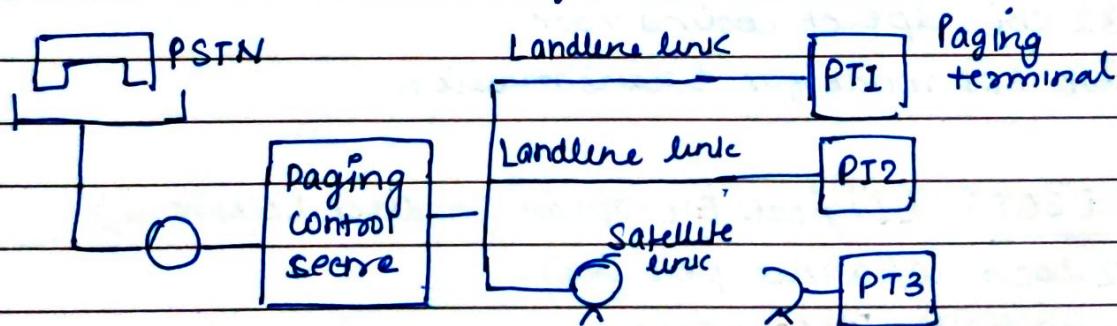
Message sent to paging subscriber by using paging system  
access no. Issued message → page.



(Radio tower → Base station → subscriber)

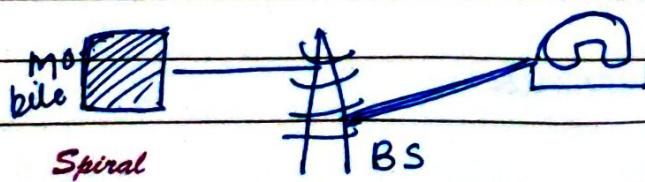
Simulcasting: Large radio towers that simultaneously broadcast a page from each base station.

Paging system are designed to provide reliable comm<sup>n</sup> to subscriber wherever they are.

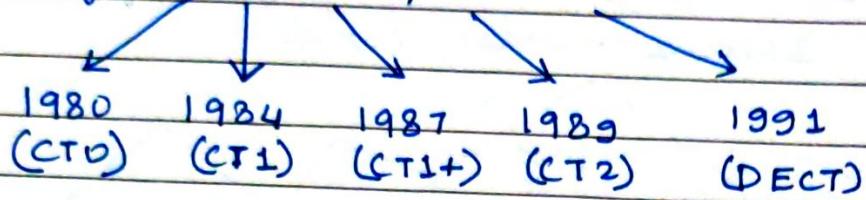


### ③ Coordless Telephone System:

- (i) Designed to provide low cost wireless communication to PSTN.
- (ii) Fully duplex comm<sup>n</sup> that can wirelessly connect a portable handset to dedicated base st which is connected to dedicated telephone lines.



They are upgraded in 5 phases



First generation: Only for home use and communication only possible with dedicated base stations.

- (ii) few ten of meters.

Second generation: Can be used in outdoor as well

- (ii) combined with paging systems
- (iii) few hundred of meters.

#### → CT2:

- (i) Developed in Europe (1989)
- (ii) 40 FDMA channel
- (iii) 32 Kbps speech coding rate
- (iv) Use TDD mode for transmission

#### → DECT: (Digital European Cordless telephone)

- (i) 12 local channels per freq.
- (ii) Also have sleep mode
- (iii) Get conversation from one time slot to another (time slot transfer)
- (iv) support seamless handoff
- (v) compatible with GSM and allow mobility

#### → DHS: (Personal handy phone system)

- |  |                         |
|--|-------------------------|
| (i) Developed in Japan                     | (v) 32 Kbps coding rate |
| (ii) Also have sleep mode                  | (vi) Support handoff.   |
| (iii) TDMA / TDD                           |                         |
| (iv) BW partition → <sup>77</sup> channels |                         |

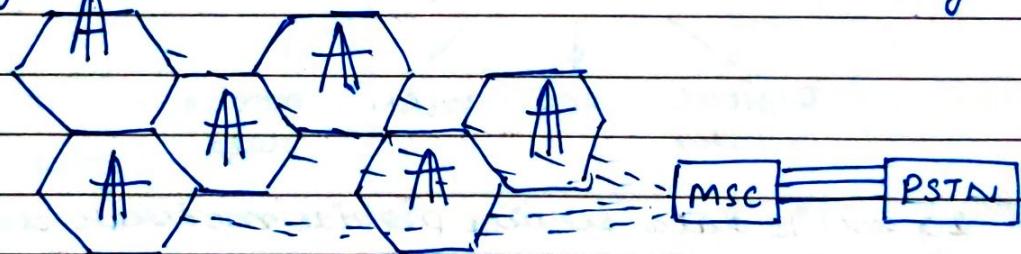
→ PACS: (Personal access control system)

- (i) designed using WLL (Wireless local loop)
- (ii) 32 Kbps speech coding rate
- (iii) Use TDMA / FDD
- (iv) supports roaming management

#### (4) Cellular telephone system:

- (i) It is also known as PCS
- (ii) Provide two way comm<sup>n</sup> at high speed with regional or national coverage.
- (iii) Main principle → to reuse frequency

→ The coverage area of cellular system is divided into non overlapping cells where same set of channel is assigned to each cell. This same channel is also assigned in another cell some distance away.



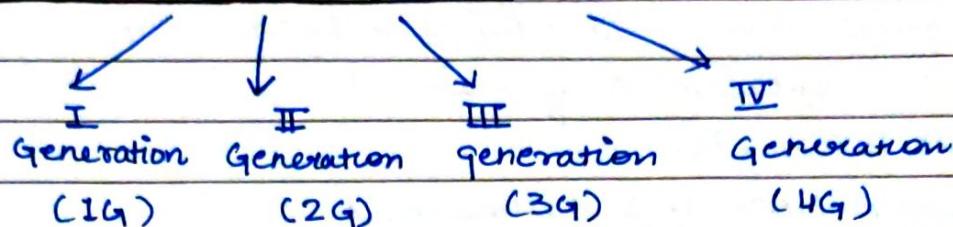
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→ The operation within a cell is controlled by BS which consist of Tx and Rx.

