CELLULAR AND MOBILE COMMUNICATIONS

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY: KAKINADA
KAKINADA – 533 003, Andhra Pradesh, India
DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

III Year - II Semester		L	T	P	C
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CELLULAR & MOBILE COMMUNICATION
(Professional Elective 2)

Course Objectives:

The student will be introduced to:

- Understand the basic cellular concepts like frequency reuse, cell splitting, cell sectoring etc and various cellularsystems.
- Understand the different types of interference s influencing cellular andmobile communication.
- Understand the frequency management, channel assignment and variouspropagation effects in Cellularenvironment.
- Understand the different types antennas used at cell site andmobile.
- Understand the concepts of handoff and types ofhandoffs.
- Understand the architectures of GSM and 3G cellularsystems.

UNIT I

CELLULAR MOBILE RADIO SYSTEMS: Introduction to Cellular Mobile System, uniqueness of mobile radio environment, operation of cellular systems, consideration of the components of Cellular system, Hexagonal shaped cells, Analog and Digital Cellular systems.

CELLULAR CONCEPTS: Evolution of Cellular systems, Concept of frequency reuse, frequency reuse ratio, Number of channels in a cellular system, Cellular traffic: trunking and blocking, Grade of Service; Cellular structures: macro, micro, pico and femto cells; Cell splitting, Cell sectoring.

UNIT II

INTERFERENCE: Types of interferences, Introduction to Co-Channel Interference, real time Co-Channel interference, Co-Channel measurement, Co-channel Interference Reduction Factor, desired C/I from a normal case in a omni-directional Antenna system, design of Antenna system, antenna parameters and their effects, diversity receiver, non-cochannel interference-different types.

UNIT III

FREQUENCY MANAGEMENT AND CHANNEL ASSIGNMENT: Numbering and grouping, setup access and paging channels, channel assignments to cell sites and mobile units: fixed channel and non-fixed channel assignment, channel sharing and borrowing, overlaidcells.

CELL COVERAGE FOR SIGNAL AND TRAFFIC: Signal reflections in flat and hilly terrain, effect of human made structures, phase difference between direct and reflected paths, straight line path loss slope, general formula for mobile propagation over water and flatopen area, near and long distance propagation, antenna height gain, form of a point to pointmodel.

UNIT IV
HANDOFF STRATEGIES:
Concept of Handoff, types of handoff, handoff initiation, delaying handoff, forced handoff, mobile assigned handoff, intersystem handoff, soft and hard hand offs, vehicle locating methods, dropped call rates and their evaluation.

UNIT V
DIGITAL CELLULAR NETWORKS: GSM architecture, GSM channels, multiple access schemes; TDMA, CDMA, OFDMA.3G and 4G Wireless Standards GSM , GPRS , WCDMA , LTE , Wi-MAX, Introduction to 5G standards.

TEXT BOOKS:

1. Mobile Cellular Telecommunications – W.C.Y. Lee, Tata McGraw Hill, 2nd Edn.,2006.
2. Principles of Mobile Communications – Gordon L. Stuber, Springer International2nd Edition,2007.
3. Advanced Wireless Communications-4G By. Savo G Glisic, John Wiley & Sons Publication 2ndEdition

REFERENCES:

1. Wireless Communications – Theodore. S. Rapport, Pearson education, 2nd Edn.,2002.
2. Wireless Communication and Networking – Jon W. Mark and WeihuaZhqung, PHI,2005.
3. Fundamentals of Wireless CommunicationBy. David Tse and Pramod Viswanath, Cambridge UniversityPress

Course Outcomes:
At the end of this course the student can able to:

- Identify the limitations of conventional mobile telephone systems; understandthe concepts of cellularsystems.
- Understand the frequency management, channel assignment strategies and antennasin cellularsystems.
- Understand the concepts of handoff and architectures of various cellularsystems.

Unit -1

Cellular Mobile Radio Systems

Introduction to cellular System (or) Basic cellular Systems

There are four elements in cellular System. those are mobile unit, cell site, MTSO, Voice & data links

Mobile unit :-

→ Mobile unit consists of a transceiver, control unit, power unit, and an antenna System.

→ Transceiver means both transmitter & Receiver

→ This transceiver used by the subscriber for Voice and data calls.

→ power unit provides power Supply to all the Circuits & elements in the mobile unit.

→ Tuning the transmitter, receiver, display managem Execution of handoff & etc are monitored and controlled by control unit.

Cell site :-

→ cell site is an interface between mobile unit & MTSO.

→ A Small part of CGSA is called as 'cell'

→ A cell with antenna equipment is called as cell site.

→ cell site consists of an antenna, transmitter, receiver, control unit, power unit, radio cabinets (channels).

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→ power unit consists of supply provided by local provider & a generator as stand-by power supply.

→ Radio cabinates are the channels which are assigned to the cell site, these channels will be assigned to mobile units as per the requirements.

Voice & data links (Transmission links):-

→ A transmission link is required between cell site & MTSO for the exchange of voice & data signals.

→ Optical fibre cables (OFC) are the preferred transmission links as they offer huge bandwidth, least loss, less noise etc.

→ Alternative of OFC is a microwave link between cell site & MTSO.

Mobile Telephone Switching office (MTSO):-

→ MTSO is the heart of the cellular system as it is responsible for each & every activity.

→ It consists of several switches & processors

→ Switches are used to provide a link between calling & called subscribers.

→ Processors are used for performing all the activities of MTSO.

→ MTSO activities includes

(i) Mobile unit validation

(ii) Billing meter maintenance

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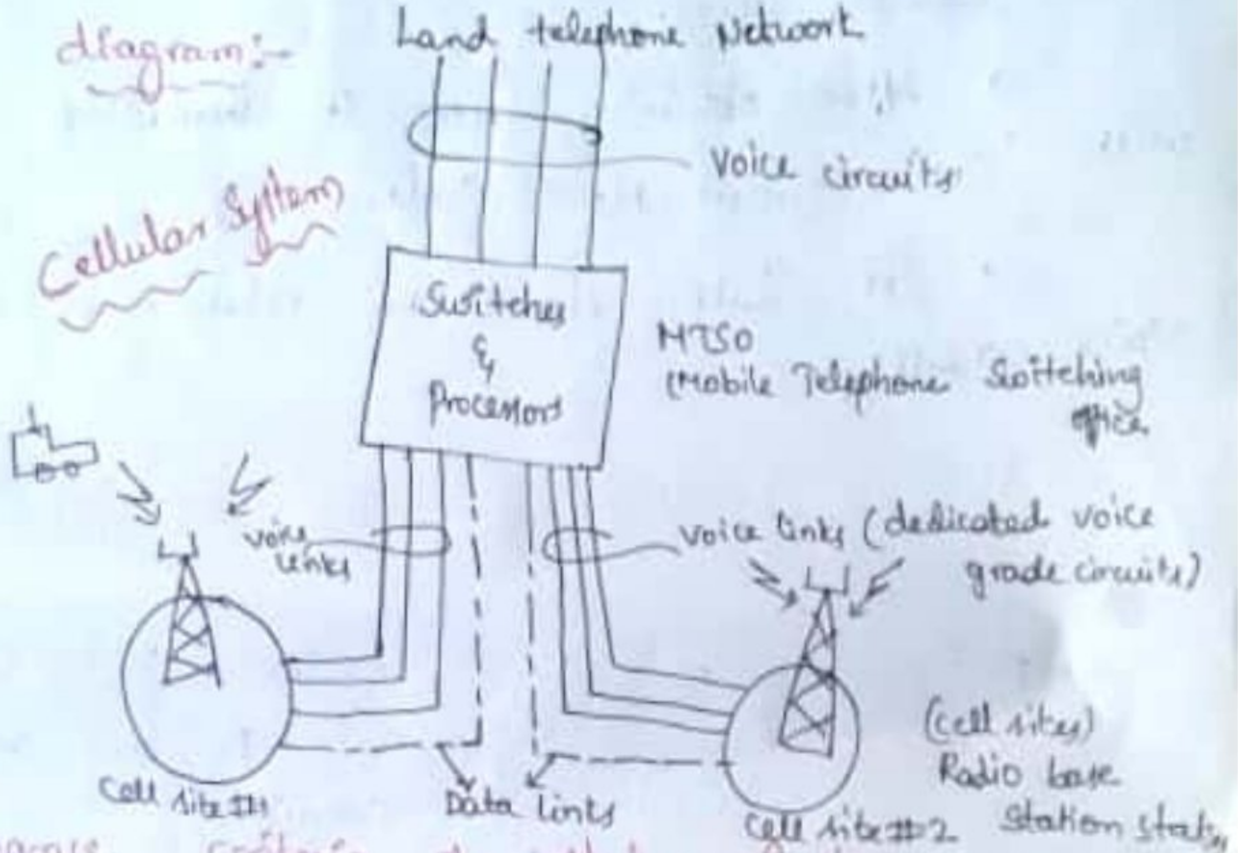
(iii) Hand off Execution

(iv) channel sharing & borrowing

diagram:-

Cellular System



Performance criteria of cellular System :-

There are 3 factors on which the performance of cellular System depends.

1. Voice Quality
2. Service Quality
3. Special Features

Voice Quality :-

→ Voice Quality is a basic factor and it must be maintained at very good (or) excellent level for any cellular System

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→ To estimate the voice Quality subscriber opinion must be collected & based on this 'MOS' (Mean opinion Score).

→ After obtaining MOS, it should be verified with 'CM' (circuit Merit) Scale.

→ CM Scale shows the relation between MOS Voice Quality

CM Scale	Score (MOS)	Voice Quality
CM5	5	Excellent - Voice is clear, no repetitions are required
CM4	4	Very good - Voice is clear, occational repetitions are required
CM3	3	Good - voice is understandable frequent repetitions are required.
CM2	2	Average / fair - Speech is Understandable with effort
CM1	1	Poor - Speech is not Understandable

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(3)

→ As per the CM Scale, voice Quality must be either in CM4 (or) CM5, So MOS must be greater than 4.

→ If the voice call is maintained as Excellent (or) Very good then performance of the cellular System is high w.r.to the voice Quality

Service Quality:-

Service Quality depends on 3 parameters

(i) Coverage

(ii) Grade of Service

(iii) No. of dropped calls.

i Coverage:- It is not mandatory to provide 100% coverage but the following conditions must be maintained for good performance of cellular System

→ In flat area, coverage must be 90% and 75% subscribers must be Satisfied with the Coverage.

→ In hilly area, coverage must be 75% and 90% subscribers must be satisfied with the coverage.

ii Grade of Service (blocking):-

→ During the busy hour, no. of call attempts are highest.

→ In that case there is a Possibility of

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blocking.

→ As per cellular standards, allowed blocking

B = 2% max.

→ If blocking is less than 2% then the performance of cellular system is considered as good.

(iii) No. of dropped calls :-

→ During the busy hour if 'Q' calls are made & 'Q-1' calls are completed then no. of incomplete (or) dropped call is 'one'.

→ Dropped call rate is given by $\frac{1}{Q}$

→ The dropped call rate must be zero (or) near zero to make good performing system.

Special Features :-

Any feature (or) service which attracts more subscribers into system is considered as special feature.

Such as

1. Unlimited calls
2. Unlimited data
3. Voice stored (VSR) box
4. call forwarding
5. call waiting
6. Automatic roaming (or) Navigation Services

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IV Operation of cellular System:-

The operation of cellular System includes 5 steps:

1. Mobile unit initialization.
2. Mobile originated call
3. N/w originated call
4. Call termination.
5. Hand off.

(1) Mobile Unit initialization:-

Powering up the mobile unit, Scanning & searching for strongest setup channel, Tuning the mobile unit to the nearest cell site & obtaining the network access these are the different activities of mobile unit initialization.

) Mobile originated call:-

→ It is an outgoing call made from the mobile unit.

→ Sends MIN (Mobile Identification no) & called subscriber no to nearest cell site

→ Receives the nearest & delivers it to the MTSO.

→ Receives the request from the cell site

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→ Instructs the cell site to move the mobile unit onto a free voice channel pair. (6)

→ Connects the mobile unit to the called subscriber through a switch

→ voice transmission

→ voice Reception

→ Voice transmission

→ Voice Reception.

(3) N/W originated call :—

→ Receives the request from PSTN (or) other N/W & delievers MIN details to all cell site

→ Transmitts the page information in the entire coverage area.

→ Sends the acknowledgment to the cell site about matching of MIN.

→ Sends the control signal with voice channel frequency information.

(4) Call termination :—

→ At the end of conversation, if the mobile use turns off the transmitter by processing call end button. Then it is called as call termination.

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(8) Hand off :—

During a call, if the mobile unit is moving from one cellsite to the other then it must be moved from old voice channel to new voice channel pair is called as Handoff.

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Analog cellular System)

1) AMPS

2) NMT

3) NTT

Amps — Advanced mobile phone Systems

→ It is the analog mobile phone system developed by Bell Labs and officially introduced in America in 1983 & Australia in 1987

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→ In the first generation cellular technology that uses separate frequencies (or) channels for each conversation.

→ In AMPS, the cell centers can flexibly assign channels to handsets based on signal strength.

NMT — Nordisk mobile Telephone

NMT N/W :-

→ NMT Network is also known as Nordic System

→ This system was mainly developed by Scandinavian Countries (Denmark, Norway, Sweden, Finland) in collaboration co-operation with Spain & Saudi Arabia.

→ The NMT system serves about 1,00,000 Subscribers and provides handoffs, roaming facilities.

NTT N/W :- NIPPON TELEGRAPH And Telephone corporation.

→ This corporation has developed an 800 MHz land mobile telephone system in 1979 to provide service to Tokyo area

→ This s/m provides service to approximately 40,000 Subscribers in 900 cities.

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Uniqueness of mobile radio environment

Cell splitting :-

→ If the load of the cell site is more and the channels assigned to that site are not sufficient then various techniques such as channel sharing & borrowing may be use.

→ If all the above methods fails in handling the additional load then only option left out is cell splitting.

→ Dividing the big old cell site into several smaller new cell sites is cell-splitting.

→ After splitting, each part of old cellsite is considered as full cellsite.

→ No. of cellsites and the no. of channels in the system increases.

→ There are two approaches in cell splitting.

→ As per the load & requirement, different approches can be used in cell splitting

→ Considering the 1st approach ie dividing old cell site to 4 new cell sites

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$$\text{New cell area} = \frac{\text{old cell area}}{4}$$

$$\text{New cell radius} = \frac{\text{old cell radius}}{2}$$

New traffic load handling = old traffic load handling × 4

→ There are two types of cell splitting
1. permanent splitting
2. Dynamic splitting.

Permanent Splitting:-

→ This is recommonded for loads which are created on long term basis

→ After P.S, each new cell site must be equipped with an antenna & other elements on permanent basis

→ The existence of old cell site will not be there after permanent splitting. i.e, this process cannot be reversed.

Ex If new business zones (or) S/w Parks are established in specific cell site area then permanent spilting is used to handle the additional load.

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Dynamic Splitting:-

→ This is recommended for the loads which are created on short term basis i.e., for the days/weeks.

→ The process of dynamic splitting is similar to the permanent splitting but the antenna's equipment installation is not concrete.

→ Portable cell sites are used in dynamic splitting i.e., a truck with antenna and all other necessary equipment installed.

→ The process of dynamic splitting is reversible i.e., old cell site can be restored after the completion of event.

Ex Exhibition, fares, and event in a stadium & etc needs dynamic splitting.

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Cellular Structures :-

Micro cell zone concept :-

→ In sectoring, cell site must be divided into sectors and appropriate antennas must be used designed for each sector.

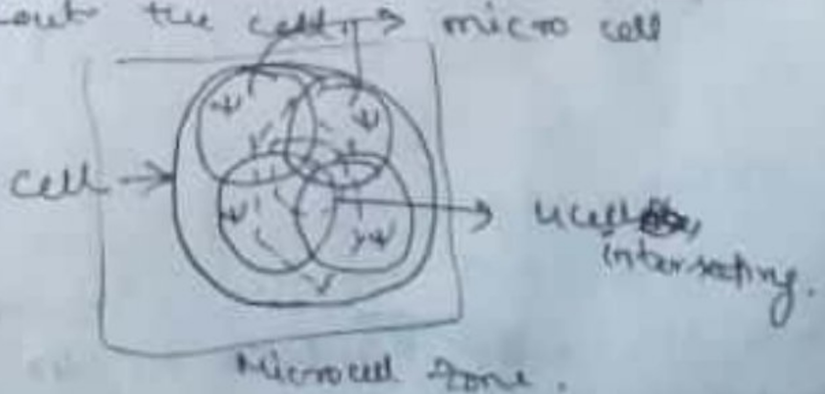
→ To avoid these issues of sectoring micro cell zone concept is used.

→ Improvement in coverage can be achieved by microcells i.e., conceptual division of a cell site.

→ Each microcell zone uses a directional antenna & it radiates the power into the cell site.

→ During a call if the mobile unit travels from one zone to other, then it retains the Existing channel i.e., no hand off.

→ This mechanism offers good coverage at the boundaries & throughout the cell.



Microcell zone.

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→ It is called "Time division Multiplexing"

→ freq. reuse in the Spain domain can be divided into two categories.

(i) Same freq assigned in two different geographic areas, such as AM or FM radio stations using the same freq. in different cities.

(ii) Same freq. repeatedly used in a same general area in one system is used in cellular systems.

(iii) Freq reuse distance:-

→ The min. distance which allows the same freq. to be reused will depend on many factors,

such as a) the no. of cochannel cells.

b) the type of geographic terrain.

c) the antenna height

d) the transmitted power at each cell site.

→ The freq reuse distance

$$D = \sqrt{3K}R.$$

k is the freq reuse pattern.

$k = 4$; $D = 3.46R$

$k = 7$; $D = 4.6R$

$k = 12$; $D = 6R$

$k = 19$; $D = 7.55R$

→ If the cellsites transmitt the same power, then K increases and the freq reuse distance D increases.

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iii) Number of (changing) Customers in the System:-

→ The traffic conditions in the area during a busy hour are some of the parameters that will help determine both the sizes of different cells and the no. of channels in them.

→ The maximum no. of calls per hour per cell is driven by the traffic conditions at each particular cell.