(ii) This is connected to high speed dedicated comm<sup>n</sup> link to MSC which coordinate the activities of all the BSs in limited region to provide connection to other fixed n/w such as PSTN.

e.g. (GSM, AMPS, D-AMPS, IS-95)

## (5) Generation of cellular System:

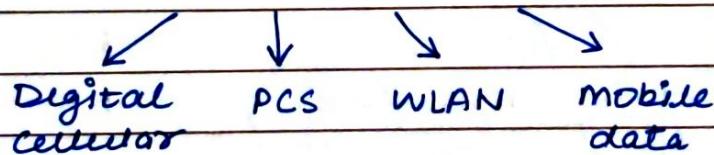


### → First generation (1G):

- (i) uses FDD schemes
- (ii) typical allocated band in each direction is 25 MHz.
- (iii) uses analog cellular system  
e.g. AMPS, NMT

### → Second generation (2G):

- (i) shift from analog to digital system
- (ii) supports all 4 sectors of wireless industry.



- (iii) 2G mobile data service provide moderate data rate and wide coverage area access to packet switch N/W
- (iv) 2G WLAN provides high data rate.

### → Third generation (Internet System):

- (i) It offers better capacity, high speed wireless internet (upto 2 mbps), wireless multimedia services
- (ii) Enable person to communicate with anyone at anytime and anywhere.
- (iii) provide more reliable service feature

→ Fourth generation (4G and Beyond):

(i) In this user has freedom and flexibility to select any desired source with reasonable QoS.

(ii) High usability.

(iii) Support multimedia service at low transmission cost

### ⑥ Comparison b/w wireless systems:

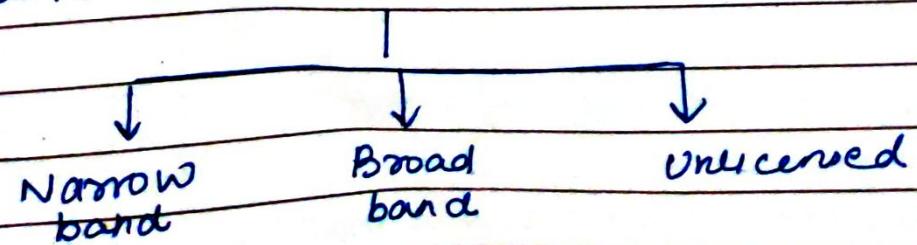
Parameter	cordless	Paging	cellular
Description	They are telephone with wireless handset that comm' using radio waves with B.S	Gives indications like musical alert, name calling etc to particular indi. whom system want at telephone	Radio NW destin- ated over areas called cells each served by at least one Tkt known as Base station.
Standards	CT2, DECT, PALS, GSM	POCSAG, FEEX, GSC	AMPS, NAMPS, VSDC, IS-95
multiple access	FDMA, TDMA	simplex	FDMA, CDMA, TDMA
used for	short distance	Country to country	within NW
mobile st.	MS coverage area is low	MS coverage area is high.	MS coverage area is high
Infra	Few infrastructure	High infra.	High infra
complexity	Moderate complexity <i>(Signal cost is low)</i>	Low complexity <i>H/W cost low</i>	High complexity <i>H/W cost moder</i>

	1 GHz	<1 GHz	1-3 GHz
Functionality	Transceiver	Receiver	Transreceiver
Coverage range	Low coverage	High coverage	Low coverage

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### → Personal communication service:

- (i) It is a type of wireless mobile service with advanced coverage and that delivers services at a personal level. It generally refers to a modern mobile communication that boosts the capabilities of conventional cellular N/W and fixed line telephony N/W as well.
- (ii) Also known as digital cellular
- (iii) It works similar to cellular N/W in basic operations but requires more service provider infrastructure to cover a wider geographical area.
- (iv) PCS generally includes :
  - a) wireless comm" (data, voice & video)
  - b) mobile PBX
  - c) Paging and Texting
  - d) wireless radio
- (v) TDMA, CDMA, GSM, 2G, 3G, 4G are common tec used to deliver a PCS.

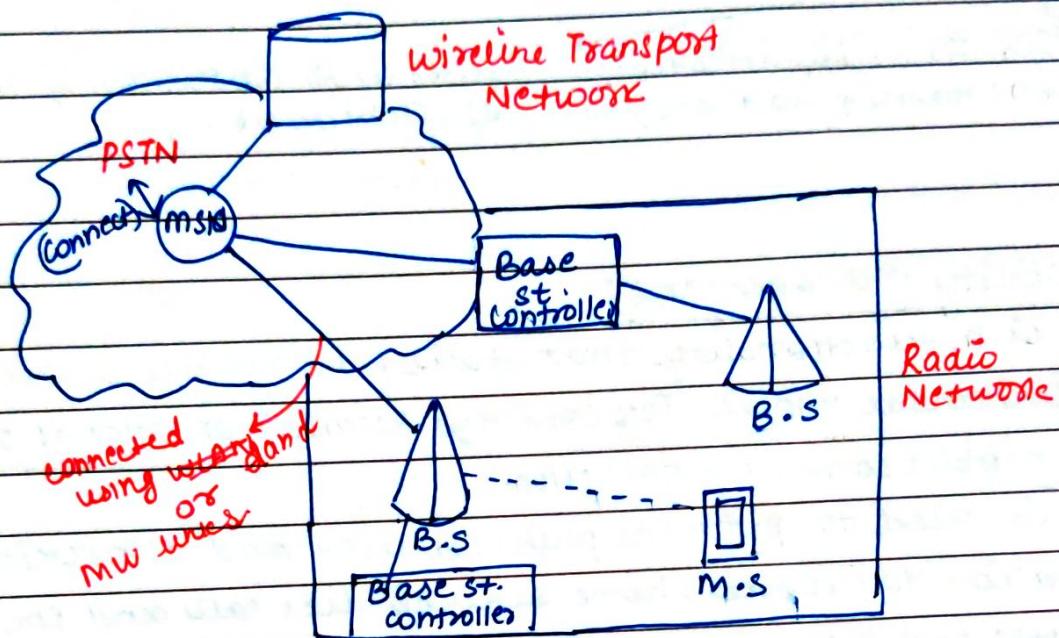


PSTN → Public switched telephone N/W  
MSN → mobile switching N/W.  
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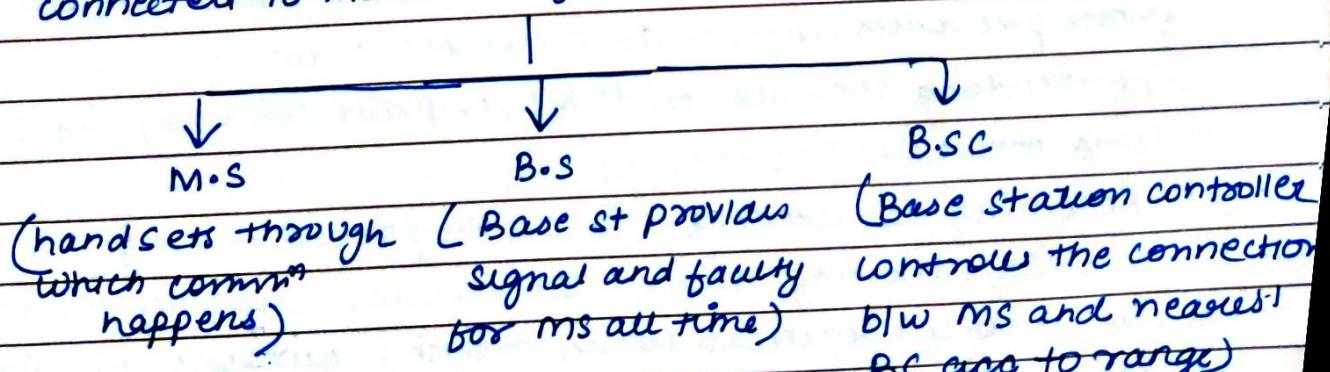
### → PCS architecture:

PCS architecture basically consists of two parts

- Radio Network
- Wireline Transport Network

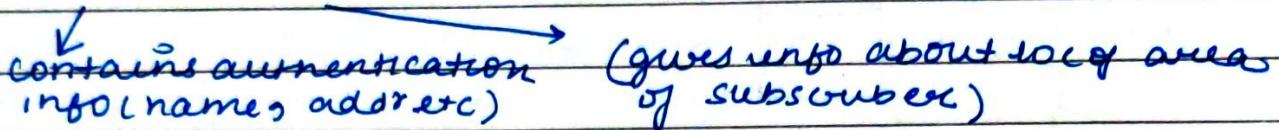


Radio N/W → PCS users carry mobile st. to comm. with a BS in a PCS N/W. MS The radio coverage of a base st. is called cell. In GSM each cell is controlled by BSC which are connected to MSN through BS.



(checks security, data rate, functions)

b) Wireline Transport N/W → An MSC is a telephone exchange configured specially for mobile apps & interfaces MS with PSTN. MSC are also connected to mobility database to track the location of MS and roaming management. (HLR and VLR are those databases)



### → mobility management:

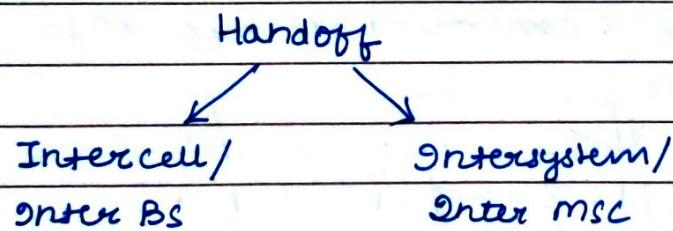
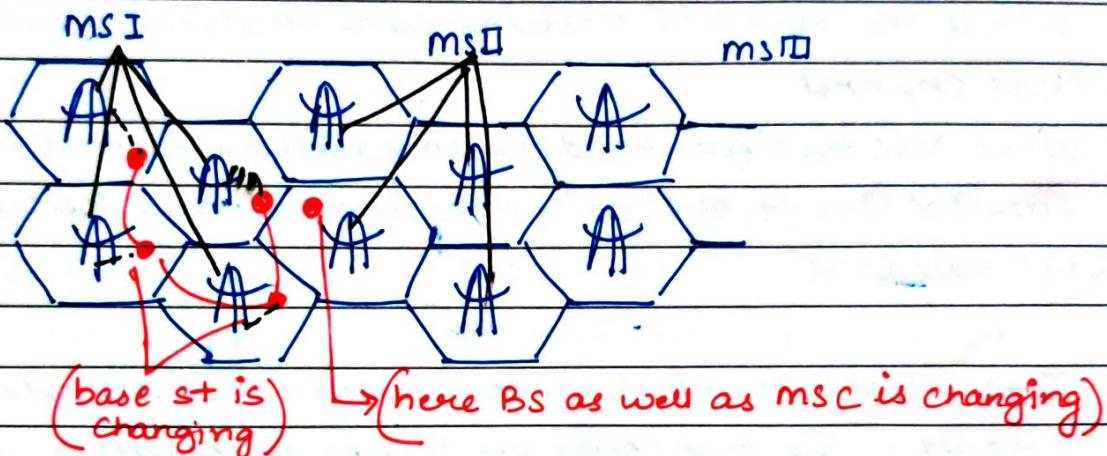
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- (i) It is a functionality that facilitates mobile device op in Universal mobile Telecom sys (UMTS) or Global system for mobile comm (GSM) N/W.
- (ii) It is used to p+trace physical user and subscriber location to provide phone services like calls and SMS.
- (iii) UMTS and GSM are each made up of separate cells (BS) that cover specific geographical area.
- (iv) The loc. update procedure allows a mobile device to notify when shifting between areas. When a mobile device recognizes that an area code differs from previous update it executes a loc update by sending loc. req. to its N/W, prior loc & specific temp. mobile subscriber ID.
- (v) Roaming is among the basic procedures of mobility management. It enables subscribers to use mobile services when moving outside geo. area of a specific N/W.

It refers to the way the N/W manages the movement of mobile subscribers which significantly affect performance of the PCS N/W.

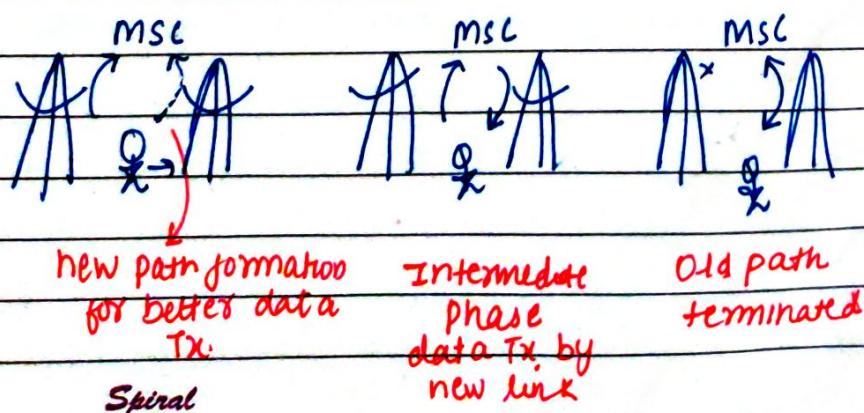
### → Network signalling: Handoff:

It is the process which Enable call to proceed uninterrupted when moved user moves from one cell to another or one system to another.