→ After the max. no. of freq. channels per cell has been implemented in each cell.

Cell Sectoring:- coverage ↑

→ Improvement in coverage is difficult in omni directional antenna System, as it may leads to interference

→ Therefore to improve the coverage with out getting interference directional antennas are required.

→ To use directional antennas in cellular system each cell must be divided into sectors.

→ There are two types of sectorization possible for each cells

i) 3- Sector case

ii) 6-Sector case.

3-Sector case:-

→ 3 Sector case requires 3 antenna elements. [illegible] 120° [illegible] beam reflectors are used as antennas.

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6-Sector case:-

In 6-Sector case, 6 antenna elements are required & 60° ~~they are placed~~ ~~angles b/w antenna elements~~ in beam reflectors are used as antenna

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Problem

An antenna has $D = 4$, $R_{rad} = 40\,\Omega$, $R_{dis} = 10\,\Omega$
Find antenna efficiency and maximum power gain

Given that,

For an antenna,

Directivity $D = 4$

Radiation resistance, $R_{rad} = 40\,\Omega$

dissipation resistance, $R_{dis} = 10\,\Omega$

Antenna efficiency $\eta = ?$

Max power gain, $G_{Pmax} = ?$

Then, the expression for efficiency of an antenna is given by

$$\text{Efficiency } \eta = \frac{R_{rad}}{R_{rad} + R_{dis}}$$

$$\eta = \frac{40}{40+10} = \frac{40}{50} = \frac{4}{5} = 0.8$$

$$= 0.8 \times 100\%$$

$$= 80\%$$

$$\boxed{\eta = 80\%}$$

Then, the expression for max power gain in terms of directivity and efficiency of antenna is given by;

$G_{Pmax} = \eta D$

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$G_{P(max)} = \eta D$

$= 0.8 \times 4$

$= 3.2$

And $G_{p(max)}(dB) = 10 \log_{10}(3.2$

$= 5.05 \, dB$

$G_{p(max)} = 5.05 \, dB$

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Problem

During busy hour, the number of calls per hour Q_i for each 10 cells is 2000, 1500, 3000, 500, 1000, 1200, 1800, 3200, 2600 & 800. Assume that 60% of the car phones will be used during this period and that one call is made per car phone. Find the no. of customers in the system.

Sol Given that,

In a cellular system during a busy hour, the number of calls per hour for each 10 cells is,

$Q_1 = 2000$; $Q_2 = 1500$; $Q_3 = 3000$; $Q_4 = 500$

$Q_5 = 1000$; $Q_6 = 1200$; $Q_7 = 1800$; $Q_8 = 3200$

$Q_9 = 2600$; $Q_{10} = 800$

The percentage of car phones used during the busy period, $\eta_c = 60\%$

Total no. of customers in the system $M_t = ?$

Then, the total no. of calls per hour per car phone is given by

$$Q_t = \sum_{i=1}^{10} Q_i$$

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$$Q_t = Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_6 + Q_7 + Q_8 + Q_9 + Q_{10}$$

$$= 2000 + 1500 + 3000 + 500 + 1000 + 1200 + 1800 + 3100 + 2600 + 800$$

$$= 17600$$

$Q_t = 17600$ calls per hour

∴ The total no. of customers in the system is given by

$$M_t = \frac{Q_t}{\eta_c} = \frac{17600}{0.6} = 29333.33$$

$$\boxed{M_t \cong 29334}$$

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1) Uniqueness of Mobile radio Environment:—

→ when compared to any other wireless communication system, few features are unique in mobile / cellular communication.

→ This includes.

1) propagation loss
2) fading
3) Delay spread
4) Coherence Bandwidth.

Propagation loss:—

→ propagation loss depends on the propagation distance.

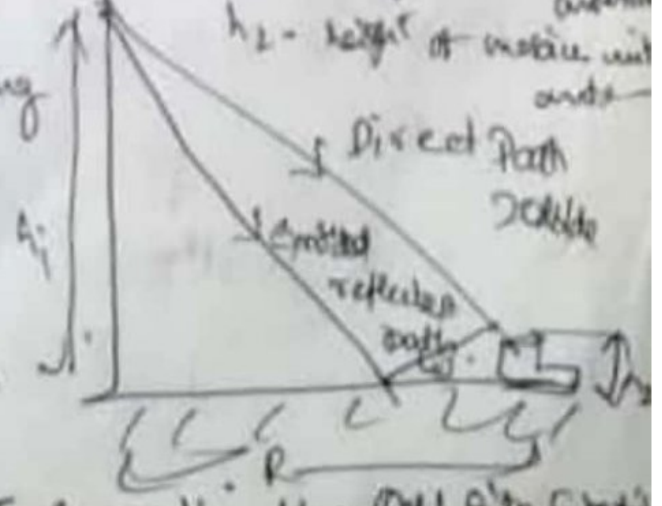
→ If the distance is more the loss will be more

h_1 – height of cell site antenna

h_2 – height of mobile unit antenna

→ If the direct path is existing b/w cell site & Mobile unit, loss is considered as 20dB/dec

→ If the signal is hitting the ground propagation loss is considered as 40dB/dec



R = separation b/w cell site & mobile

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→ If the signal is reflected from surface of the water loss will be either 20 dB/dec (or) 40 dB/dec for fresh water & salt water. (5)

→ If the signal is propagating through the forest the loss will be 65 db/dec.

Fading :-

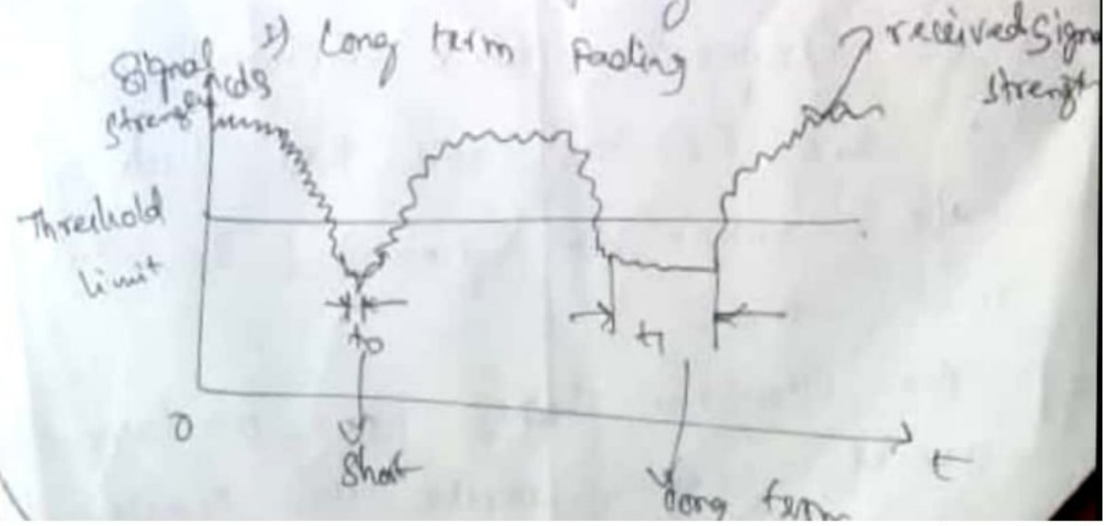
→ Variations in the received signal strength due to the channel characteristics is called as "Fading"

→ If the received signal strength is above the threshold then the effect of fading is negligible.

→ If the received signal strength is bellow the threshold, then the effect of fading must be reduced.

→ 2 types of fading

1) Short term fading
2) Long term fading



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Delay spread (Δ)

→ In multipath fading environment, due to the delay in the arrival rate of different paths, delay spread occurs.

coherence bandwidth (B) :-

→ It is the bandwidth in which either amplitude (or) phase of multipath signals are having high degree of similarity.

→ For fading amplitudes, the coherence Bandwidth is given by

$$B_c = \frac{1}{2\pi\Delta}$$

→ Similarly for fading phases the

$$B_c = \frac{1}{4\pi\Delta}.$$

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Hexagonal Shaped cells :-

→ The hexagonal shaped communication cells are artificial and that such a shape cannot be generated in the real world.

→ The circular shapes have overlapped areas which make the unclear

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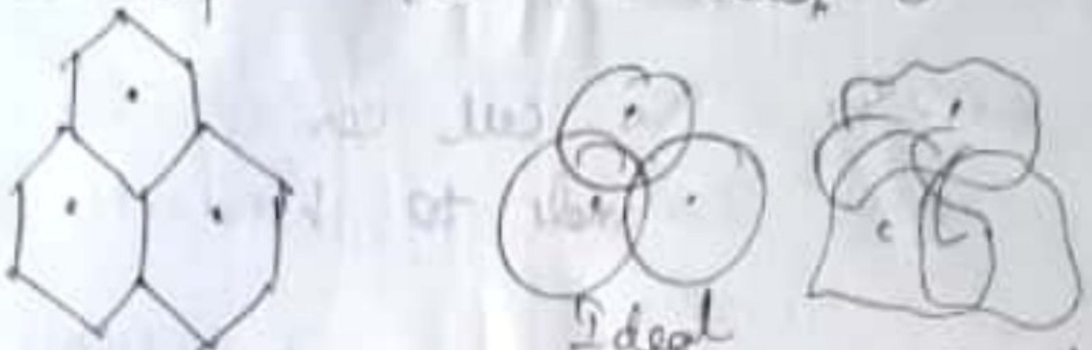
→ The hexagonal shaped cells fit the planned area nicely with no gap and no overlap. b/w the hexagonal cells ③



Ideal

Real

fictious cell layout → our Engineers draw hexagonal shaped cells on layout to simplify the planning & designing of a cellular system.

→ when compared to all the three shapes, the hexagonal cell shape has the largest area for a given distance b/w the perimeter pts and center of a polygon.

→ Hexagonal shape is suitable for Omni directional antennas, thus hexagonal shaped cells are widely accepted for mobile communication.

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Interference

Introduction to Co-channel Interference :-

→ In cellular system, the allocated frequency spectrum will be utilized several times is called frequency re use

→ Due to the freq reuse, same freq band may be assigned to different cell sites of single CGSA then interference may occur.

Def:-

The interference is occuring between same frequency assinged cell sites (Co-channel cell sites) then it is called as "Co-channel interference."

→ It may be present in the system due to lesser frequency reuse distance, high power at cell site, improper design etc.

→ TO know or estimate cochannel interference areas in the system (or) to generate interference map, two tests ie., test-1 & test-2 conducted.

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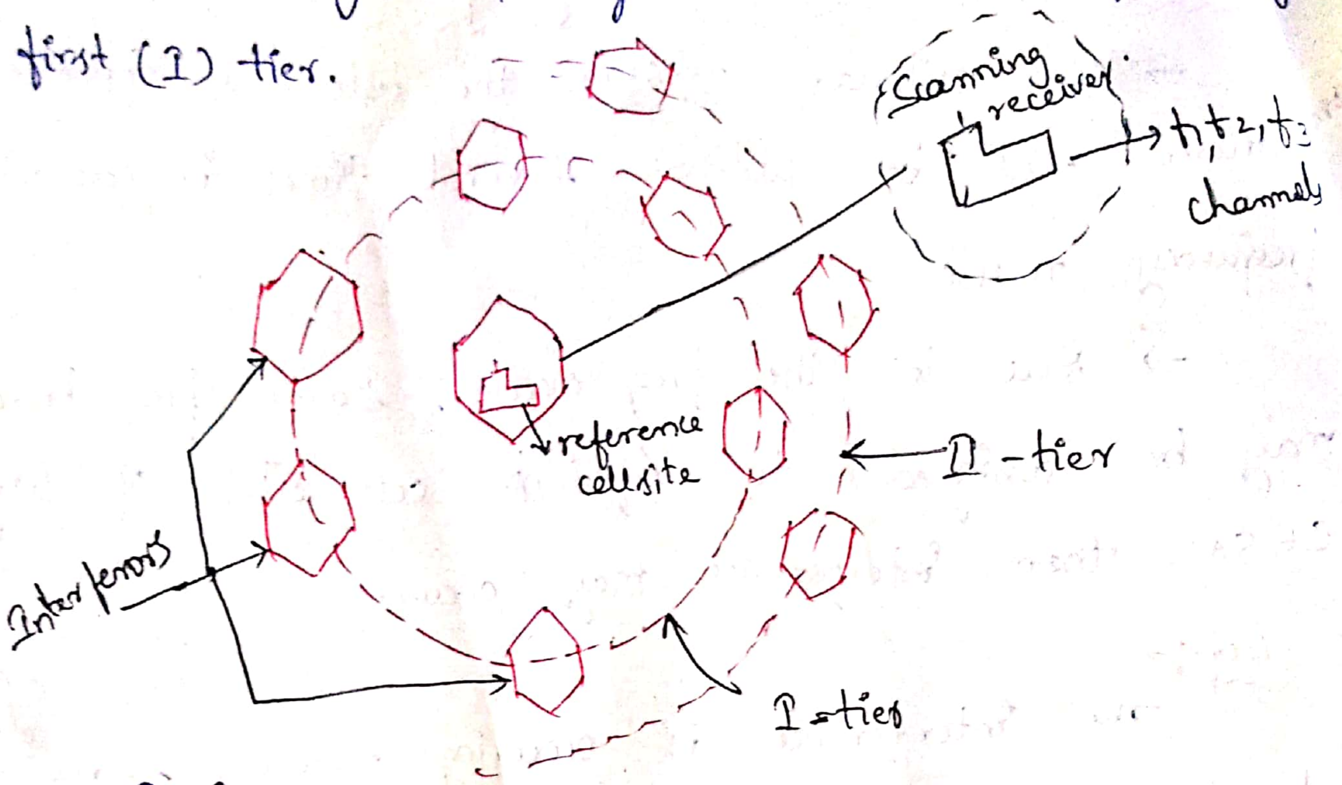
Test-1 Finding cochannel interference areas from mobile receiver

→ Assuming K=7 System with 6 interferers first (I) tier.



→ During the test a Scanning receiver is used at reference cellsite & it consists of f_1, f_2, f_3 channels to measure and record carrier, interference, Noise respectively.

→ Both Scanning receiver and interfacing mobile unit of I - tier cellsite is maintained at same channel.

→ Then from the received signal, the three components will be recorded.

→ This process will be repeated for all 6 interfererors.

→ Based on recorded values on f_1, f_2, f_3 C/I & C/N are estimated.

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→ If both C/I & C/N > 18 dB (greater than) then there is no interference and no coverage issues system is properly designed.

→ If C/I < 18 dB and C/N > 18 dB then there is interference in the system but no coverage issues.

→ If both C/I & C/N < 18 dB and C/I ≅ C/N then there is interference and also coverage issue in the system.

→ If both C/I & C/N < 18 dB and C/I < C/N then there is severe interference in the system with noise, system is not designed properly.

Test-2 :-

→ The setup for test-2 is similar to the setup used during test-1, except scanning receiver used at the mobile unit.

→ A setup similar to scanning receiver is used at the cellsite to measure and record the components received from mobile unit.

→ During this test, power received from the mobile unit is monitored, measured and recorded.

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where

→ From these values top 10% is considered for interference measurement and bottom 10% is considered for carrier measurement.

→ From the above analysis, C/I & C/N is estimated.

→ Then the conditions mentioned in test-1 are applied.

Real time co-channel interference measurement at mobile transceivers:

Assuming the mobile carrier is angle modulated then the received signal at mobile transceiver may have carrier and interference components.

$$\text{Carrier} - e_1 = S(t) \sin(\omega t + \phi_1)$$

$$\text{Interference} - e_2 = I(t) \sin(\omega t + \phi_2)$$

∴ The received signal at mobile unit is equal to

$$e(t) = e_1 + e_2$$

$$e(t) = S(t) \sin(\omega t + \phi_1) + I(t) \sin(\omega t + \phi_2)$$

Above expression can be written as

$$e(t) = R \sin(\omega t + \psi)$$

where R - amplitude spectrum of received signal
ψ - Phase spectrum of received signal

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where,

$$R = \sqrt{(S(t)\cos\phi_1 + I(t)\cos\phi_2)^2 + (S(t)\sin\phi_1 + I(t)\sin\phi_2)^2}$$

$$\psi = \tan^{-1}\left[\frac{S(t)\sin\phi_1 + I(t)\sin\phi_2}{S(t)\cos\phi_1 + I(t)\cos\phi_2}\right]$$

→ To simplify the amplitude spectrum 'R' envelope, detection of received signal is required

$$R^2 = S^2(t) + I^2(t) + 2\,S(t)\cdot I(t)\cos(\phi_1 - \phi_2) \quad \text{—— (A)}$$

→ By Applying & using KOZONO & SAKAMOTO'S analysis on eq (A), following assumptions can be made,

$$X = S^2(t) + I^2(t)$$

$$Y = 2S(t)\,I(t)\cos(\phi_1 - \phi_2)$$

→ Considering $S(t)$, $I(t)$, ϕ_1, ϕ_2 as independent random variables then average process on X & Y gives

$$\overline{X} = \overline{S^2(t)} + \overline{I^2(t)}$$

$$\overline{Y} = \overline{S^2(t)} \cdot \overline{I^2(t)}$$

∴ The signal to interference ratio (or) carrier to interference ratio is given by

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$$\Gamma = \frac{\overline{S^2(t)}}{\overline{I^2(t)}} = k + \sqrt{k^2-1}$$

where $k = \frac{\overline{X^2}}{\overline{Y^2}} - 1$

→ For the computation of Γ, the hardware required is envelope detector, A/D converter & a micro computer.

→ During A/D conversion, the delay (or) sampling rate must satisfy the following conditions

(i)

$$S(t) \simeq S(t+\Delta t)$$

$$I(t) \simeq I(t+\Delta t)$$

→ To satisfy the above two conditions, Δt must be very small (0) and hardware cannot be designed for that much smaller delays.

→ The real time co-channel interference measurement at mobile transceiver is difficult to acheive in practice.

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Channel Interference reduction factor (q) :-

→ It depends on the frequency reuse distance 'D' and radius of the cellsite 'R'.