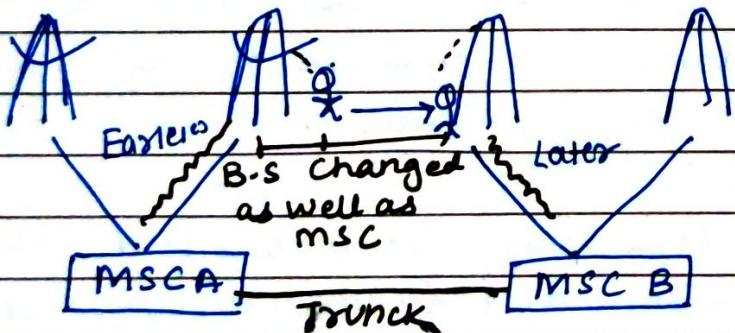
- ① The inter BS Hand off seq. When mobile unit travel from one BS to another BS while old un New connected to same MSC.

Steps for connection:



- (i) When the signal received from the current BS is not strong enough the MS momentarily suspend conno and initiate the handoff procedure by signalling on an idle channel in the new BS. Then conno on old BS is released.
- (ii) When MSC recx the signal it transfers the user to the selected idle channel of the new BS and new conn path is setup.
- (iii) After the MS has been transfer to the new BS, it signal the NHO and resume conversation through that channel.
- (iv) When MSC receives handoff completion signal the connection to old BS is terminated and resource are released

- ② Intersystem Handoff is required when mobile unit travel from one coverage region to another while new and old BS controlled by diff. MSC



[after trunk → req. from one msc to another]  
 [after this only another msc will send data via it]

→ Handoff detection techniques:

(i) MCHO: (Mobile controlled Handoff)

- a) In this scheme the MS determine the handoff requirement and control handoff process.
- b) In this method
  - \* MS continuously monitors the signal quality from the current BS and several candidate BS for handoff.
  - \* When handoff criteria is met, MS choose the best BS with best signal strength.

(ii) NCHO: (Network controlled handoff)

- a) In this scheme the BS determine the handoff req and control handoff process.
- b) In this BS cont. monitors the signal quality from ms. When handoff criteria is met BS inform the ms to arrange the handoff to another BS.
- c) The N/W ask all nearby BS to monitor the signal from ms and based on this info BS N/W chooses BS with best signal strength and connection transferred to new BS.

(iii) MAHO: (Mobile Assisted handoff)

- a) In this handoff procedure is controlled by N/W with help of MS.
- b) In this N/W asks MS to measure signal from surrounding BS, MS sends info to old BS using which the N/W checks the handoff req.

→ Channel Assignment strategies:

(i) FCA : (Fixed channel assign)

- a) In this each cell is allocated pre determined set of voice channel.
- b) If any user calls within a cell only available unused channel may be used.
- c) If all channel is occupied call is blocked & service denied.

(ii) BCA : (Borrowing channel assignment)

- a) In this strategy a cell can borrow channel from neighbouring cell when all its own channels are occupied.
- b) The MSC supervises this borrowing process and ensure borrowing channel does not interfere any call in progress.

(iii) DCA : (Dynamic channel assignment)

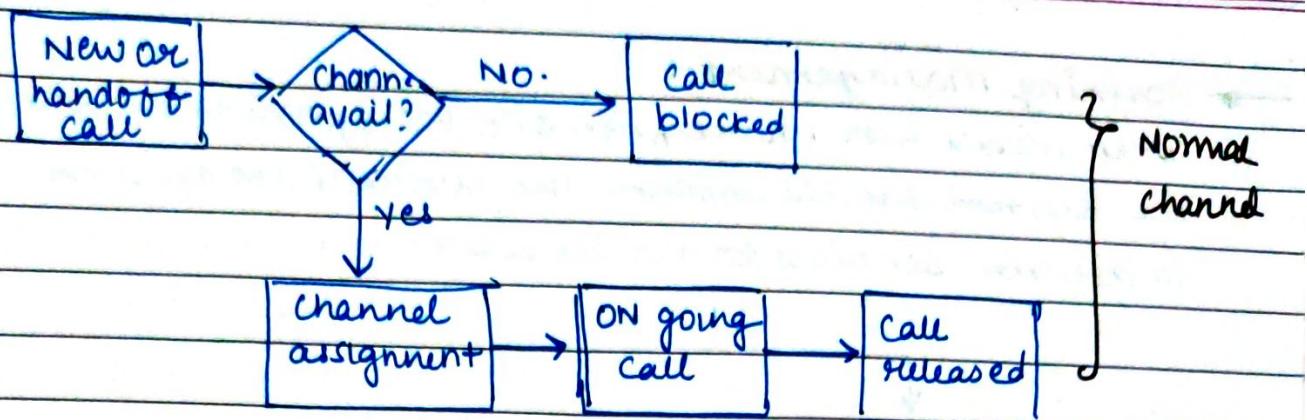
- a) Instead of allocating voice channel to diff cell permanently the serving BS has to req. a channel from MSC whenever call req. is made.
- b) MSC follow algo and then allocate channel to reg. cell.
- c) Thus DCA reduces likelihood of blocking.

→ Prioritising Handoffs:

(i) NPS : (Non priority scheme)

In this handoff calls or new call both are handle by BS in same manner, i.e. if hand off call is blocked. wins if no channel is available.

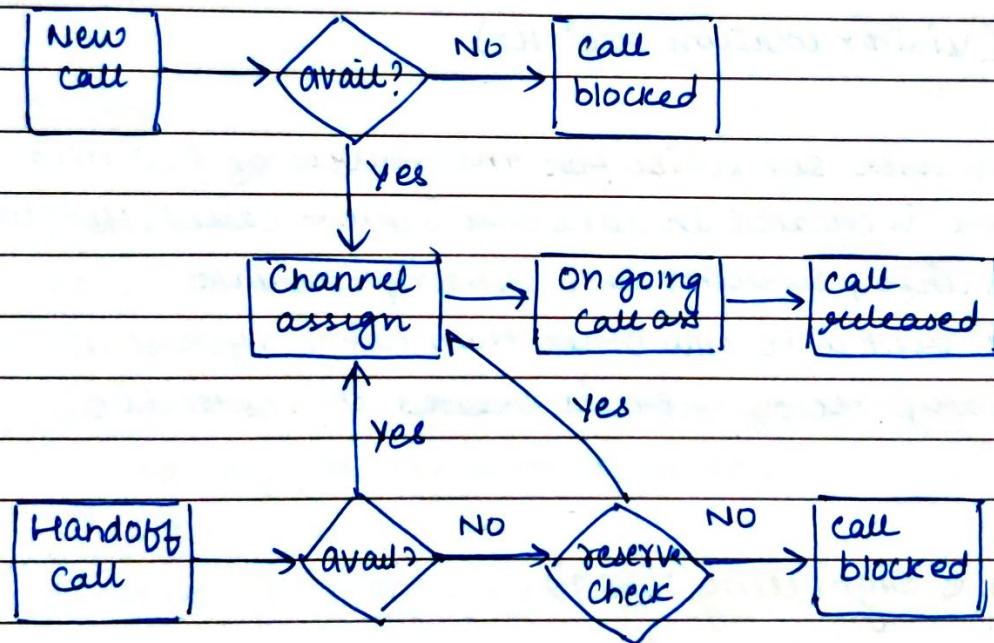
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### (ii) RCS : ( Reserved channel scheme)

In this channel is divided into 2 parts

- (i) Normal channel → (for both)
- (ii) Reserved channel → (can use hand off call)



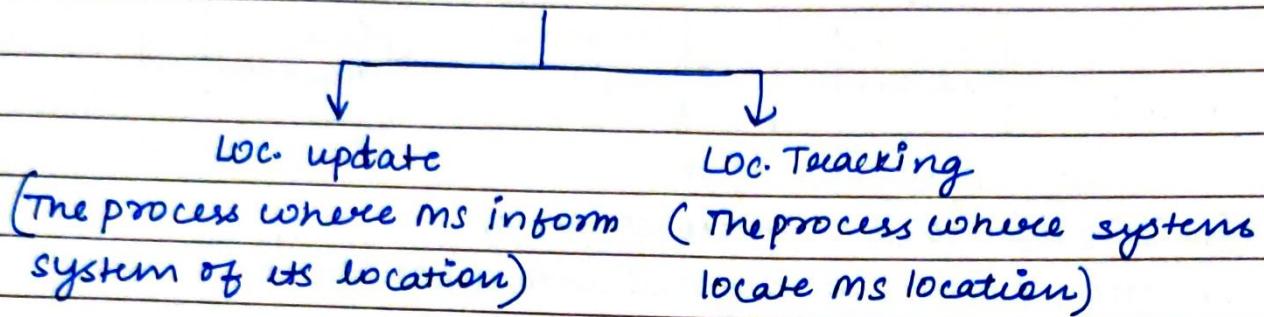
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### (iii) SRS: (Subrating scheme)

- (i) When free channel avail work similar NPS
- (ii) When handoff req. come and a free channel is not ava  
SRS creates a new channel by subtracting (breaking)  $n^{1/2}$   
existing cells. One will be used for existing calls  
another for handoff req.

## → Roaming Management:

When mobile user moves from one PCS system to another the system should inform the current loc of user to deliver services to mobile user.

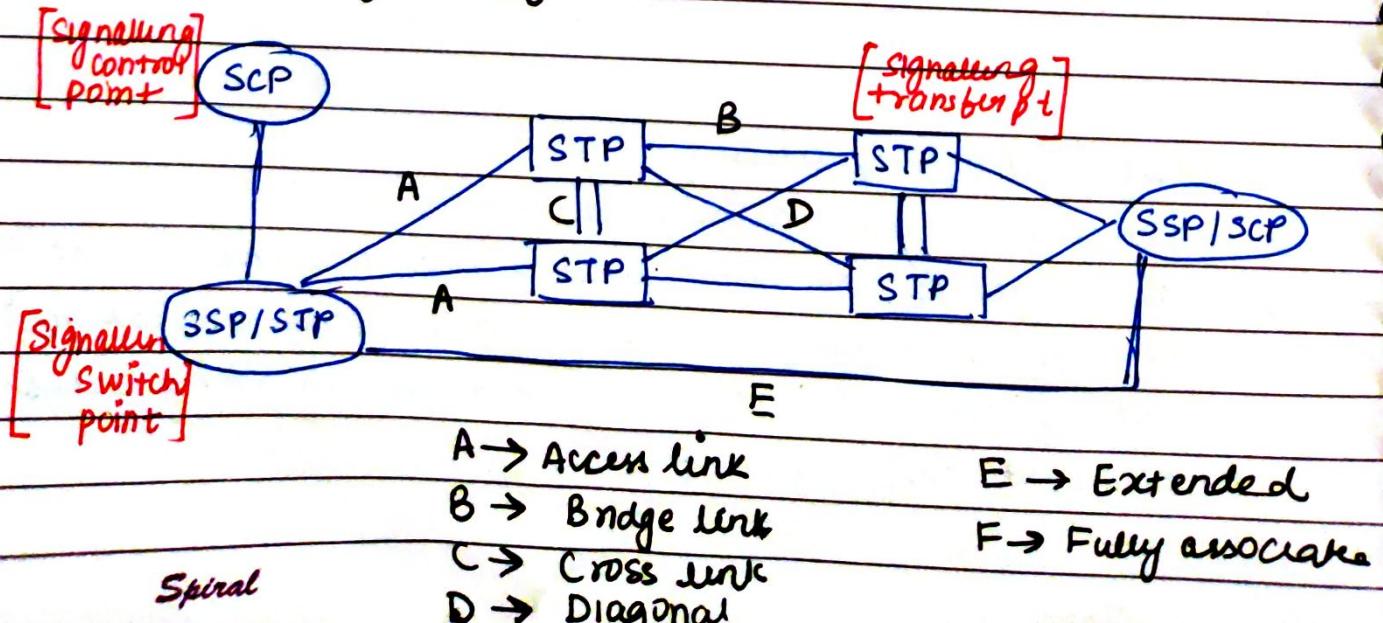


For updating loc. 2 database are there

- (i) HLR (Home location register) → (stores data of user)
- (ii) VLR (Visitor location register)

- (i) When a user subscribe for the service of PCS N/W a record is created in data base system called HLR like profile info, current loc, subscription info.
- (ii) If ms visit a PC N/W Other than home system a temporary rec of user is created in visitor loc.

## → Network Signalling: (SS7)



(i) SSP:

- a) It is an interface to telephone N/W
- b) It converts voice signal to SS7 signal link
- c) Local exchange to subscriber

(ii) SCP:

- a) It is an interface with database
- b) Handles database queries and subscribers info.

(iii) STP:

- a) It is basically a network node
- b) Works as a router

→ A link:

Connects SCP/STP to SSP and provides info of subscriber

→ B link:

Connects STP to STP

→ C link:

Connects STP ~~to~~ STP only and works for route failure and in that case provide another path

→ D link:

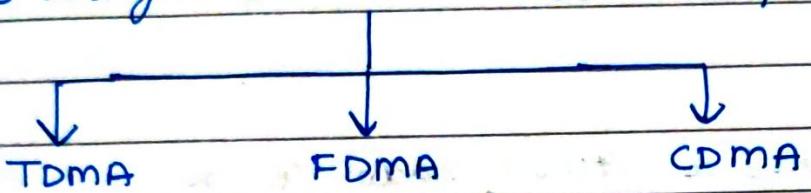
Connects STP - STP diagonally.