→ cochannel interference reduction factor is given by

$$q = D/R$$

→ If 'R' is constant then $q \propto D$

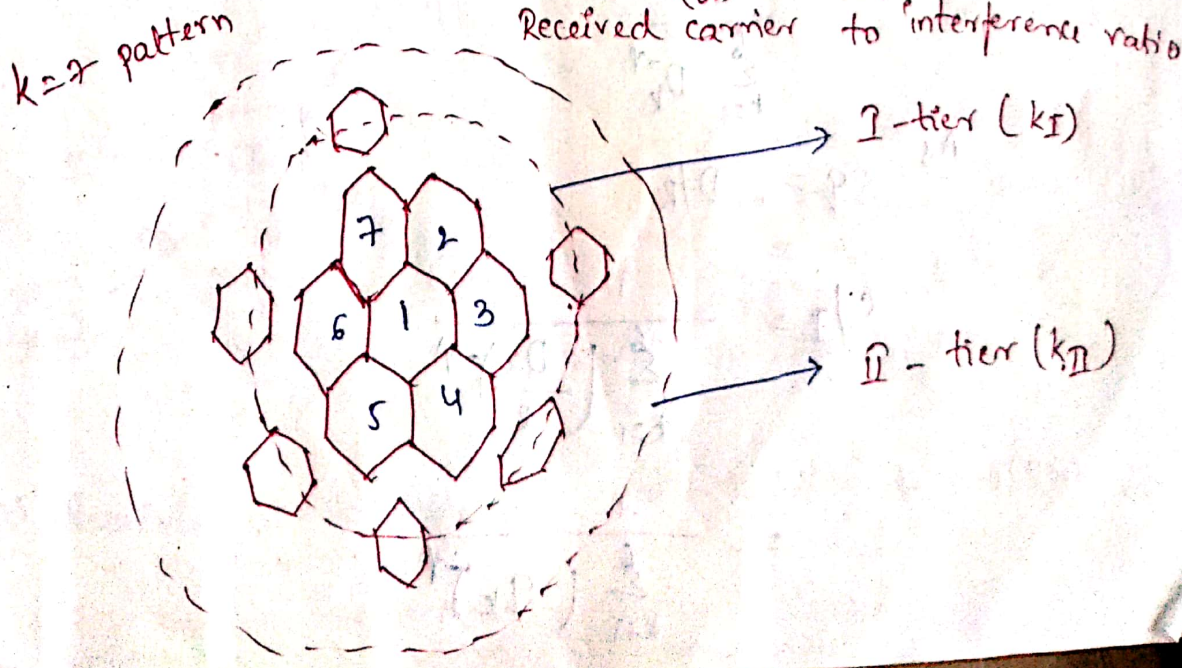
→ frequency reuse distance must be maintained large to avoid interference.

→ Reuse distance is a function of K_I & C/I

i.e., $D = f(K_I, C/I)$

where K_I = first tier (or) interference
no. of cochannel interfering cells in first tier

C/I = Carrier to interference ratio (or) Received carrier to interference ratio



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for $k=7$ pattern,

→ There are 6 interferers in each tier

→ Interference at the reference cell site due to I tier interference only.

→ C/I ratio i.e., the ratio of carrier power to the interference power is given by

$$C/I = \frac{C}{\sum_{k=1}^{k_I} I_k}$$

→ we know that the carrier power is given by

$$C \propto R^{-\gamma}$$

$$C/I = \frac{R^{-\gamma}}{\sum_{k=1}^{6} I_k}$$

where γ - propagation path loss slope

→ As the interference power also experience the propagation loss, for separation of 'D', I is given as

$$I \propto D^{-\gamma}$$

$$C/I = \frac{R^{-\gamma}}{\sum_{k=1}^{6} D_k^{-\gamma}}$$

As

$$q = D/R$$

$$C/I = \frac{1}{\sum_{k=1}^{6} \left(\frac{D_k}{R}\right)^{-\gamma}}$$

$$= \frac{1}{\sum_{k=1}^{6} (q_k)^{-\gamma}}$$

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$$\therefore \; C/I = \frac{1}{\sum_{k=1}^{6} q^{-n}}$$

where q_k is the co-channel interference reduction factor with k^{th} co-channel interfering cell.

Desired C/I from a Normal case in a Omni directional Antenna system :-

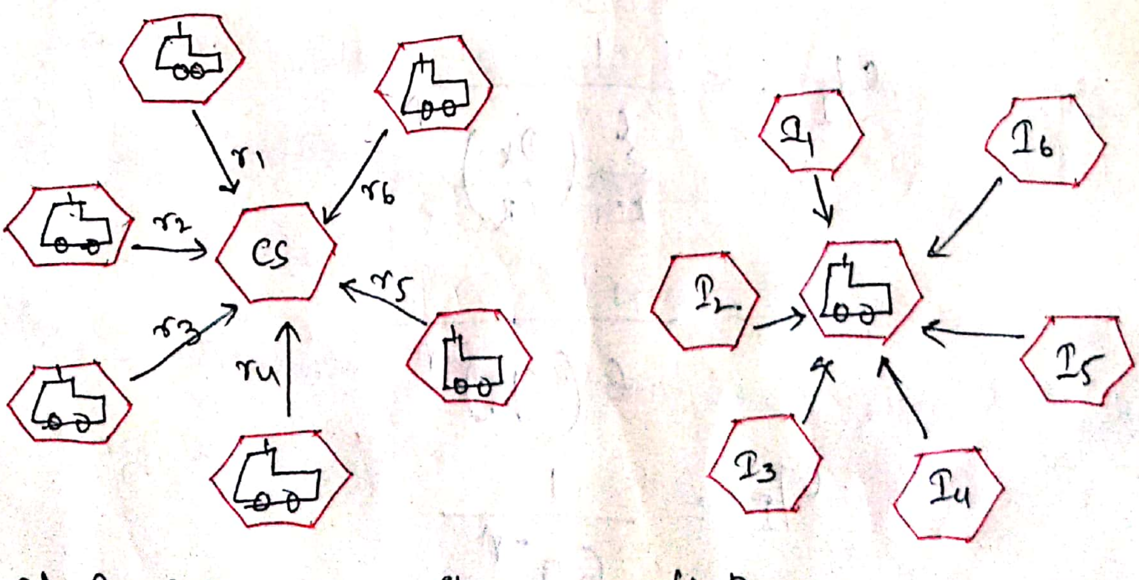
There are two methods of estimating C/I ratio

① Analytical Method

② Solution obtained from simulation

Analytical Method :-

Assuming $k=7$ system with 6-interferors in I tier.



a) Receiving at cell site   b) Receiving at mobile unit

Co-channel interference for six interface

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→ The received signal at the mobile unit c. the desir...
of 3 components C, I, N
↓ ↓ ↓
Carrier Interference Noise

→ In interference environment, Noise is negligible
→ C/I ratio is estimated from the received po...
→ It is given by,

$$C/I = \frac{1}{\sum_{k=1}^{6} q_k^{-r}}$$

→ As a normal case in omni directional antenna system considering all interferors are with uniform distance

$$D_k = D\ (D_1 = D,\ D_2 = D,\ D_3 = D, \ldots\ldots\ D_6 = D)$$

As $q = D/R$

$$C/I = \frac{1}{\sum_{k=1}^{6} \left(\frac{D_k}{R}\right)^{-r}}$$

$$= \frac{1}{6\,(q)^{-r}}$$

$$C/I = \frac{1}{6q^{-r}}$$

→ As per the cellular systems standards, for ground propagation $(r=4)$.

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The desired C/I to be maintained is

$$C/I = 18\ dB$$

$$q = \left[6\ (C/I)\right]^{1/\gamma}$$

$$q = \left[6\ (18^{\ dB/10})\right]^{1/4}$$

After simplification

$$q = 4.41$$

→ q = 4.41 for the assumed conditions to maintain C/I = 18 dB.

For the standard equation,

$C/I = 18\ dB$ $\gamma = 4$.

Solution obtained from Simulation :-

→ The output of analytical method is valid only for specific conditions, of reference cell site

→ To obtain a general solution for all cell sites, simulation tools (CAD tools) computer added tools may be used.

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→ If desired C/I ratio are q estimated simulation tools then all cores and conditions for different cell sites can be applied.

→ K=7 system the solution obtained from Radio simulation for all conditions is

$q = 4.6$ to maintain $C/I = 18\,dB$.

Antenna Parameters and their Effects:—

Antenna Parameters:— → The performance of antenna can be described by various parameters.

→ Every antenna parameter will effect on the performance efficiency of antenna.

→ They are

1. Radiation pattern
2. Beam width
3. Gain
4. Power density
5. Radiation intensity
6. Directivity
7. Efficiency
8. Effective aperture
9. Antenna Bandwidth

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10. Front to Back ratio

11. polarization

12. Input Impedance

Radiation pattern:-

→ An antenna is a fundamental radiating component of an electrical system, that links free space with the receiver.

→ The energy radiated by an antenna is not uniform in all the directions.

→ It is strong in one direction and weak (or) zero in some other direction.

→ The amount of energy being radiated in a direction is measured as the field strength at a point located at distance from the antenna.

→ It is a graphical representation of radiation properties as a function of the space co-ordinates.

→ The radiation pattern of antenna is usually measured in far-field.

→ The power received at a constant distance (radius) is known as power pattern.

→ If sidelobes are minimum (or) zero in a pattern such a system is said to be an efficient antenna system.

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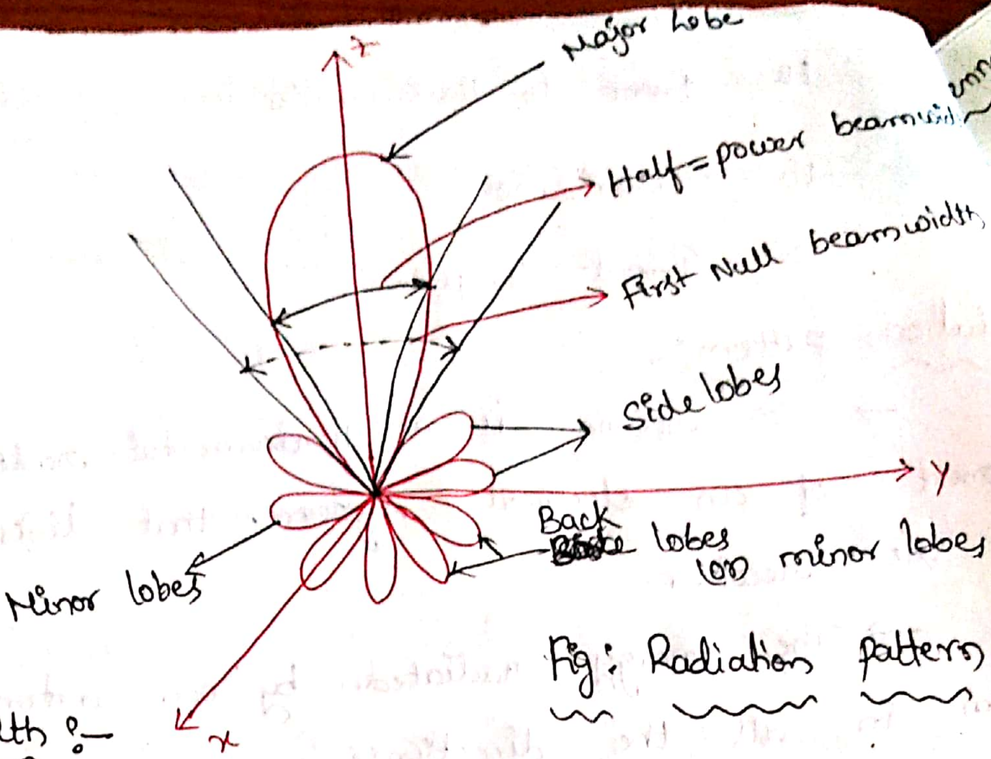

Fig: Radiation pattern

Beam width :-

→ For an antenna it is a measure of directivity, it is an angular width that is measured on the pattern between two points where the power radiated falls to half of its maximum value.

→ It is known as "half power beam width".

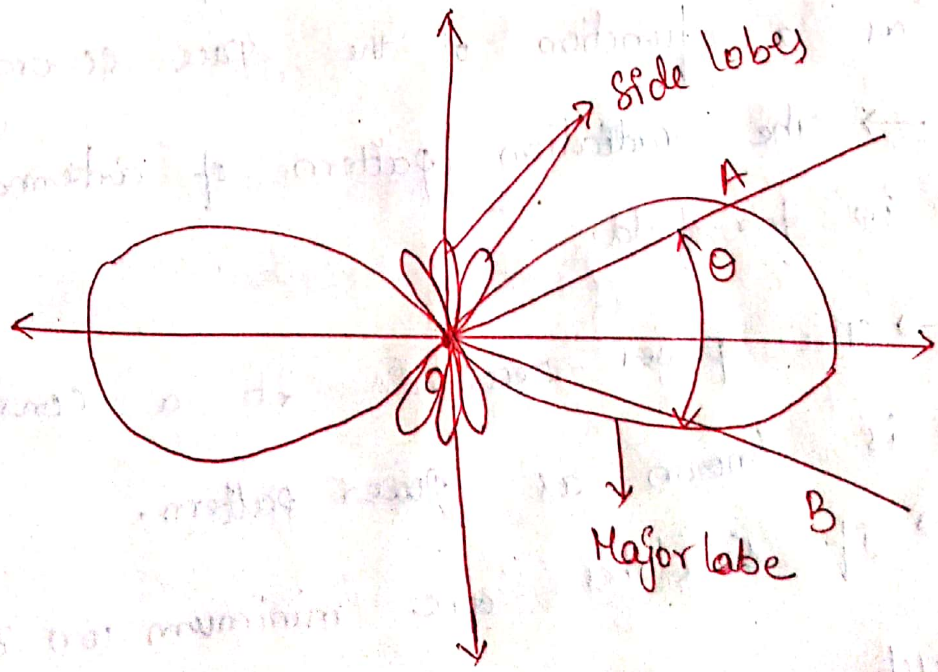

Fig: Beam width

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Bandwidth, Antenna Gain :-

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Gain is defined as ratio of maximum radiation intensity from the reference antenna having power input level in same direction.

$$\text{Gain}(G) = \frac{\text{maximum radiation intensity from test antenna setup}}{\text{maximum radiation intensity from a reference antenna having same power output}}$$

Directivity gain is defined as the ratio of antenna radiation intensity in the direction to that of the average radiation power level.

$$\text{Directive Gain} = \frac{\text{Radiation intensity in given direction}}{\text{Average radiated power level}}$$

Power gain is defined as the ratio of radiation intensity to that total average input power.

$$\text{Power gain } (G_p) = \frac{\text{Radiation intensity in a particular direction}}{\text{Total average power input}}$$

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Power Density :-

→ The electromagnetic waves are generally used to transport the data through a guiding medium or wireless medium from one point to another point.

→ The electromagnetic waves are associated with energy and power.

→ The amount of power associated with it is expressed by an instantaneous pointing vector as

$$W = E \cdot H$$

where,

W = pointing vector

E = Electric field intensity

H = Magnetic field intensity.

Radiation Intensity :-

→ The radiation intensity in a direction is the power per unit solid angle.

(or)

→ It is the power radiated from the antenna per unit solid angle.

→ It is denoted as "ϕ".

→ The unit of the power & Solid angle are watts & Steradian.

→ And thus the radiation intensity quality is watts per radian square.

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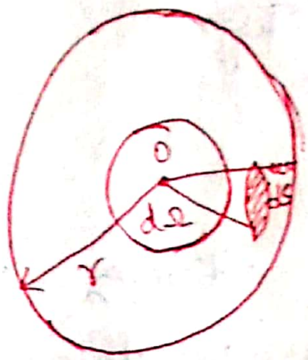
→ Let the ds is elemental surface area, r is the radius & dΩ be the solid angle, then

$$d\Omega = \frac{ds}{r^2} \text{ (or) } ds = r^2 d\Omega$$



Radiation Intensity : Fig

Directivity:-

→ The directivity of an antenna setup is defined as ratio of radiation intensity in a particular direction to the radiation intensity arranged in all the directions.

→ It is denoted as 'D'.

$$D = \frac{\text{Max. radiation intensity of the test (or) subjected antenna}}{\text{Avg. intensity of radiation of the test antenna}}$$

→ Directivity is dimensionless, if the solid angle is narrow then directivity will be high.

→ Directivity ∝ Solid angle under measurements

$$KD = G$$

where,

K = Efficiency factor

D = Directivity ; G = Gain

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→ If the losses are minimum in an then gain 'G' will be maximum and it will equal to directivity D.

→ Thus, for a high efficient system the dir.. of antenna should be high.

Efficiency :—

→ The antenna efficiency is defined as the ratio of power radiated to that of the total power input given to the antenna.

→ It is denoted as 'η'.

$$\text{Antenna Efficiency } \eta = \frac{\text{Total power radiated}}{\text{Total input power.}}$$

→ If the current I flows in antenna then,

$$\eta = \frac{I^2 R_r}{I^2(R_1+R_r)}$$

$$\eta = \left(\frac{R_r}{R_1+R_r}\right) 100\%$$

where,

R_1 = ohmic loss resistance of antenna

R_r = Radiation resistance

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Effective Aperture :-

→ The maximum effective aperture is denoted as effective aperture.

→ It is defined as the ratio of maximum received power to that of the power density of the incident wave.

$$A_{e(max)} = \frac{\text{Maximum received power}}{\text{Power density of incident wave}}$$

Antenna Bandwidth :-

→ The bandwidth of antenna is influenced by several parameters and it is defined in many ways as listed below:

→ Antenna bandwidth is defined as the range of frequencies in which the antenna performance meets a specific standard.

→ It is the bandwidth in which gain 'G' is higher than an acceptable value.

→ It is the bandwidth in which the given front-to-back ratio (FTB) is achieved.

→ It is the bandwidth in which the standing wave ratio (SWR) is maintained below the reflected value.

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Front to back ratio :-

The front to back ratio is defined as the ratio of power radiated in the desired direction to that of the power radiated in opposite directions.

$$FTB = \frac{\text{Power radiated in desired direction}}{\text{Power radiated in opposite direction}}$$

Polarization :-

→ An antenna polarization is defined as the polarization of the wave radiated in a given direction.