## → Multiple access techniques:

In wireless comm systems it is often desirable to allow the subscriber to send information simultaneously from the MS to BS while receiving info from BS to MS.

Hence a cellular system divides any given area into cells where a mobile unit in each cell comm with BS.

**Main aim:** To able to inc the capacity of channel as possible in given BW with sufficient quality of service



### (i) TDMA (Time division multiple access):

In the cases where cont. Tx is not req. hence TDMA

- is used. It divides a single channel into time slots where each user makes use of non overlapping slots.
- TDMA is not continuous but occur in bursts hence handoff is simple.
- Duplexers are not req. as Tx and Rx occur at diff slots.
- BW can be supplied or demand to diff users by concatenating or reassigning slots based on priority.

In this division of calls happens on time basis. System first digitizes calls then combines convo in unified digital stream on single radio channel. Then it divides each channel into time slots and is assigned to each call during convo.

(Digital technique)

(ii) FDMA: (Freq. Division multiple access)

It is basic technology for advanced mobile phone services.

- a) It allots diff sub band freq. to each diff user to access N.
- b) If FDMA is not in use, channel is left idle instead of allotting to others.
- c) Implemented in narrow band system
- d) Less complex than TDMA.
- e) Filtering is done to reduce interference
- f) BS and MS rx and tx data continuously.

(Analog technique)

(iii) CDMA: (Code Division multiple access)

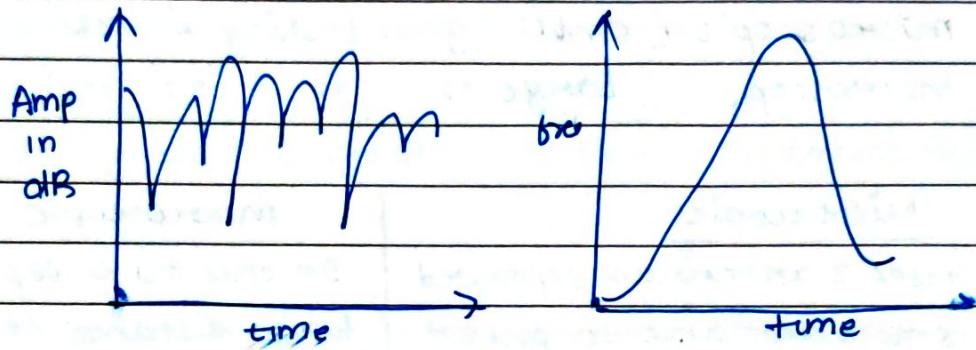
It is an example where several transmitters use a single channel to send info simultaneously.

- a) every user use full avail. spectrum
- b) recommended for voice and data comm
- c) while multiple codes occupy same channel, users having same code can comm with each other.
- d) Handoff is very well handled.

In this every bit of a convo is tagged with specific and unique code. Now the data is split into small parts and is tagged with unique code. Now this data in small pieces is sent over discrete freq. avail at any time in the range.

→ Rayleigh fading:

- (i) It is assumed that variation in signal passed through Rayleigh fading channel would follow Rayleigh distribution
- (ii) This model assumes that the mag of signal passed through a Tx medium will vary randomly or fade acc to Rayleigh distribution — the residual comp of sum of 2 uncorrected gaussian random variable
- (iii) It is caused by multipath reception (reflected and scattered waves)



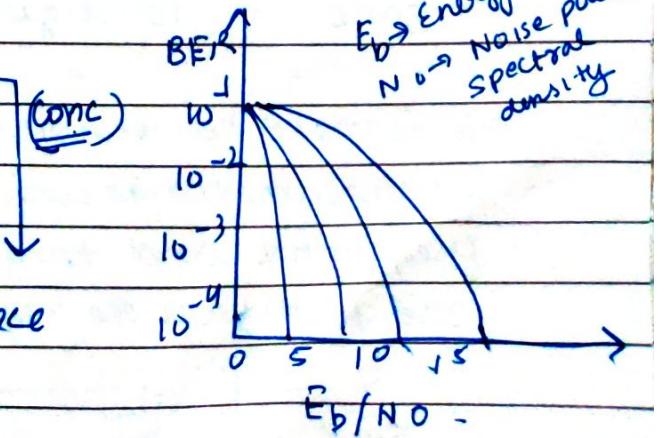
It is commonly used to describe statistical time varying nature of rx signals of flat fading signal and can be given as below:

$$g(r) = \begin{cases} \frac{r}{\sigma^2} \exp\left(-\frac{r^2}{2\sigma^2}\right) & 0 < r \leq \infty \\ 0 & r < 0 \end{cases}$$

→ BER performance in Fading channel:

(Bit rate)

- (i) BER is a function of  $E_b/No$  and is plotted for various fading channel.
- (ii) As  $BER \downarrow E_b/No \uparrow$
- (iii) AWGN exhibit good performance (conc)
- (iv) Rayleigh poor performance
- (v) Flat fading poor performance



## → Diversity modelling :

- (i) This was introduced to compare and overcome deep fading.
- (ii) As in deep fading if we have a single channel the connection will get interrupted or link will degrade due to fading. Hence to remove this problem
- (iii) multiple links i.e applied b/w Tx and Rx which won't affect comm. even after fading.
- (iv) Diversity modelling is divided into 2 parts
  - a) microscopic (small signal fading is men)
  - b) macroscopic (Large " " " " )

### Microscopic

(i) It uses 2 antennas separated by small distance to prevent small scale fading

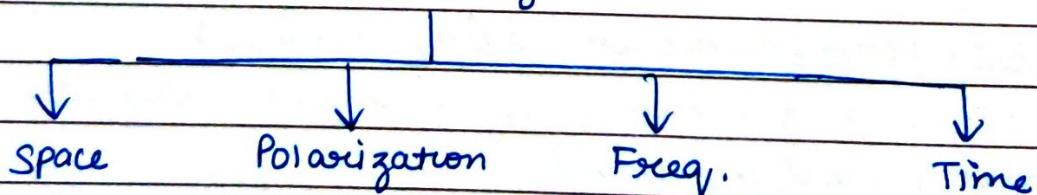
(ii) By selecting strong signal at all time a rx can mitigate small scale fading

### macroscopic

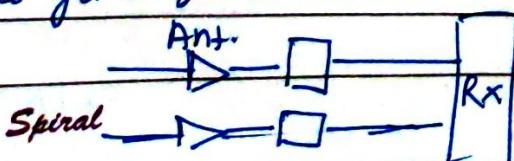
In this BS is separated by large distance that is not shadowed hence mobiles acquire better SNR.