→ It describes above the electric vector quality $\bar{E}$.

→ The electric vector $\bar{E}$ & magnetic vector $\bar{H}$ are perpendicular to each other.

→ Polarization of an electromagnetic wave is defined as the wave radiated (or) received by the antenna in a particular direction.

→ The antenna is said to be either vertically polarized (or) horizontally polarized.

→ If there is an undesired polarization from

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antenna is observed it is called "cross polarization." (11)

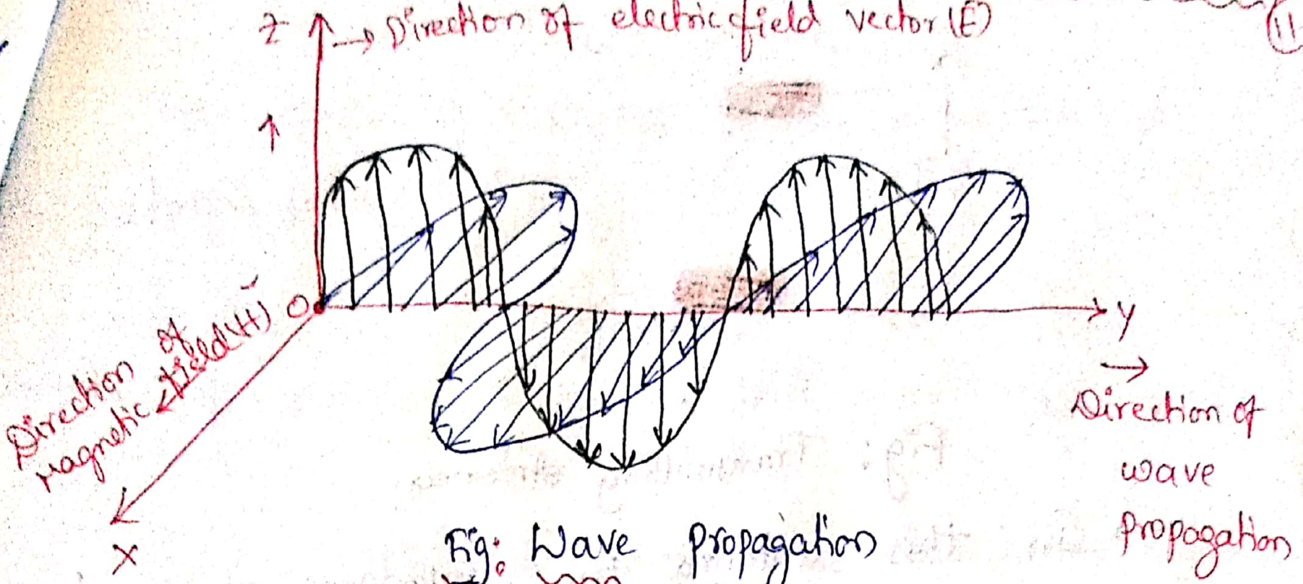

Fig: Wave propagation

Antenna Input Impedance :-

→ The antenna input impedance (or "self impedance" and it is also known as "feed point impedance" (or "driving point impedance".

→ A simple two terminal network shows the impedance that is offered to transmission line by antenna.

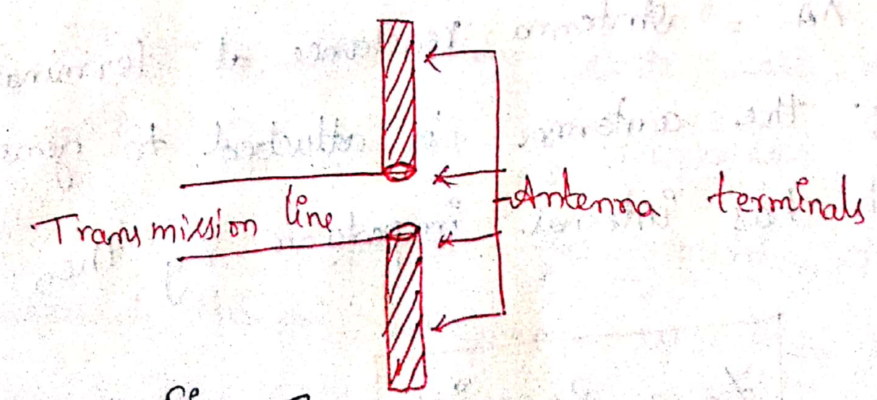

Fig: Transmission line with antenna as load.

→ In case of the antenna is loss less than the terminal impedance will be equal to the self-impedance of the antenna.

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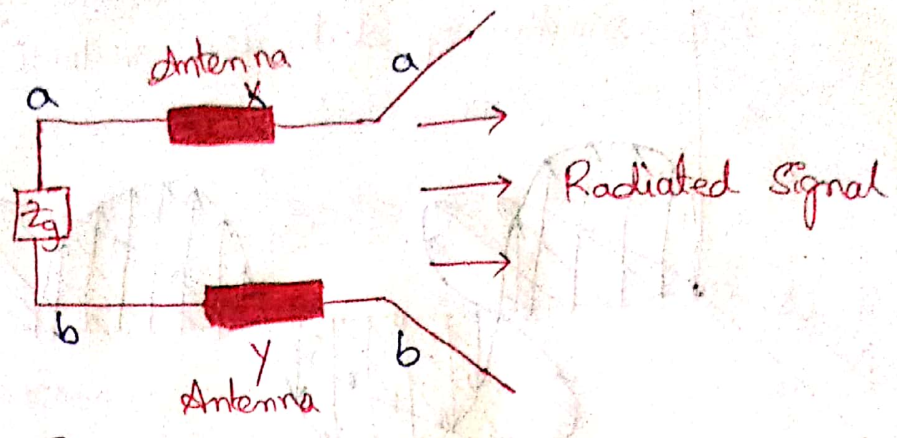

Fig: Transmitting Antenna.

→ In this antenna the impedance at the terminal a, b is known as input impedance where there is no load attached the antenna impedance is expressed as,

$$Z_A = R_A + jX_A$$

where

Z_A = Antenna impedance at terminal x-y

R_A = Antenna resistance at terminal x-y

X_A = Antenna reactance at terminal x-y

→ If the antenna is attached to generator 'g' which has internal impedance Z_g then

$$Z_g = R_g + jX_g$$

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...ts of antenna parameters on the cell Interferers:

The effects of antenna parameters on the cell interferers are given below.

(i) In an omni-directional antenna system, the number of principal interferers for a worst case will be six.

(ii) For k = 7 cell pattern, the carrier to interference ratio is less than 18 dB (≅ 17 dB). the effect of cell interferers will be reduced by increasing the 'K' value

(iii) In a directional antenna system, the number of principal interferers are reduced from six to two.

(iv) Thus, the carrier to interference ratio in this case will be higher than the C/I ratio obtained in omni-directional antenna.

(v) In directional antenna system, ~~the number of principal interferers are redu~~ each cell is divided into sectors with different set of frequencies.

(vi) In a valley (or) a flat ground, the co-channel and adjacent channel interference can be effectively reduced by lowering the antenna height.

(vii) The co-channel interference between the cells can also be reduced by using a notch in the titled antenna pattern.

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(viii) Thus, the notch in the mechanically tilted an Pattern reduces the co-channel Interference.

(ix) The, umbrella pattern can also used to reduce the co-channel Interference as the tilted directional antenna pattern.

(x) . In certain cases, reducing transmitted power can be more effective in eliminating the co-channel interference than reducing antenna height.

Diversity receiver (or) Diversity Schemes for Interference reductions :-

→ The signal transmitted from the mobile reaches the transceiver station many times with different amplitudes and phases due to multipath reflections.

→ It results in fading of the signal and the reception of the signal may be lost.

→ Diversity scheme helps ~~the~~ in increasing the chances of finding the signal with highest receive strength.

→ It gives multiple signals to the antenna whose fading characteristics are uncorrelated.

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→ Diversity scheme is a unique technique to (13) minimize the Interference and to strengthen the signal.

→ It is applied at the receiving end.

→ Diversity scheme can be implemented in two ways,

① Usage of selective chamber to combine the multiple correlated signals into a single stream.

② Usage of other types of combiners, which are, in general 2dB, better in performance than the selective combiner.

Selective Combining Technique :-

→ In selective combining, the diversity receiver selects the antenna with highest received power and discards the signals from remaining antennas.

→ Every curve has a corresponding correlation coefficient represented by 'ρ'.

→ The desired outcome in the diversity scheme is achieved at 'ρ = 0'

→ In the space diversity technique, the value of correlation coefficient ρ is found to be less than 0.7 at the cell site.

→ Using this correlation coefficient ρ, the two antennas are separated satisfying the requirement of

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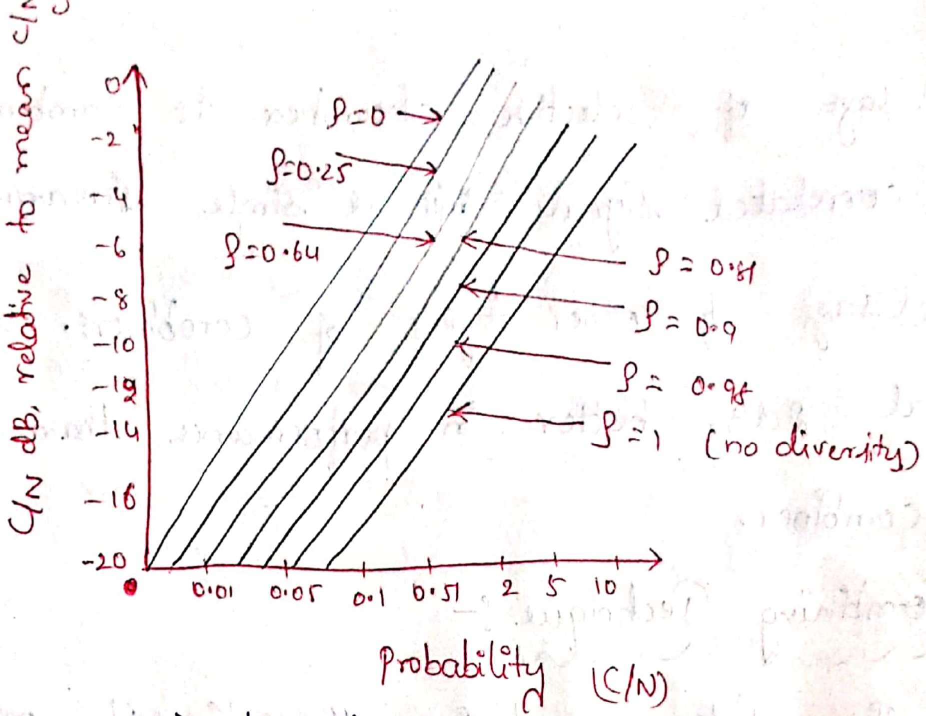
$$\frac{h}{d} = 11$$

where,

h = height of the antenna

d = Antenna separation.



→ The figure shows the response of selective combiner.

→ From the graph, consider a threshold value of 10 dB below the average power value.

→ The percentages of the signal below the threshold value with and without applying the diversity scheme are compared at the cell site and at the mobile unit.

At the Mobile Unit:-

→ From the response curves in figure, the curves of ρ=0 and ρ=1 are compared.

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→ The percentage of the signal is 10% below threshold value for non-diversity. (14)

→ Similarly, signal and the percentage of signal is 1% below the threshold for diversity.

→ It can be concluded that there is a decrease of 10 dB in the power for the diversity signal.

At the cell site :-

→ From the figure, the curves of $\rho = 0.7$ and $\rho = 1$ are compared.

→ The difference of signal is 10 percent below the threshold value for non-diversity and it is 2% below threshold value for the diversity signal.

→ The transmission of this signal from the mobile transmitter to the cell site receiver can extremely minimize the interference.

Non-Cochannel Interference Types :-

The different types of non-co-channel interference are given below.

They are

1. Adjacent-channel Interference
2. Near-End-Far-End Interference
3. Interference between Systems
4. Long distance interference.

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1) Adjacent channel Interferences:-

→ The interference which is due to the adjacent channels in a particular system is known as adjacent channel interference.

→ The adjacent channel interference can be minimized by the same method, which is used to minimize co-channel interference.

→ This adjacent ~~co~~-channel interference can be estimated by

(i) Channel assignment

(ii) Filter characteristics

(iii) Reduction of near-end-~~far~~ end interference

→ Adjacent channel interference is again classified into two types.

(a) Next channel interference

(b) Neighbouring channel interference.

Near-End-Far-End Interference:-

In one cell:-

→ As the vehicles are moving, some mobile units may come close to the cell site, having high signal strength such that adjacent channel interference occur.

→ In this case, the interference appears at the receiving end of the cell site.

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(15)

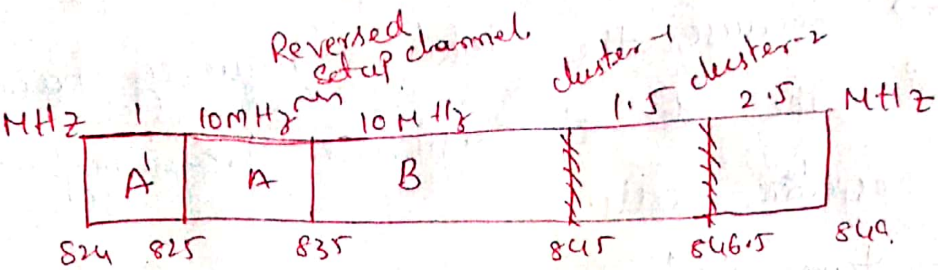
→ The frequency channels of both cells of the two systems must be co-ordinated in the neighbourhood of the two system frequency bands.

→ The two causes of near-end-far-end interference is,

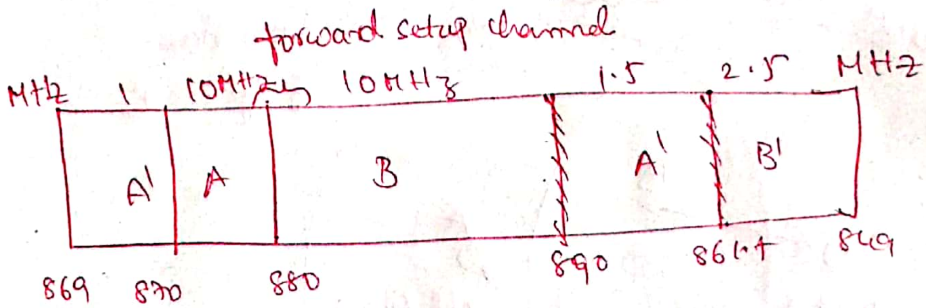
a) Interference caused on the setup channels.

b) Interference caused on the voice channels.

a) Interference caused on the setup channels:-



a) Reversed channels



b) forward channels.

b) Interference caused on the voice channels:-

→ The two clusters sets generates interference in the adjacent channel and must be ignored.

→ channel separation depends on two assumptions.

(i) Received Interference at the mobile unit

(ii) Received Interference at the cell site.

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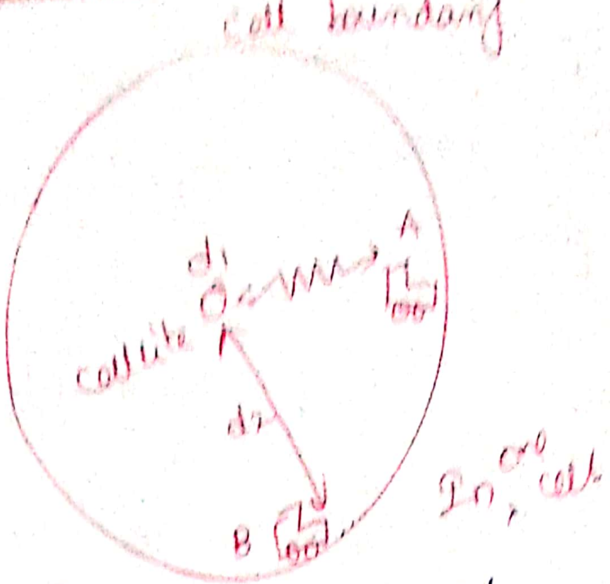
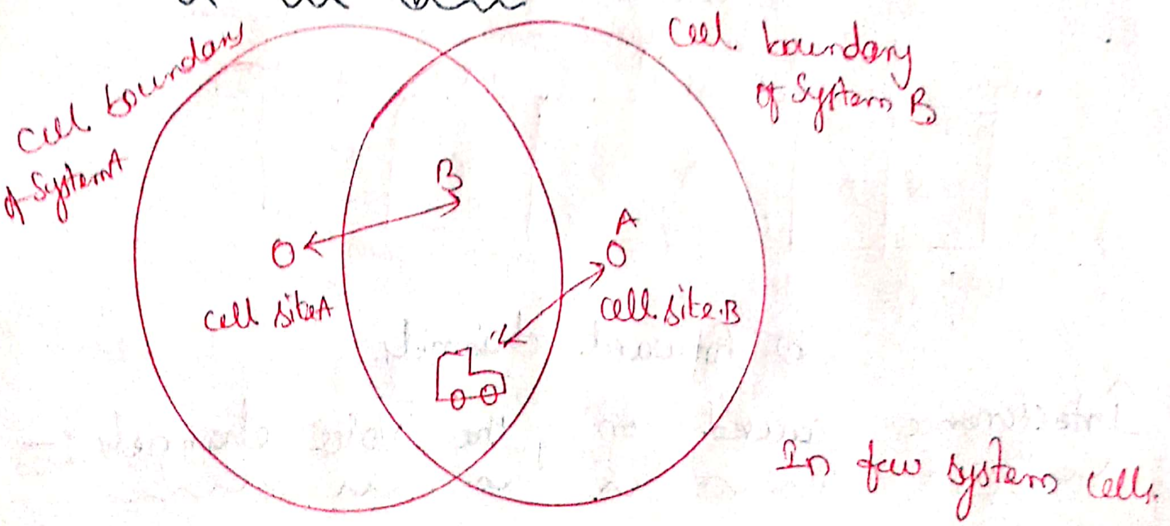


→ In order to avoid the near-end-far interference, the separation of five channels bandwidth is needed for few adjacent channels in a cell.