Such contrasting reduces large scale fading.

### Types of Diversity



- (i) This is most conventional method in which we have several antennas which are separated by diff freq. band and they reach to receiver. Even if one got defade rest will reach to rx



There are 4 types of subdivision:

- a) Selection diversity
- b) Feedback diversity
- c) Maximum ratio diversity
- d) Equal gain diversity

- (ii) This is used where signal is transmitted using pair of polarized antenna and rx by another pair of antenna.  
then fading channel can be rx hence this diversity is used  
→ Circular and linear diversity antenna is used
- (iii) In this info is sent on carrier from transmitter end to receiver end.
- (iv) In time diversity info is transmitted repeatedly after a specific time. It leads to repetition of signal also.

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### → Wireless channels and fading:

Wireless comm is prone to noise, interference and other channel obstruction which change over time unpredictably resulting degradation of signal.

Losses in signal causes both in Tx of signal in short distances as well as long distances

Long distances

Here loss is due to path loss and shadowing.

Path loss → degradation of signal due to dissipation in path because of propagation effects  
Shadowing → caused by obstacles that absorbs power.

→ small scale fading  
short distances

Here loss is caused due to multipath delay and dopplers spreading.

Multipath spreading → addition of constructive & deconstructive signal components while propagation.  
Doppler spread → change in freq of EM due to relative motion of rx wrt Tx. & velocity and direction of motion of rx wrt arrival of wave.

#### ① Small scale Fading :

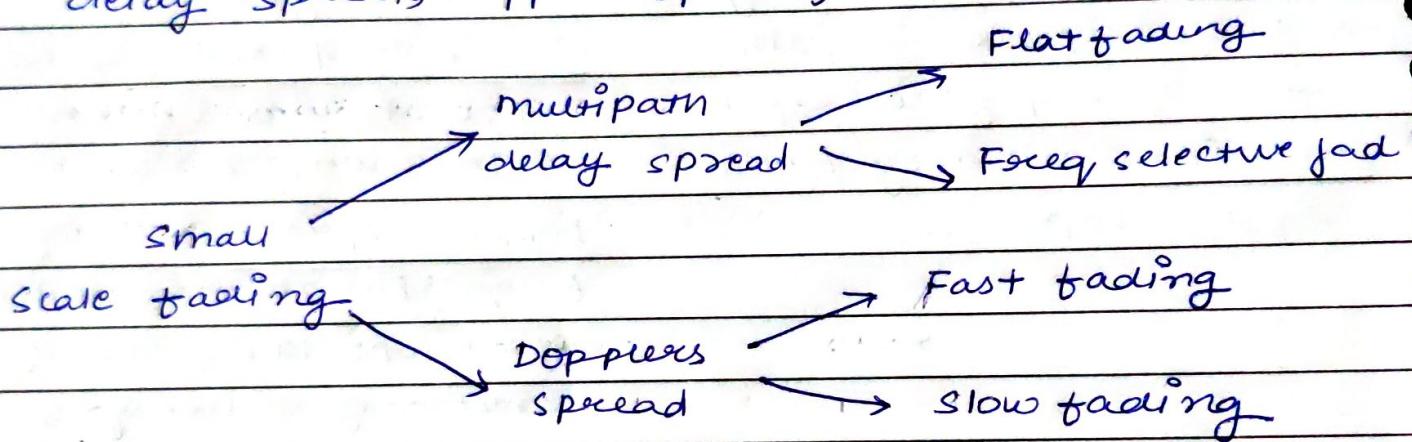
- (i) Describes rapid fluctuations of amplitude of RF signal over a short period of time and distance.
- (ii) Fading is the phenomenon caused due to interference b/w two or more versions of Tx signal which arrives at the rx at slightly diff times.  
These are delayed version of Tx signal caused due to rx and called multipath waves.

### Reasons of small scale fading

- Rapid change in signal strength over small distance
- Random freq mod. effects due to doppler shifts
- Time dispersion due to multipath delays.

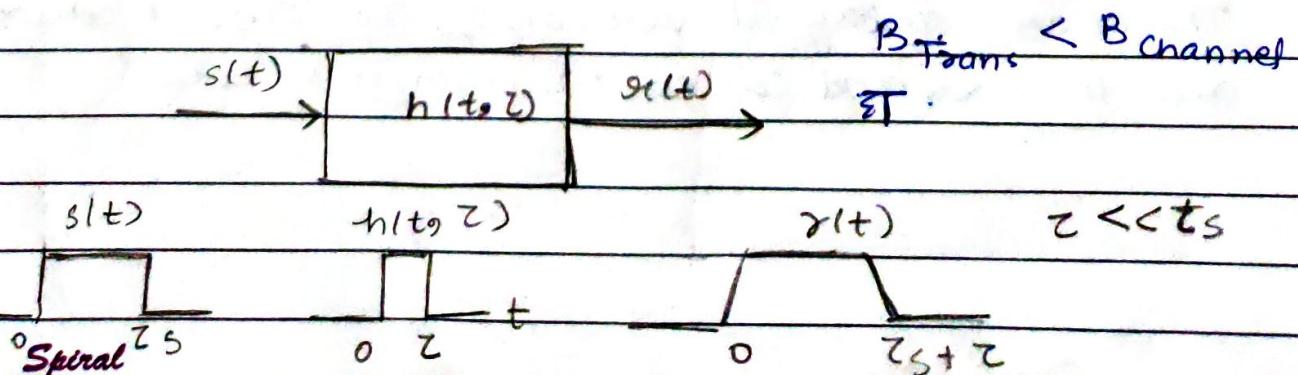
### Types of Small Scale Fading :

Type of fading experienced by Tx signal depends on the nature of Tx signal wrt characteristics of channel. i.e (depends on relation b/w signal parameters i.e BW, symbol period etc and channel parameters i.e delay spread, doppler spread).