→ Because, the total frequency channels are distributed in the set of assigned frequency channels in their respective cells.

In cells of two Systems:-



→ In the above figure, it can be seen that the mobile unit 'A' is at the boundary of its cell site 'A' and close to cell site 'B', similarly Mobile unit 'B' is closer to cell site 'A'.

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Interference between Systems:-

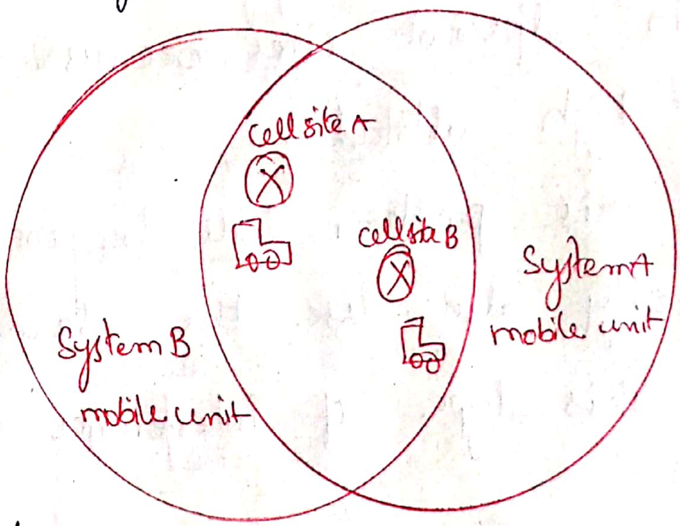
In this case, we need to consider the following two cases

(i) In one city

(ii) In adjacent cities

(i) **In one City:-** Consider that there are two Systems, A and B operating in a particular city.

→ A call is being initiated through system A, when the mobile unit of system A is closer to the cell site of system B.



System 'A' cell site in System 'B' cell coverage

→ The above figure shows the inter-system interference in one ~~single~~ city.

→ The interference products will produce the cross talk by leaking these products into the receiving channel of System B.

(ii) **In adjacent cities:-**

→ The interference is also provided in the absence of co-ordination between the frequency channel

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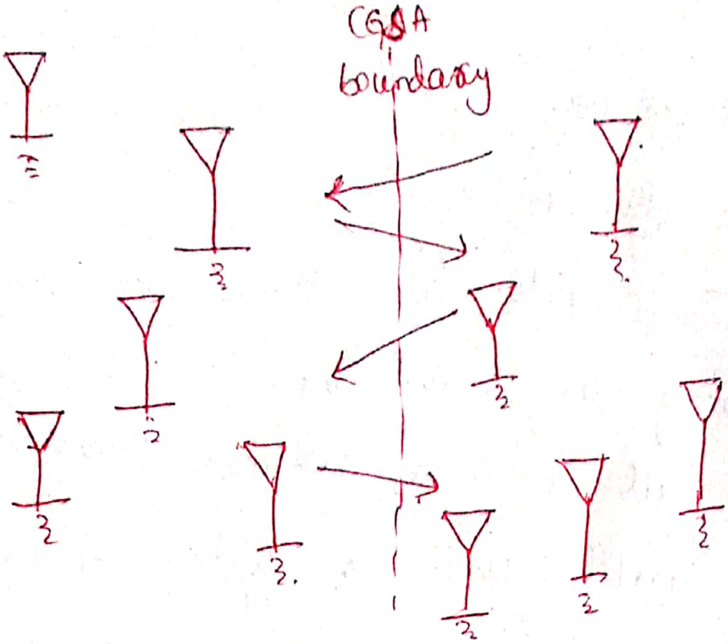
usage of two systems operating at same fre band and in two adjacent cities.



→ The above figure illustrates the intersystem interference in adjacent cities because of base-station situated at high altitude.

→ This problem will be more severe, if the neighbouring city also use the same system block

→ This type of interference can be eliminated by

a) avoiding the usage of same frequency in the adjacent cities.

b) Reducing the antenna heights

c) Using directional antennas for low capacity systems.

④ Long distance Interference:-

→ Long distance interference will effect the propagation of signals in the two areas. They are,

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(17)

(i) Over water path

(ii) Over land path

(i) Over water path :-

→ The following several reports will illustrate the long distance interference in over water path.

1). In Massachusetts Bay, a 41-mi over water path is operating at 1.5 GHz.

a) Low ducts

b) High ducts

2) In the region between Charleston, South Carolina and Daytona Beach, Florida, a 275-mi overwater path is operating at 812 and 857 MHz.

(ii) Over land path :-

→ Tropospheric scattering above a land path is not steady and can be changed instantaneously while the tropospheric scattering over water path.

→ This long distance propagation will be throughout their nationwide system.

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UNIT-III

CELL COVERAGE FOR SIGNALAND TRAFFIC

SIGNAL REFLECTIONS IN FLAT AND HILLY TERRAIN

The ground incident angle and the ground elevation angle over a communication link are described as follows. The ground incident angle 0 is the angle of wave arrival incidentally pointing to the ground as shown in Fig. 1.1. The ground elevation angle is the angle of wave arrival at the mobile unit as shown in Fig. 1.1

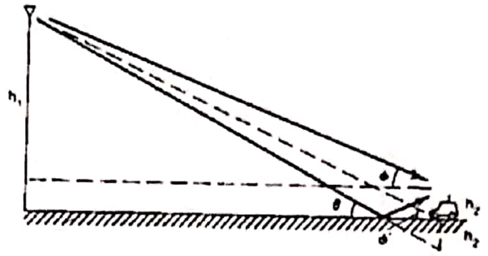

Figure 1.1 Representation of Ground Incident Angle θ and Ground Elevation Angle ϕ

Based on Snell's law, the reflection angle and incident angle are the same. Since in graphical display we usually exaggerate the hilly slope and the incident angle by enlarging the vertical scale, as shown in Fig. 1.2, then as long as the actual hilly slope is less than 100, the reflection point on a hilly slope can be obtained by following the same method as if the reflection point were on flat ground. Be sure that the two antennas (base and mobile) have been placed vertically, not perpendicular to the sloped ground. The reason is that the actual slope of the hill is usually very small and the vertical stands for two antennas are correct. The scale drawing in Fig. 1.2 is somewhat misleading however, it provides a clear view of the situation.

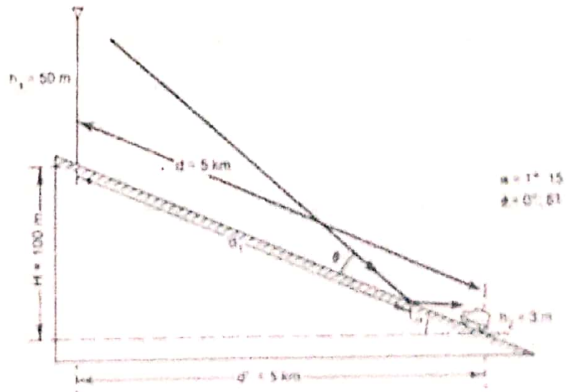

Fig 1.2 Ground reflection angle and reflection point

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PHASE DIFFERENCE BETWEEN THE DIRECT PATH AND THE REFLECTED PATH

Based on a direct path and a ground reflected path, the equation

$$P_r = P_0 \left(\frac{1}{4\pi d/\lambda}\right)^2 \left|1 + a_v e^{j\Delta\phi}\right|^2$$

where a_v = the reflection coefficient
$\Delta\phi$ = the phase difference between a direct path and a reflected path
P_0 = the transmitted power
d = the distance
λ = the wavelength

Indicates a two-wave model which is used to understand the path-loss phenomenon in a mobile radio environment. It is not the model for analyzing the multipath fading phenomenon. In a mobile environment av = -1 because of the small incident angle of the ground wave caused by a relatively low cell-site antenna height. Thus,

$$P_r = P_0 \left(\frac{1}{4\pi d/\lambda}\right)^2 \left|1 - \cos\Delta\phi - j\sin\Delta\phi\right|^2$$

$$= P_0 \frac{2}{(4\pi d/\lambda)^2}(1 - \cos\Delta\phi) = P_0 \frac{4}{(4\pi d/\lambda)^2}\sin^2\frac{\Delta\phi}{2}$$

where $\Delta\phi = \beta\,\Delta d$

and Δd is the difference, $\Delta d = d_1 - d_2$, from Fig. 4.4.

$$d_1 = \sqrt{(h_1 + h_2)^2 + d^2}$$

and

$$d_2 = \sqrt{(h_1 - h_2)^2 + d^2}$$

Since Δd is much smaller than either d_1 or d_2,

$$\Delta\phi = \beta\,\Delta d \approx \frac{2\pi}{\lambda}\frac{2h_1h_2}{d}$$

Then the received power of Eq. (4.2-3) becomes

$$P_r = P_0 \frac{\lambda^2}{(4\pi)^2 d^2}\sin^2\frac{4\pi h_1 h_2}{\lambda d}$$

If $\Delta\phi$ is less than 0.6 rad, then $\sin(\Delta\phi/2) \approx \Delta\phi/2$, $\cos(\Delta\phi/2) \approx 1$, then

$$P_r = P_0 \frac{4}{16\pi^2(d/\lambda)^2}\left(\frac{2\pi h_1 h_2}{\lambda d}\right)^2 = P_0\left(\frac{h_1 h_2}{d^2}\right)^2$$

, thus

$$\Delta P = 40 \log\frac{d_1}{d_2} \quad \text{(a 40 dB/dec path loss)}$$

$$\Delta G = 20 \log\frac{h'_1}{h_1} \quad \text{(an antenna height gain of 6 dB/oct)}$$

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Where P is the power difference in decibels between two different path lengths and G is the gain (or loss) in decibels obtained from two different antenna heights at the cell site. From these measurements, the gain from a mobile antenna height is only 3 dB/oct, which is different from the 6 dB/oct . Then

$$\Delta G' = 10 \log \frac{h'_2}{h_2}$$

CONSTANT STANDARD DEVIATION ALONG A PATH-LOSS SLOPE

When plotting signal strengths at any given radio-path distance, the deviation from predicted value. is approximately 8 dB.1012 This standard deviation of 8 dB is roughly true in many different areas. The explanation is as follows. When a line-of-sight path exists, both the direct wave path and reflected wave path are created and are strong. When an out-of-sight path exists, both the direct wave path and the reflected wave path are weak. In either case, according to the theoretical model, the 40-dB/dec path-loss slope applies. The difference between these two conditions is the 1-mi intercept (or 1-km intercept) point. It can be seen that in the open area, the 1-mi intercept is high. In the urban area, the 1-mi intercept is low. The standard deviation obtained from the measured data remains the same along the different path-loss curves regardless of environment.

Support for the above argument can also be found from the observation that the standard deviation obtained from the measured data along the predicted path-loss curve is approximately 8 dB. The explanation is that at a distance from the cell site, some mobile unit radio paths are line-of-sight, some are partial line-of-sight, and some are out-of-sight. Thus the received signals are strong, normal, and weak, respectively. At any distance, the above situations prevail. If the standard deviation is 8 dB at one radio-path distance, the same 8dB will be found at any distance. Therefore a standard deviation of 8 dB is always found along the radio path as shown in Fig.3

The standard deviation of 8 dB from the measured data near the cell site is due mainly to the close-in buildings around the cell site. The same standard deviation from the measured data at distant locations is due to the great variation along different around the cell site. The same standard deviation from the measured data at a distant location is due to the great variation along different radio paths.

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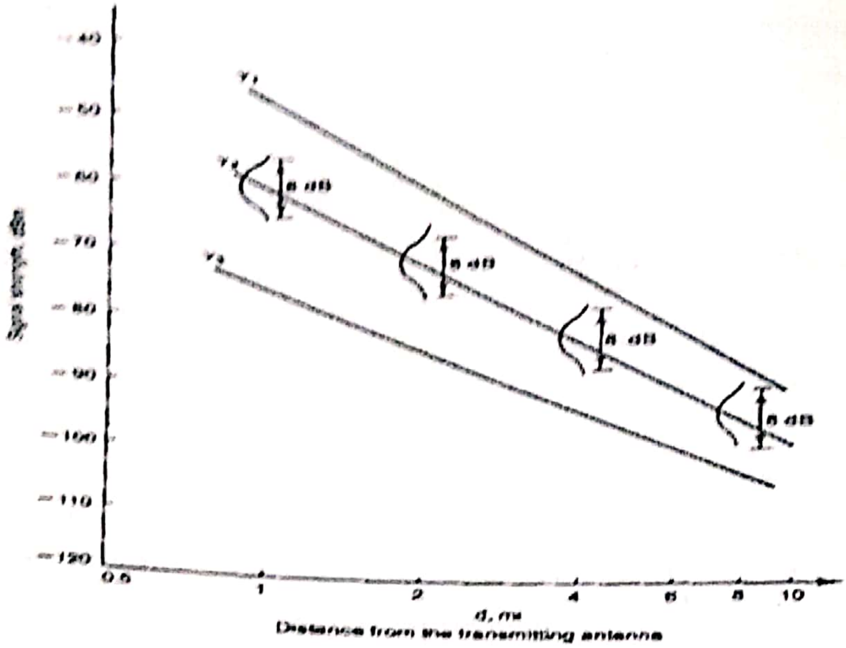

Fig 3 An 8-dB local mean spread

MERITS OF POINT-TO-POINT MODEL

The area-to-area model usually only provides an accuracy of prediction with a standard deviation of 8 dB, which means that 68 percent of the actual path-loss data are within the ± 8 dB of the predicted value. The uncertainty range is too large. The point-to-point model reduces the uncertainty range by including the detailed terrain contour information in the path-loss predictions.

The differences between the predicted values and the measured ones for the point-to-point model were determined in many areas. In the following discussion, we compare the differences shown in the Whippany, N.J., area and the Camden- Philadelphia area. First, we plot the points with predicted values at the x-axis and the measured values at the y-axis, shown in Fig. 4. The 450 line is the line of prediction without error. The dots are data from the Whippany area, and the crosses are data from the Camden-Philadelphia area. Most of them, except the one at 9 dB, are close to the line of prediction without error.

The mean value of all the data is right on the line of prediction without error. The standard deviation of the predicted value of 0.8 dB from the measured one.

In other areas, the differences were slightly larger. However, the standard deviation of the predicted value never exceeds the measured one by more than 3 dB. The standard deviation range is much reduced as compared with the maximum of 8 dB from area-to-area models. The point-to-point model is very useful for designing a mobile cellular system with a radius for each cell of 10 mi or less. Because the data follow the log-normal distribution, 68 percent of predicted values obtained from a point-to-point prediction model are within 2 to 3 dB. This point-to-point prediction can be used to provide overall coverage of all cell sites and to avoid co-

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channel interference. Moreover, the occurrence of handoff in the cellular system can be predicted more accurately.

The point-to-point prediction model is a basic tool that is used to generate a signal coverage map, an interference area map, a handoff occurrence map, or an optimum system design configuration, to name a few applications.

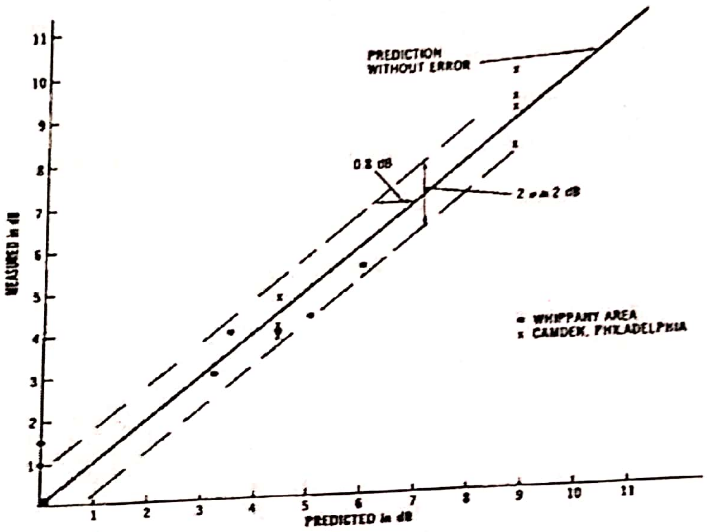

Fig.4. Indication of errors in point-to-point predictions under non obstructive conditions.

FOLIAGE LOSS

Foliage loss is a very complicated topic that has many parameters and variations. The sizes of leaves, branches, and trunks, the density and distribution of leaves, branches, and trunks, and the height of the trees relative to the antenna heights all be considered. An illustration of this prv1em is shown in Fig. 5.1. There are three levels: trunks, branches, and leaves. In each level, there is a distribution of sizes of trunks, branches, and leaves and also of the density and spacing between adjacent trunks, branches, and leaves. The texture and thickness of the leaves also count. This unique problem can become very complicated and is beyond the scope of this book. For a system design, the estimate of the signal reception due to foliage loss does not need any degree of accuracy.

Furthermore, some trees, such as maple or oak, lose their leaves in winter, while others, such as pine, never do. For example, in Atlanta, Georgia, there are oak, maple, and pine trees. In summer the foliage is very heavy, but in winter the leaves of the oak and maple trees fall and the pine leaves stay. In addition, when the length of pine needles reaches approximately 6 in., which is the half wavelength at 800 MHz, a great deal of energy can be absorbed by the pine trees. In these situations, it is very hard to predict the actual foliage loss.

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However, a rough estimate should be sufficient for the purpose of system design. In tropic zones, the sizes of tree leaves are so large and thick that the signal can hardly penetrate. In this case, the signal will propagate from the top of the tree and deflect to the mobile receiver. We will include this calculation also.

Sometime the foliage loss can be treated as a wire-line loss, in decibels per foot or decibels per meter, when the foliage is uniformly heavy and the path lengths are short. When the path length is long and the foliage is non uniform, then decibels per octaves or decibels per decade are used. In general, foliage lose occurs with respect to the frequency to the fourth power. Also, at 800 MHz the foliage Lou along the radio path is 40 dB/dec, which is 20 dB more than the free- space loss, with the same amount of additional loss for mobile communications. Therefore, if the situation involves both foliage loss and mobile communications, the total loss would be 60 dB/dec (=20 dB/ dec of free-space loss + additional 20 dB due to foliage loss + additional 20 dB due to mobile communication).