### (i) Flat fading Channel →

- caused by time dispersion due to multipath component
- occurs in Rx signal if channel has const gain and linear phase response over  $BW > BW$  transmitted signal channel
- most common type of fading
- In this Spectral charac. of Tx signal is preserved in Rx signal while strength changes with time



conditions for flat fading

- (i)  $B_{\text{transmitted signal}} < B_{\text{channel}}$
- (ii)  ~~$T_{\text{signal}} > T_{\text{channel}}$  (Rate of change of channel should be faster than signal)~~
- (iii) Delay spread  $<$  symbol period

(iv) For eq. selective fading channel :

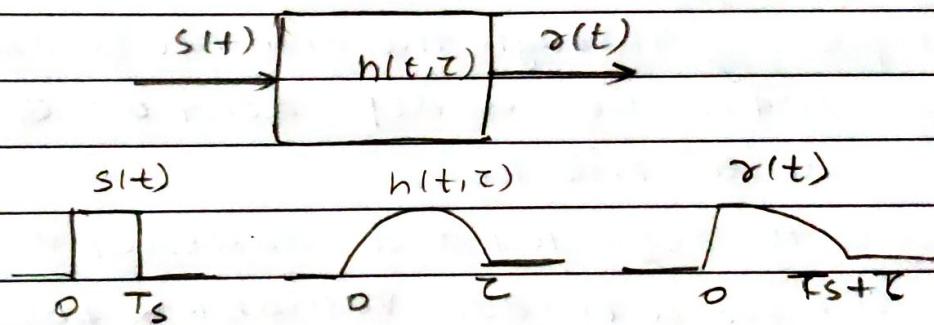
- caused due to time dispersion due to delayed multipath components.
- occurs in rx signal if channel has constant gain and linear phase response over BW channel  $<$  BW signal.

Condition for selective fading

- (i) BW signal  $>$  B channel

(ii)  ~~$T_{\text{channel}} > T_{\text{signal}}$~~  Delay spread  $>$  symbol period

- Received signal includes faded and delayed signal so hence signal is distorted and InterSymbol Interference is induced.



(v) Fast fading channel :

- caused due to freq dispersion due to doppler spread
- Rate of change of channel is faster than rate of change of Tx signal.
- Doppler spread is greater than Tx signal.

- (i)  $T_{\text{signal}} > T_{\text{channel}}$  ( $T_s \rightarrow$  symbol period)
- (ii)  $B_{\text{signal}} < B_{\text{doppler spread}}$

#### (iv) Slow fading channels :

- caused due to freq dispersion due to doppler spread
  - Rate of change of channel is slower than Tx signal
  - Impulse response is static
  - Doppler spread is smaller than Tx signal
- (i)  $T_s \ll T_c$  ( $T_c \rightarrow$  coherence time)  
(ii)  $B_{\text{signal}} > B_{\text{doppler}}$  ( $T_s \rightarrow$  symbol period)

#### ② Rayleigh and Rician fading channels :

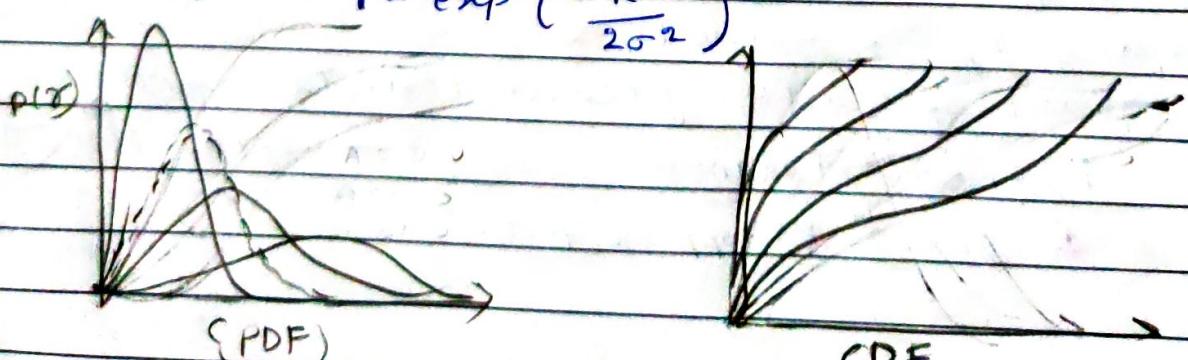
These fading occurs to a signal as a result of effect of propagation channel.

##### (i) Rayleigh fading channel :

- Based on Rayleigh distribution which is used to describe statistical time varying nature of rx waveform of a flat fading signal
- Signal passing through this channel follows rayleigh distn
- Rayleigh distribution is dependent on Gaussian and Normal distribution.
- Caused due to reflected and scattered waves
- PDF and CDF for a random variable  $X$  following Rayleigh distribution is given as

$$p(x) = \frac{\pi}{2\sigma^2} x \exp\left(-\frac{x^2}{2\sigma^2}\right) \quad 0 \leq x \leq \infty$$

$$P(x) = 1 - \exp\left(-\frac{x^2}{2\sigma^2}\right) \quad x > 0$$



Rayleigh distribution for (A)

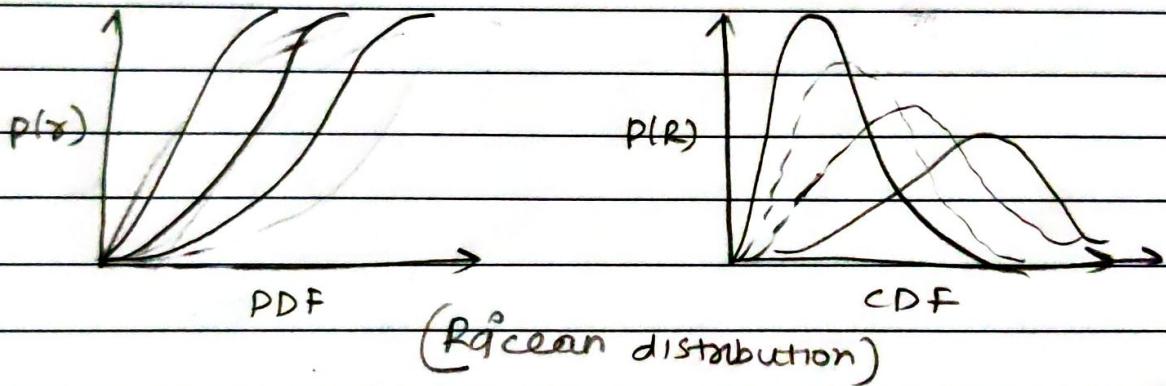
## (ii) Rician fading channels :

- A ~~wireless~~ wireless channel modelled when there exists non-fading signals, LOS propagation path, random multipath components and these are superimposed on a non-fading signal.
- At the ~~at~~ receiver the OIP signal having effect of all these components resulting weaker signal following Rician distribution.

→ PDF and CDF are given as

$$p_{R1} = \int \frac{x}{\sigma^2} e^{-\frac{(x^2+A^2)}{2\sigma^2}} I_0\left(\frac{Ax}{\sigma^2}\right) \quad A > 0 \quad x > 0$$

$$P(R) = 1 - Q\left(\frac{A}{\sigma}, \frac{\sigma}{\sigma}\right)$$



## ③ BER performance in fading channels :

- BER stands for bit error rate per bit transferred.
- It is a function of  $E_b/N_0$  plotted for various channel
- $BER \downarrow, E_b/N_0 \uparrow$
- As Attenuating the chan