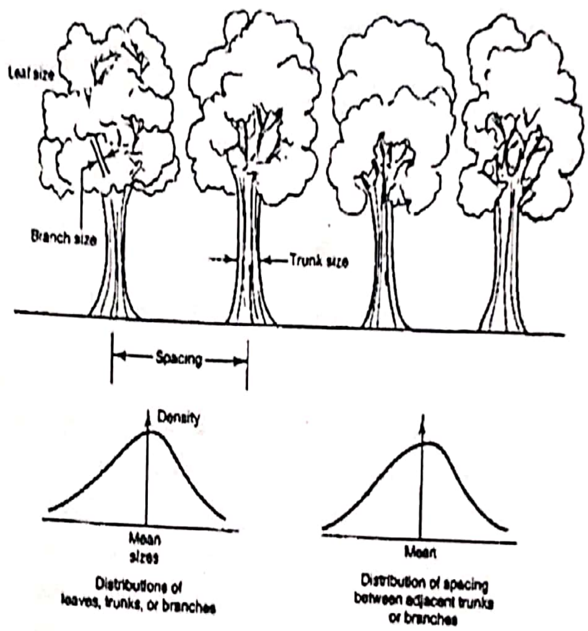

Fig.5.1. A characteristic of foliage environment

This situation would be the case if the foliage would line up along the radio path. A foliage loss in a suburban area of 58.4 dB/dec is shown in Fig.5.2. As demonstrated from the above two examples, close-in foliage at the transmitter site always heavily attenuates signal reception. Therefore, the cell site should be placed away from trees.

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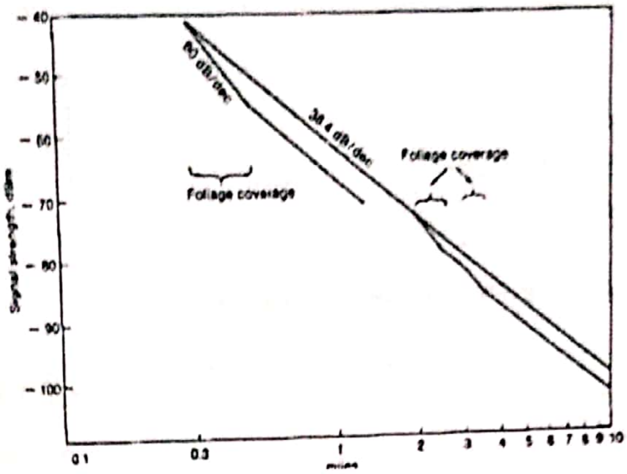

Fig.5.2. Foliage loss calculation in suburban areas

SMALL SCALE MULTIPATH PROPAGATION

The multipath propagation of radio signals over a short period of time or to travel a distance is considered to be the small scale multipath propagation. As every type of multipath propagation results in generating a faded signal at receiver, the small scale multipath propagation also results in small scale fading. Hence, the signal at the receiver is obtained by combining the various multipath waves. These waves will vary widely in amplitude and phase depending on the distribution of the intensity and relative propagation time of the waves and bandwidth of the transmitted signal.

The three fading effects that are generally observed due to the small scale multipath propagation are,

1. Fast variations in signal strength of the transmitted signal for a lesser distance or time interval.
2. The variations in Doppler shift on various multipath signals are responsible for random frequency modulation
3. The time dispersed signals are resulted due to multipath propagation delays.

In order to determine the small scale fading effects, we employ certain techniques. They are,

D Direct RF pulse measurement

E Spread spectrum sliding correlation measurement.

F Swept frequency measurement.

The first technique provides a local average power delay profile.

The second technique detects the transmitted signal with the help of a narrow band receiver preceded by a wide band mixer though the probing (or received) signal is wide band.

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The third technique is helpful in finding the impulse response of the channel in frequency domain. By knowing the impulse response we can easily predict the signal obtained at the receiver from the transmitter.

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EFFECT OF PROPAGATION OF MOBILE SIGNALS OVER WATER AND FLAT OPEN AREA

PROPAGATION OVER WATER OR FLAT OPEN AREA:

Propagation over water or fiat open area is becoming a big concern because it is very easy to interfere with other cells if we do not make the correct arrangements. Interference resulting from propagation over the water can be controlled if we know the cause. In general, the permittivity's Er of seawater and fresh water are the same, but the conductivities of seawater and fresh water are different. We may calculate the dielectric constants Ec where Ec = Er - j60σλ. The wavelength at 850MHz is 0.35m. Then Eo (sea water) = 80 - j84 and Ec (fresh water)=80-jO.021.

However, based upon the reflection coefficients formula with a small incident angle both the reflection coefficients for horizontal polarized waves and vertically polarized waves approach 1. Since the 180* phase change occurs at the ground reflection point, the reflection coefficient is -1. Now we can establish a scenario, as shown in Fig 10.1 Since the two antennas, one at the cell site and the other at the mobile unit, are well above sea level, two reflection points are generated. The one reflected from the ground is close to the mobile unit; the other reflected from the water is away from the mobile unit. We recall that the only reflected wave we considered in the land mobile propagation is the one reflection point which is always very close to the mobile unit. We are now using the formula to find the field strength under the circumstances of a fixed point-to-point transmission and a land-mobile transmission over a water or flat open land condition.

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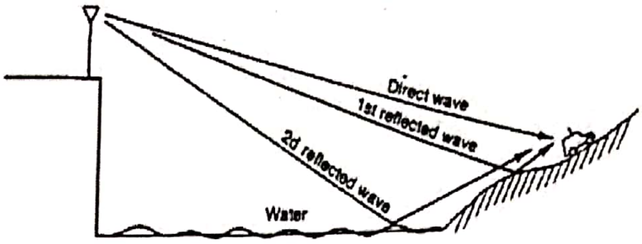

Fig 10.1.A model for propagation over water

BETWEEN FIXED STATIONS: The point -to-point transmission between the fixed stations over the water or flat open land can be estimated as follows. The received power P_r can be expressed as (see Fig.10.2)

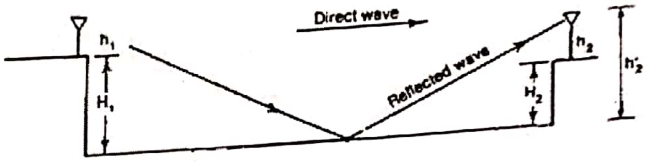

Fig 10.2.Propagation between two fixed stations over water or flat open land.

$$P_r = P_t \left(\frac{1}{4\pi d/\lambda}\right)^2 \left|1 + a_v e^{-j\phi_v} \exp(j\,\Delta\phi)\right|^2$$

where P_t = transmitted power
d = distance between two stations
λ = wavelength
a_v, ϕ_v = amplitude and phase of a complex reflection coefficient, respectively

_ϕ is the phase difference caused by the path difference M between the direct wave and the reflected wave, or

$$\Delta\phi = \beta\,\Delta d = \frac{2\pi}{\lambda}\,\Delta d$$

The first part of i.e. the free-space loss formula which shows the 20 dB/dec slope; that is, a 20-dB loss will be seen when propagating from 1 to 10 km.

$$P_0 = \frac{P_t}{(4\pi d/\lambda)^2}$$

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The complex reflection co-efficient and can be found from the formula

$$a_r e^{-j\phi_r} = \frac{\epsilon_c \sin\theta_1 - (\epsilon_c - \cos^2\theta_1)^{1/2}}{\epsilon_c \sin\theta_1 + (\epsilon_c - \cos^2\theta_1)^{1/2}}$$

When the vertical incidence is small, θ is very small and

$$a_v \approx -1 \quad \text{and} \quad \phi_v = 0$$

It can be found from equation. Ec is a dielectric constant that is different for different media. The reflection coefficient remains -1 regardless of whether the wave is propagated over water dry land, wet land, Ice, and so forth. The wave propagating between fixed stations is illustrated in Fig. 10.2.

$$P_r = \frac{P_t}{(4\pi d/\lambda)^2}|1 - \cos\Delta\phi - j\sin\Delta\phi|^2$$
$$= P_0(2 - 2\cos\Delta\phi)$$

since _ϕ is a function of d and d can be obtained from the following calculation. The effective antenna height at antenna 1 is the height above the sea level.

$$h_1' = h_1 + H_1$$

The effective antenna height at antenna 2 is the height above the sea level.

$$h_2' = h_2 + H_2$$

As shown in Fig.10.2 where h1 and h2 are actual heights and H1and H2 are the heights of hills. In general, both antennas at fixed stations are high, so the resection point of the wave will be found toward the middle of the radio path. The path difference d can be obtained from Fig. 10.2 as

$$\Delta d = \sqrt{(h_1' + h_2')^2 + d^2} - \sqrt{(h_1' - h_2')^2 + d^2}$$

Since $d \gg h_1'$ and h_2', then

$$\Delta d \approx d\left[1 + \frac{(h_1' + h_2')^2}{2d^2} - 1 - \frac{(h_1' - h_2')^2}{2d^2}\right] = \frac{2h_1'h_2'}{d}$$

Then

$$\Delta\phi = \frac{2\pi}{\lambda}\frac{2h_1'h_2'}{d} = \frac{4\pi h_1'h_2'}{\lambda d}$$

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MOBILE-TO-MOBILE PROPAGATION

In mobile-to-mobile land communication, both the transmitter and the receiver are in motion. The propagation path in this case is usually obstructed by buildings and obstacles between the transmitter and receiver. The propagation channel acts like a filter with a time-varying transfer function H (f, t) which can be found in this section.

The two mobile units M1 and M2 with velocities V1 and V2 respectively are shown in Fig.11.1. Assume that the transmitted signal from M1 is

$$s(t) = u(t)e^{j\omega t}$$

The receiver signal at the mobile unit M_2 from an ith path is

$$s_i = r_i u(t - \tau_i)e^{j[(\omega_0 + \omega_{1i} + \omega_{2i})(t - \tau_i) + \phi_i]}$$

where $u(t)$ = signal
ω_0 = RF carrier
r_i = Rayleigh-distributed random variable
ϕ_i = uniformly distributed random phase
τ_i = time delay on ith path

and

ω_{1i} = Doppler shift of transmitting mobile unit on ith path

$$= \frac{2\pi}{\lambda} V_1 \cos \alpha_{1i}$$

ω_{2i} = Doppler shift of receiving mobile unit on ith path

$$= \frac{2\pi}{\lambda} V_2 \cos \alpha_{2i}$$

Where a1i and a2i are random angles as shown in Fig.11.1. Now assume that the received signal is the summation of n paths uniformly distributed around the azimuth.

$$s_r = \sum_{i=1}^{n} s_i(t) = \sum_{i=1}^{n} r_i u(t - \tau_i)$$
$$\times \exp\{j[(\omega_0 + \omega_{1i} + \omega_{2i})(t - \tau_i) + \phi_i]\}$$
$$= \sum_{i=1}^{n} Q(\alpha_{i,t})u(t - \tau_i)e^{j\omega_0(t - \tau_i)}$$

where $$Q(\alpha_i, t) = r_i \exp\{j[(\omega_{1i} + \omega_{2i})t + \phi_i']\}$$
$$\phi_i' = \phi - (\omega_{1i} + \omega_{2i})\tau_i$$

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UNIT IV (A)

CELLSITE AND MOBILE ANTENNAS

SPACES-DIVERSITY ANTENNAS

Two-branch space-diversity antennas are used at the cell site to receive the same signal with different fading envelopes, one at each antenna. The degree of correlation between two fading envelopes is determined by the degree of separation between two receiving antennas. When the two fading envelopes are combined, the degree of fading is reduced. Here the antenna setup is shown in Fig. 5a.

Equation is presented as an example for the designer to use.

$\eta = h/D = 11$ (8.13-1)

Where h is the antenna height and D is the antenna separation. From Eq., the separation $d \geq 8\lambda$ is needed for an antenna height of 100 ft (30 m) and the separation $d \geq 14\lambda$ is needed for an antenna height of 150 ft (50 m). In any Omni cell system, the two space-diversity antennas should be aligned with the terrain, which should have a U shape as shown in Fig.5b. Space-diversity antennas can separate only horizontally, not vertically; thus, there is no advantage in using a vertical separation in the design.

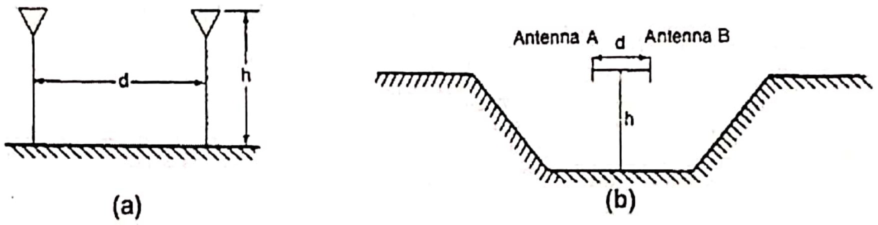

Fig.6.10.Diversity antenna spacing at cell site: (a) n=h/d (b) Proper arrangement with two antennas

UMBRELLAS-PATTERN ANTENNAS

In certain situations, umbrella-pattern antennas should be used for the cell-site antennas.

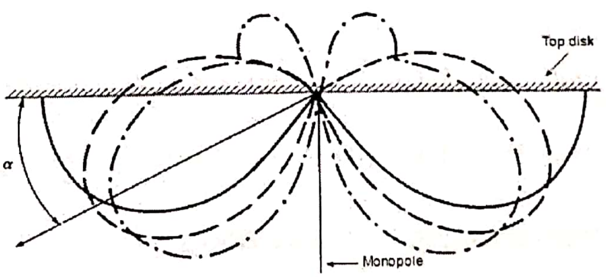

Fig. Vertical-plane patterns of quarter-wavelength stub antenna on infinite ground plane (solid) and on finite ground planes several wavelengths in diameter (dashed line) and about one wavelength in diameter (dotted line).

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i) NORMAL UMBRELLA-PATTERN ANTENNA:

For controlling the energy in a confined area, the umbrella-pattern antenna can be developed by using a monopole with a top disk (top-loading) as shown in Fig. The size of the disk determines the tilting angle of the pattern. The smaller the disk, the larger the tilting angle of the umbrella pattern.

ii) BROADBAND UMBRELLA-PATTERN ANTENNA:

The parameters of a Discone antenna (a bio conical antenna in which one of the cones is extended to 180° to form a disk) are shown in Fig. The diameter of the disk, the length of the cone, and the opening of the cone can be adjusted to create an umbrella-pattern antenna.

iii) INTERFERENCE REDUCTION ANTENNA:

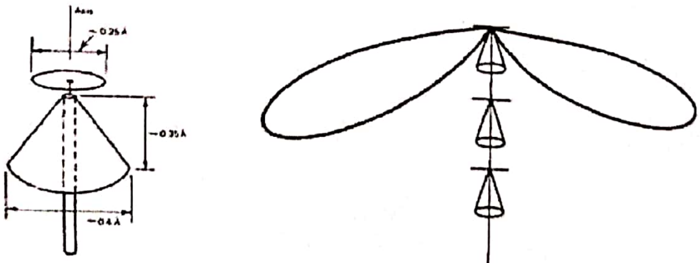
A design for an antenna configuration that reduces interference in two critical directions (areas) is shown in Fig.6.3. The parasitic (insulation) element is about 1.05 times longer than the active element.

iv) HIGH-GAIN BROADBAND UMBRELLA-PATTERN ANTENNA:

A high-gain antenna can be constructed by vertically stacking a number of umbrella-pattern antennas as shown in Fig.

$$E_0 = \frac{\sin[(Nd/2\lambda)\cos\phi]}{\sin[(d/2\lambda)\cos\phi]} \cdot \text{(individual umbrella pattern)}$$

where ϕ = direction of wave travel
N = number of elements
d = spacing between two adjacent elements



(a) (b)

Fig. Discone antennas (a) Single antenna; (b) An array of antenna

MINIMUM SEPARATION OF CELL-SITE RECEIVING ANTENNAS

Separation between two transmitting antennas should be minimized to avoid the inter modulation. The minimum separation between a transmitting antenna and a receiving antenna is necessary to avoid receiver

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desensitization. Here we are describing a minimum separation between two receiving antennas to reduce the antenna pattern ripple effects. The two receiving antennas are used for a space-diversity receiver.

Because of the near field disturbance due to the close spacing, ripples will form in the antenna patterns (Fig.). The difference in power reception between two antennas at different angles of arrival is shown in Fig. . If the antennas are located closer; the difference in power between two antennas at a given pointing angle increases. Although the power difference is confined to a small sector, it affects a large section of the street as shown in Fig. .

If the power difference is excessive, use of space diversity will have no effect reducing fading. At 850 MHz, the separation of eight wavelengths between two receiving antennas creates a power difference of ±2 dB, which is tolerable for the advantageous use of a diversity scheme.

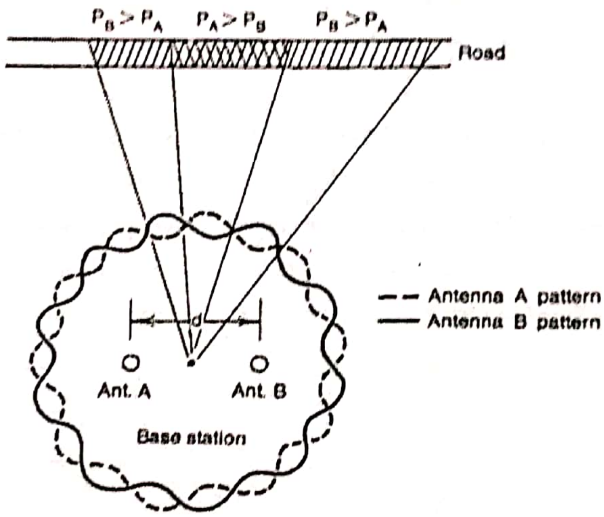

Fig. Antenna pattern ripple effect

MOBILE ANTENNAS

The requirement of a mobile (motor-vehicle–mounted) antenna is an Omni-directional antenna that can be located as high as possible from the point of reception. However, the physical limitation of antenna height on the vehicle restricts this requirement. Generally, the antenna should at least clear the top of the vehicle. Patterns for two types of mobile antenna are shown in Fig.

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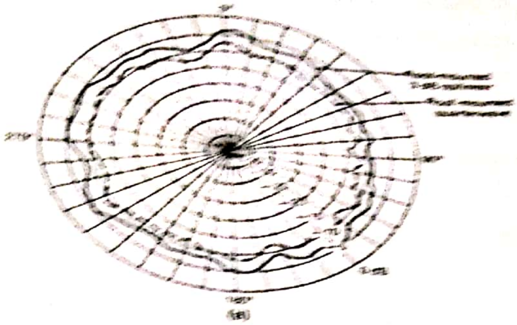

Fig. Mobile antenna patterns (a) Roof mounted 3-dB-gain collinear antenna versus roof-mounted quarter-wave antenna, (b) Window-mounted "on-glass" gain antenna versus roof-mounted quarter-wave antenna.

ROOF-MOUNTED ANTENNA:

The antenna pattern of a roof-mounted antenna is more or less uniformly distributed around the mobile unit when measured at an antenna range in free space as shown in Fig.9.2. The 3-dBhigh-gain antenna shows a 3-dBgain over the quarter-wave antenna. However, the gain of the antenna used at the mobile unit must be limited to 3 dB because the cell-site antenna is rarely as high as the broadcasting antenna and out-of-sight conditions often prevail. The mobile antenna with a gain of more than 3 dB can receive only a limited portion of the total multipath signal in the elevation as measured under the out-of-sight condition.

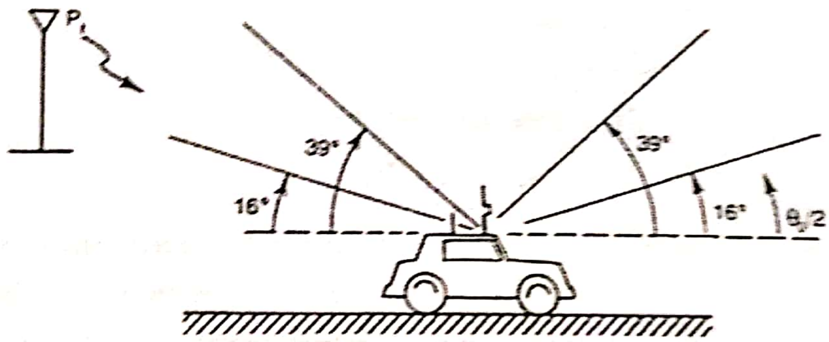

Fig. Vertical angle of signal arrival

GLASS-MOUNTED ANTENNAS:

There are many kinds of glass-mounted antennas. Energy is coupled through the glass; therefore, there is no need to drill a hole. However, some energy is dissipated on passage through the glass. The antenna gain range is 1 to 3 dB depending on the operating frequency. The position of the glass-mounted antenna is

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always lower than that of the roof-mounted antenna; generally there is a 3-dBdifference between these two types of antenna. Also, glass mounted antennas cannot be installed on the shaded glass found in some motor vehicles because this type of glass has a high metal content.

MOBILE HIGH-GAIN ANTENNAS:

A high-gain antenna used on a mobile unit has been studied. This type of high-gain antenna should be distinguished from the directional antenna. In the directional antenna, the antenna beam pattern is suppressed horizontally; in the high-gain antenna, the pattern is suppressed vertically.

To apply either a directional antenna or a high-gain antenna for reception in a radio environment, we must know the origin of the signal. If we point the directional antenna opposite to the transmitter site, we would in theory receive nothing. In a mobile radio environment, the scattered signals arrive at the mobile unit from every direction with equal probability. That is why an Omni directional antenna must be used.

The scattered signals also arrive from different elevation angles. Lee and Brandt used two types of antenna, one $\lambda/4$ whip antenna with elevation coverage of 39° and one 4-dB-gain antenna (4-dB gain with respect to the gain of a dipole) with elevation coverage of 16° and measured the angle of signal arrival in the suburban Keyport-Matawan area of New Jersey. There are two types of test: a line-of-sight condition and an out-of-sight condition. In Lee and Brandt's study, the transmitter was located at an elevation of approximately 100 m (300 ft) above sea level.

The measured areas were about 12 m (40 ft) above sea level and the path length about 3 mi. The received signal from the 4-dB-gain antenna was 4 dB stronger than that from the whip antenna under line-of-sight conditions. This is what we would expect.

However, the received signal from the 4-dB-gain antenna was only about 2 dB stronger than that from the whip antenna under out-of-sight conditions. This is surprising. The reason for the latter observation is that the scattered signals arriving under out-of- sight conditions are spread over a wide elevation angle. A large portion of the signals outside the elevation angle of 16° cannot be received by the high-gain antenna. We may calculate the portion being received by the high-gain antenna from the measured beam width. For instance, suppose that a 4:1 gain (6 dBi) is expected from the high-gain antenna, but only 2.5:1 is received. Therefore, 63 percent of the signal is received by the 4-dB-gain antenna (i.e., 6 dBi) and 37 percent is felt in the region between 16 and 39°

Therefore, a 2- to 3-dB-gain antenna (4 to 5 dBi) should be adequate for general use. An antenna gain higher than 2 to 3 dB does not serve the purpose of enhancing reception level. Moreover, measurements reveal that the elevation angle for scattered signals received in urban areas is greater than that in suburban areas.

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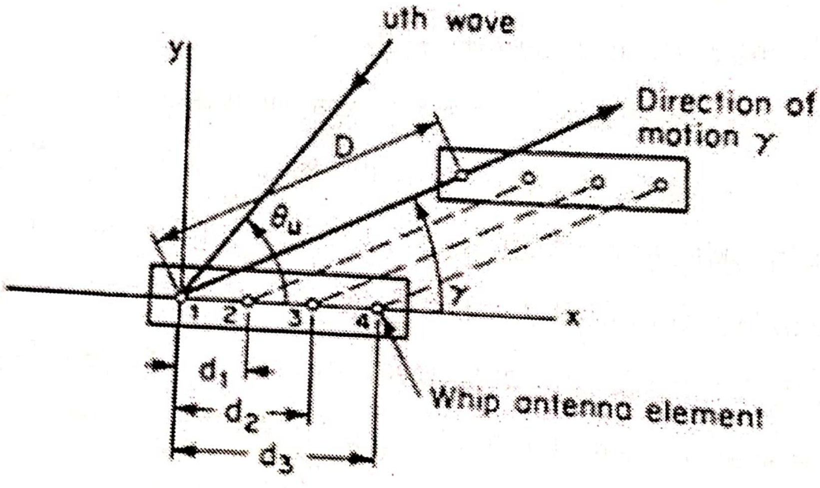
	Gain, dBi	Linear ratio	$\theta_0/2$, degrees
Whip antenna (2 dB above isotropic)	2	1.58:1	39
High-gain antenna	6	4:1	16
Low-gain antenna	4	2.5:1	24



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UNIT-IV (B)

FREQUENCY MANAGEMENT AND CHANNEL ASSIGNMENT

The function of frequency management is to divide the total number of available channels into subsets which can be assigned to each cell either in a fixed fashion or dynamically (i.e., in response to any channel among the available channels). The terms —frequency management‖ and —channel assignment‖ often create some confusion. Frequency management refers to designating setup channels and voice channels (done by the FCC), numbering the channels (done by the FCC), and grouping the voice channels into subsets (done by each system according to its preference).

Channel assignment refers to the allocation of specific channels to cell sites and mobile units. A fixed channel set consisting of one more subsets is assigned to a cell site on a long-term basis. During a call, a particular channel is assigned to a mobile unit on a short- term basis. For a short-term assignment, one channel assignment per call is handled by the mobile telephone switching office (MTSO). Ideally channel assignment should be based on causing the least interference in the system. However, most cellular systems cannot perform this way.

4.1 NUMBERING THE RADIO CHANNELS

The total number of channels at present (January 1988) is 832. But most mobile units an systems are still operating on 666 channels. Therefore we describe the 666 channel numbering first. A channel consists of two frequency channel bandwidths, one in the low band and one in the high band. Two frequencies in channel 1 are 825.030 MHz (mobile transmit) 870.030 MHz (cell-site transmit). The two frequencies in channel 666 are 844.98 MHz (mobile transmit) and 898 MHz (cell-site transmit). The 666 channels are divided into two groups: block A system and block B system. Each market (i.e., each city) has two systems for a duopoly market policy. Each block has 333 channels, as shown in Fig.1.1.

The 42 set-up channels are assigned as follows.

Channels 313-333	block A
Channels 334-354	block B

The voice channels are assigned as follows.

Channels 1-312 (312 voice channels)	block A
Channels 355-666 (312 voice channels)	block B

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	1A	2A	3A	4A	5A	6A	7A	1B	2B	3B	4B	5B	6B	7B	1C	2C	3C	4C	5C	6C	7C	
Block A system	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	
	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	
	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	
	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	
	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	
	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	
	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	
	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	
	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	
	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	
	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	
	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	
	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	
	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	—	—	—	
	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	Control channel sets
Block B system	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	
	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	
	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	
	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	
	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	
	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	
	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	
	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	
	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	
	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	
	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	
	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	
	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	
	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	
	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	
	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	—	—	—	

Fig.4.1. Frequency management chart

These 42 set-up channels are assigned in the middle of all the assigned channels to facilitate scanning of those channels by frequency synthesizers. In the new additional spectrum allocation of 10 MHz (sec Fig. 1.2.), an additional 166 channels are assigned. Since a 1 MHz is assigned below 825 MHz (or 870 MHz) in the future, additional channels will be numbered up to 849 MHz (or 894 MHz) and will then circle back. The last channel number is 1023. There are no Channels between channels 799 and 991.

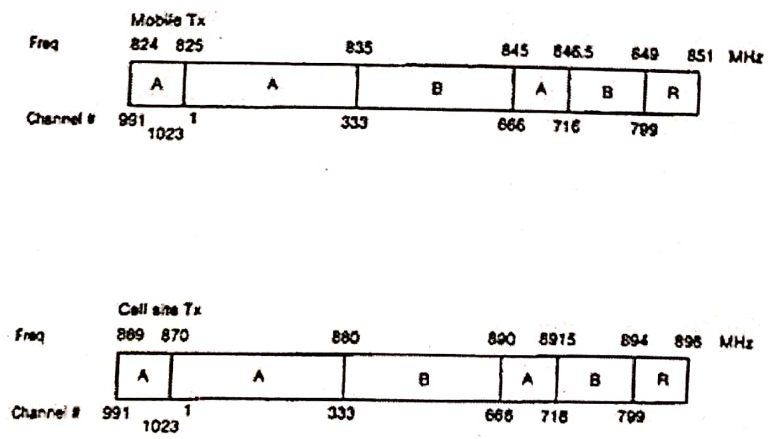

Fig.4.2. New additional spectrum allocation

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4.2 GROUPING INTO SUBSETS

The number of voice channels for each system is 312. We can group these into any number of subsets. Since there are 21 set-up channels for each system, it is logical to group the 312 channels into 21 subsets. Each subset then consists of 16 channels. In each set, the closest adjacent channel is 21 channels away, as shown in Fig.1.1. The 16 channels in each subset can be mounted on a frame and connected to a channel combiner. Wide separation between adjacent channels is required for meeting the requirement of minimum isolation. Each 16-channel subset is idealized for each 16-channel combiner. In a seven- cell frequency-reuse cell system each cell contains three subsets, iA+iB+iC, where i is an integer from 1 to 7. The total number of voice channels in a cell is about 45. The minimum separation between three subsets is 7 channels. If six subsets are equipped in an omnicell site, the minimum separation between two adjacent channels can be only three (21/6> 3) physical channel bandwidths.

For example,

1A+1B+1C+4A+4B

+4 C

Or

1A+1B+1C+5A+5B+5C

4.3 SET-UP CHANNELS

Set-up channels also called control channels are the channels designated to setup calls. We should not be confused by fact that a call always needs a set-up channel. A system can be operated without set-up channels. If we are choosing such a system all the 333 channels in each cellular system (block A or block B) can be voice channels; however each mobile unit must then scan 333 channels continuously and detect the signaling for its call. A customer who wants to initiate a call must scan all the channels and find an idle (unoccupied) one to use.

In a cellular system, we are implementing frequency-reuse concepts. In this case the set-up channels are acting as control channels. The 21 set-up channels are taken out from the total number of channels. The number 21 is derived from a seven-cell frequency-reuse pattern with three 120° sectors per cell, or a total of 21 sectors, which require 21 set-up channels. However, now only a few of the 21 setup channels are being used in each system. Theoretically, when cell size decreases the use of set-up channels should increase. Set-up channels can be classified by usage into two types: access channels and paging channels.

An access channel is used for the mobile-originating calls and paging channels for the land originating calls. For this reason, a set-up channel is sometimes called an _access channel' and sometimes called a _paging channel.' Every two- way channel contains two 30-kHz bandwidth.. Normally one set-up channel is also specified

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by two operations as a forward set-up channel (using the upper band) and a reverse set-up channel (using the lower band). In the most common types of cellular systems, one set-up channel is used for both access and paging. The forward set-up channel functions as the paging channel for responding to the mobile-originating calls. The reverse set-up channel functions as the access channel for the responder to the paging call. The forward set-up channel is transmitted at the cell site, and the reverse set-up channel is transmitted at the mobile unit. All set-up channels carry data information only.

4.3.1. ACCESS CHANNELS:

In mobile-originating calls, the mobile unit scans its 21 set-up channels and chooses the strongest one. Because each set-up channel is associated with one cell, the strongest set-up channel indicates which cell is to serve the mobile-originating calls. Th. mobile unit detects the system information transmitted from the cell site. Also, the mobile unit monitors the Busy/Idle status bits over the desired forward setup channel. When the idle bits are received, the mobile unit can use the corresponding reverse set-up channel to initiate a call.

Frequently only one system operates in a given city; for instance, block B system might be operating and the mobile unit could be set to —preferable A system.‖ When the mobile unit first scans the 21 set-up channels in block A, two conditions can occur.

1. If no set-up channels of block A are operational, the mobile unit automatically switches to block B.

2. If a strong set-up signal strength is received but no message can be detected, then the scanner chooses the second strongest set-up channel. If the message still cannot be detected, the mobile unit switches to block B and scans to block B set-up channels.

THE OPERATIONAL FUNCTIONS ARE DESCRIBED AS FOLLOWS:

1.POWER OF A FORWARD SET-UP CHANNEL [OR FORWARD CONTROL CHANNEL (FOCC)]: The power of the set-up channel can be varied in order to control the number of incoming calls served by the cell. The number of mobile-originating calls is limited by the number of voice channels in each cell site, when the traffic is heavy, most voice channels are occupied and the power of the set-up channel should be reduced in order to reduce the coverage of the cell for the incoming calls originating from the mobile unit. This will force the mobile units to originate calls from other cell sites, assuming that all cells are adequately overlapped.

2. THE SET-UP CHANNEL RECEIVED LEVEL: The setup channel threshold level is determined in order to control the reception at the reverse control channel (RECC). If the received power level is greater than the given set-up threshold level, the call request will be taken.

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3. CHANGE POWER AT THE MOBILE UNIT: When the mobile unit monitors the strongest signal strength from all Set-up channels and selects that channel to receive the messages, there are three types of message.

A. MOBILE STATION CONTROL MESSAGE. This message is used for paging and consists of one, two, or four words -DCC, MIN, SCC and VMAX.

B. SYSTEM PARAMETER OVERHEAD MESSAGE. This message contains two words, including DCC, SID, CMAX, or CPA.

c. CONTROL-FILLER MESSAGE. This message may be sent with a system parameter overhead message, CMAC—a control mobile attenuation code (seven levels).

4. DIRECT CALLS RETRY. When a cell site has no available voice channels, it can send a direct call-retry message through the set-up channel. The mobile unit will initiate, the call from a neighboring cell which is on the list of neighboring cells in the direct call-retry message.

4.3.2. PAGING CHANNELS:

Each cell site has been allocated its own setup channel (control channel). The assigned forward set-up channel (FOCC) of each cell site is used to page the mobile unit with the same mobile station control message.

Because the same message is transmitted by the different set-up channels, no simulcast interference occurs in the system. The algorithm for paging & mobile unit can be performed in different ways. The simplest way is to page from all the cell sites. This can occupy a large amount of the traffic load. The other way is to page in an area corresponding to the mobile unit phone number. If there is no answer, the system tries to page in other areas. The drawback is that response time is sometimes too long.

When the mobile unit responds to the page on the reverse set-up channel, the cell site which receives the response checks the signal reception level and makes a decision regarding the voice channel assignment based on least interference in the selected sector or underlay-overlay region.

4.4 FIXED CHANNEL ASSIGNMENT

ADJACENT-CHANNEL ASSIGNMENT:

Adjacent-channel assignment includes neighboring-channel assignment and next-channel assignment. The near-end–far-end (ratio) interference can occur among the neighboring channels (four channels on each side of the desired channel). Therefore, within a cell we have to be sure to assign neighboring channels in an Omni-directional-cell system and in a directional-antenna-cell system properly.

In an Omni-directional-cell system, if one channel is assigned to the middle cell of seven cells, next channels cannot be assigned in the same cell. Also, no next channel (preferably including neighboring channels) should be assigned in the six neighboring sites in the same cell system area (Fig. 7.3a). In a directional-antenna-

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cell system, if one channel is assigned to a face, next channels cannot be assigned to the same face or to the other two faces in the same cell. Also, next channels cannot be assigned to the other two faces at the same cell site (Fig. 7.3b). Sometimes the next channels are assigned in the next sector of the same cell in order to increase capacity. Then performance can still be in the tolerance range if the design is proper.

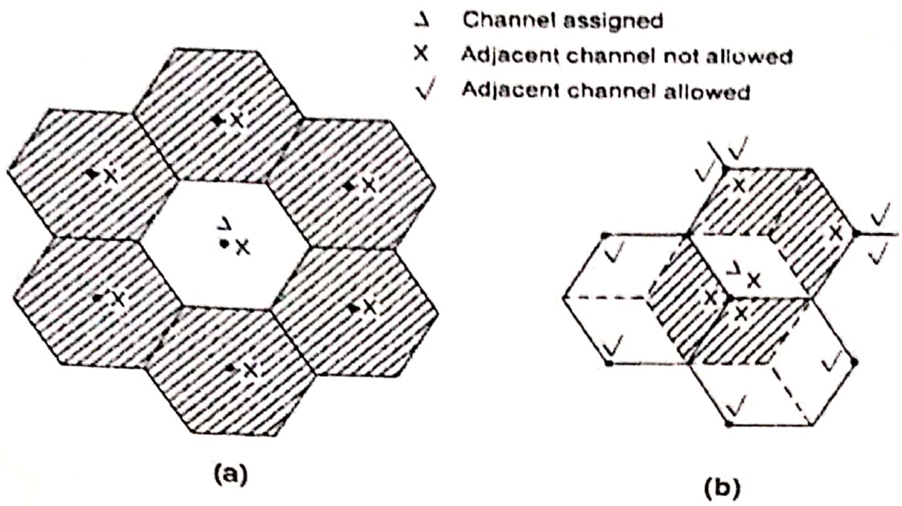

Fig.4.3 Adjacent channel assignment (a) Omni direction antenna cells; (b) Directional antenna cells

4.5 CHANNEL SHARING

Channel sharing is a short-term traffic-relief scheme. A scheme used for a seven-cell three-face system is shown in Fig. 7.2. There are 21 channel sets, with each set consisting of about 16 channels. Figure7.2 shows the channel set numbers. When a cell needs more channels, the channels of another face at the same cell site can be shared to handle the short-term overload. To obey the adjacent-channel assignment algorithm, the sharing is always cyclic. Sharing always increases the trunking efficiency of channels.

Since we cannot allow adjacent channels to share with the nominal channels in the same cell, channel sets 4 and 5 cannot both be shared with channel sets 12 and 18, a indicated by the grid mark. Many grid marks are indicated in Fig.7.2 for the same reason. However, the upper subset of set 4 can be shared with the lower subset of set 5 with no interference. In channel-sharing systems, the channel combiner should be flexible in order to combine up to 32 channels in one face in real time. An alternative method is to install a standby antenna.

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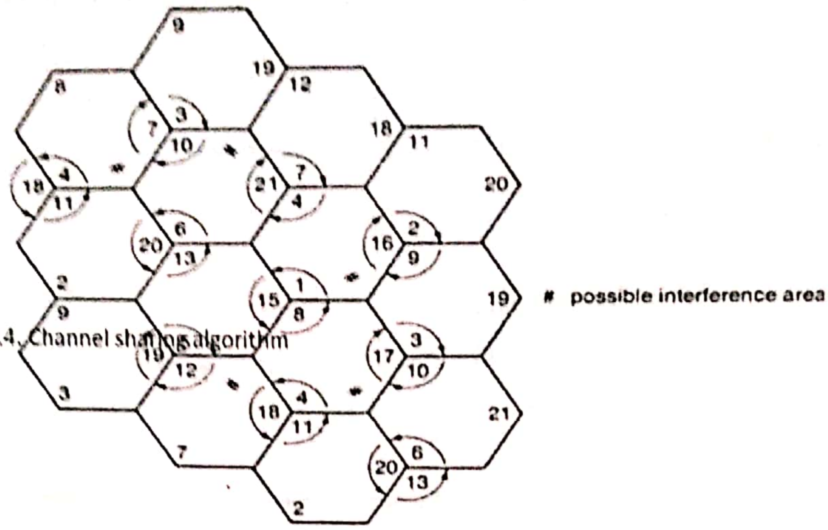

Fig.4.4. Channel sharing algorithm

4.6 CHANNEL BORROWING

Channel borrowing is usually handled on a long-term basis. The extent of borrowing more available channels from other cells depends on the traffic density in the area. Channel borrowing can be implemented from one cell-site face to another face at the same cell site. In addition, the central cell site can borrow channels from neighboring cells. The channel-borrowing scheme is used primarily for slowly-growing systems. It is often helpful in delaying cell splitting in peak traffic areas. Since cell splitting is costly, it should be implemented only as a last resort.

ADVANTAGE OF SECTORIZATION:

The total number of available channels can be divided into sets (subgroups) depending on the Sectorization of the cell configuration: the 120°-sector system, the 60°-sector system, and the 45°-sector system. In certain locations and special situations, the sector angle can be reduced (narrowed) in order to assign more channels in one sector without increasing neighboring-channel interference. Sectorization serves the same purpose as the channel-borrowing scheme in delaying cell splitting. In addition, channel coordination to avoid co-channel interference is much easier in sectorization than in cell splitting. Given the same number of channels, trunking efficiency decreases in Sectorization.

SECTORIZED CELLS: There are three basic types.

1. The 120°-sector cell is used for both transmitting and receiving Sectorization. Each sector has an assigned a number of frequencies. Changing sectors during a call requires handoffs.

2. The 60°-sector cell is used for both transmitting and receiving Sectorization. Changing sectors during a call requires handoffs. More handoffs are expected for a 60° sector than a 120° sector in areas close to cell sites (close-in areas).

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3. The 120° or 60°-sector cell is used for receiving Sectorization only. In this case, the transmitting antenna is Omni directional. The number of channels in this cell is not sub- divided for each sector. Therefore, no handoffs are required when changing sectors. This receiving-Sectorization-only configuration does not decrease interference or increase the D/R ratio; it only allows for a more accurate decision regarding handing off the calls to neighboring cells.

4.7 UNDERLAY-OVERLAY ARRANGEMENT

In actual cellular systems cell grids are seldom uniform because of varying traffic conditions in different areas and cell-site locations.

OVERLAID CELLS:

To permit the two groups to reuse the channels in two different cell-reuse patterns of the same size, an ―under laid‖ small cell is sometimes established at the same cell site as the large cell (see Fig. 7.5a). The ―doughnut‖ (large) and ―hole‖ (small) cells are treated as two different cells. They are usually considered as ―neighboring cells.‖

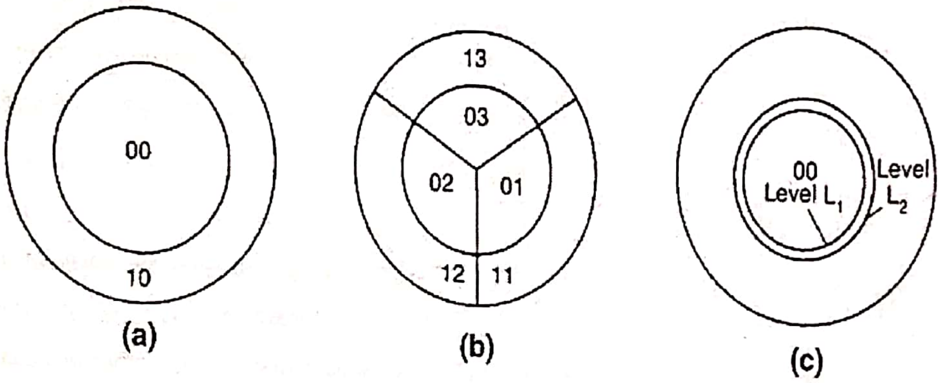

Fig.4.5.Under laid-overlaid cell arrangements. (a) Underlay-overlay in omnicell; (b) Underlay-overlay in Sectorized cell; (c) Two level handoff scheme

The use of either an Omni directional antenna at one site to create two sub ring areas or three directional antennas to create six subareas is illustrated in Fig. 4.5 b. As seen in Fig.4.5, a set of frequencies used in an overlay area will differ from a set of frequencies used in an underlay area in order to avoid adjacent-channel and co-channel interference.

The channels assigned to one combiner—say, 16 channels—can be used for overlay, and another combiner can be used for underlay.

IMPLEMENTATION:

The antenna of a set-up channel is usually Omni directional. When an incoming call is received by the set-up channel and its signal strength is higher than a level L, the under laid cell is assigned; otherwise, the overlaid cell is

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assigned. The handoffs are implemented between the under laid and overlaid cells. In order to avoid the unnecessary handoffs, we may choose two levels L1 and L2 and L1 > L2 as shown in Fig. 4.5 (c). When a mobile signal is higher than a level L1 the call is handed off to the under laid cell. When a signal is lower than a level L2 the call is handed off to the overlaid cell. The channels assigned in the under laid cell have more protection against co-channel interference.

4.8 NON FIXED CHANNEL ASSIGNMENT STRATEGY

1. FIXED CHANNEL ASSIGNMENT: The fixed channel assignment (FCA) algorithm is the most common algorithm adopted in many cellular systems. In this algorithm, each cell assigns its own radio channels to the vehicles within its cell.

2. DYNAMIC CHANNEL ASSIGNMENT: In dynamic channel assignment (DCA), no fixed channels are assigned to each cell. Therefore, any channel in a composite of N radio channels can be assigned to the mobile unit. This means that a channel is assigned directly to a mobile unit. On the basis of overall system performance, DCA can also be used during a call.

3. HYBRID CHANNEL ASSIGNMENT: Hybrid channel assignment (HCA) is a combination of FCA and DCA. A portion of the total frequency channels will use FCA and the rest will use DCA.

4. BORROWING CHANNEL ASSIGNMENT: Borrowing channel assignment (BCA) uses FCA as a normal assignment condition. When all the fixed channels are occupied, then the cell borrows channels from the neighboring cells.

5. FORCIBLE-BORROWING CHANNEL ASSIGNMENT: In forcible-borrowing channel assignment (FBCA), if a channel is in operation and the situation warrants it, channels must be borrowed from the neighboring cells and at the same time, another voice channel will be assigned to continue the call in the neighboring cell. There are many different ways of implementing FBCA. In a general sense, FBCA can also be applied while accounting for the forcible borrowing of the channels within a fixed channel set to reduce the chance of co-channel assignment in a reuse cell pattern. The FBCA algorithms based on assigning a channel dynamically but obeying the rule of reuse distance.

The distance between the two cells is reuse distance, which is the minimum distance at which no co-channel interference would occur. Very infrequently, no channel can be borrowed in the neighboring cells. Even those channels currently in operation can be forcibly borrowed and will be replaced by a new channel in the neighboring cell or the neighboring cell of the neighboring cell. If all the channels in the neighboring cells cannot be borrowed because of interference problems, the FBCA stops.

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IN THIS TWO DIFFERENT MATERIALS AVAILABLE

UNIT-V

HANDOFFS

WHY HAND OFF IS NECESSARY

In an analog system, once a call is established, the set-up channel is not used again during the call period. Therefore, handoff is always implemented on the voice channel. In the digital systems, the handoff is carried out through paging or common control channel. The value of implementing handoffs is dependent on the size of the cell. For example, if the radius of the cell is 32 km (20 mi), the area is 3217 km^2(1256 mi^2). After a call is initiated in this area, there is little chance that it will be dropped before the call is terminated as a result of a weak signal at the coverage boundary. Then why bother to implement the handoff feature? Even for a 16-km radius, cell handoff may not be needed. If a call is dropped in a fringe area, the customer simply redials and reconnects the call. Today the size of cells becomes smaller in order to increase capacity. Also people talk longer. The handoffs are very essential. Handoff is needed in two situations where the cell site receives weak signals from the mobile unit: (1) at the cell boundary, say, −100 dBm, which is the level for requesting a handoff in a noise-limited environment; and (2) when the mobile unit is reaching the signal-strength holes (gaps) within the cell site as shown in Fig.1.

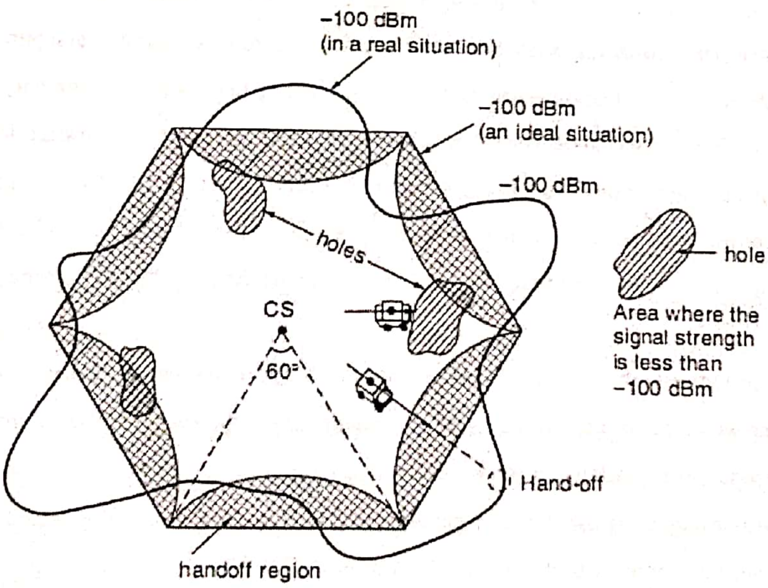

Fig.1. Occurrence of handoffs

WHAT ARE THE TWO DECISIONS MAKING PARAMETERS OF HANDOFF EXPLAIN

There are two decision-making parameters of handoff: (1) that based on signal strength and (2) that based on carrier-to-interference ratio. The handoff criteria are different for these two types. In type 1, the

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signal-strength threshold level for handoff is -100 dBm in noise-limited systems and -95 dBm in interference-limited systems. In type 2, the value of C/I at the cell boundary for handoff should be at a level, 18 dB for AMPS in order to have toll quality voice. Sometimes, a low value of C/I may be used for capacity reasons.

Type 1: It is easy to implement. The location receiver at each cell site measures all the signal strengths of all receivers at the cell site. However, the received signal strength (RSS) itself includes interference.

$$RSS = C + I$$

where C is the carrier signal power and I is the interference. Suppose that we set up a threshold level for RSS; then, because of the I , which is sometimes very strong, the RSS level is higher and far above the handoff threshold level. In this situation handoff should theoretically take place but does not. Another situation is when I is very low but RSS is also low. In this situation, the voice quality usually is good even though the RSS level is low, but since RSS is low, unnecessary handoff takes place. Therefore, it is an easy but not very accurate method of determining handoffs. Some analog systems use SAT information together with the received signal level to determine handoffs. Some CDMA systems use pilot channel information.

Type 2: Handoffs can be controlled by using the carrier-to-interference ratio C/I C+I/I = C/I

we can set a level based on C/I ,so C drops as a function of distance but I is dependent on the location. If the handoff is dependent on C/I , and if the C/I drops, it does so in response to increase in (1) propagation distance or (2) interference. In both cases, handoff should take place. In today's cellular systems, it is hard to measure C/I during a call because of analog modulation. Sometimes we measure the level I before the call is connected, and the level C + I during the call. Thus (C + I)/I can be obtained.

TYPES OF HANDOFF

There are four types of handoff:

1. **INTERSECTOR OR SOFTER HANDOFF.**

The mobile communicates with two sectors of the same cell (see Fig. 10-1). A RAKE receiver at the base station combines the best versions of the voice frame from the diversity antennas of the two sectors into a single traffic frame.

2. **INTERCELL OR SOFT HANDOFF.**

The mobile communicates with two or three sectors of different cells (see Fig. 10-2). The base station that has the direct control of call processing during handoff is referred to as the primary base station. The primary base station can initiate the forward control message. Other base stations that do not have control over call processing are called the secondary base stations. Soft handoff ends when either the primary or secondary base station is dropped. If the primary base station is dropped, the secondary base station becomes the new primary for this call. A three-way soft handoff may end by first dropping one of the base stations and becoming a two-way soft handoff. The base stations involved coordinate handoff by

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exchanging information via SS7 links. A soft handoff uses considerably more network resources than the softer handoff.

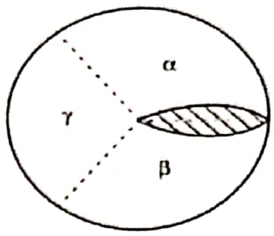

Figure 10-1 Softer Handoff

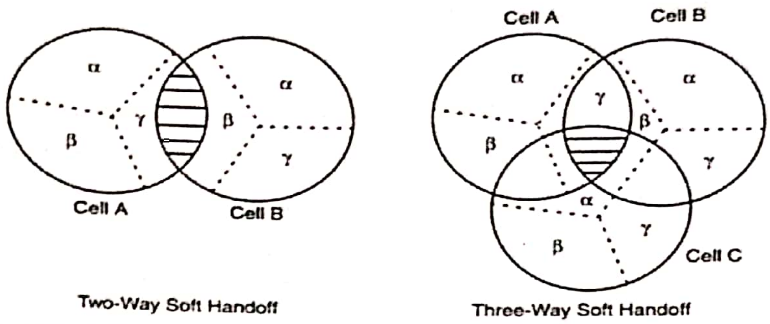

Figure 10-2 Soft Handoff

3. SOFT-SOFTER HANDOFF.

The mobile communicates with two sectors of one cell and one sector of another cell (see Fig. 10-3). Network resources required for this type of handoff include the resources for a two-way soft handoff between cell A and B plus the resources for a softer handoff at cell B.

4. HARD HANDOFF.

Hard handoffs are characterized by the break-before-make strategy. The connection with the old traffic channel is broken before the connection with the new traffic channel is established. Scenarios for hard handoff include

◆ Handoff between base stations or sectors with different CDMA carriers

◆ Change from one pilot to another pilot without first being in soft handoff with the new pilot (disjoint active sets)

◆ Handoff from CDMA to analog, and analog to CDMA

◆ Change of frame offset assignment—CDMA traffic frames are 20 ms long. The start of frames in a particular traffic channel can be at 0 time in reference to a system or it can be offset by up to 20 ms (allowed in IS-95). This is known as the frame offset. CDMA traffic channels are assigned different frame offset to avoid congestion. The frame offset for a particular traffic channel is communicated to the mobile. Both forward and reverse links use this offset. A change in offset

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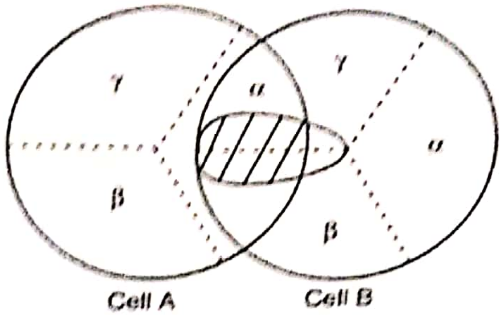

Figure 10-3 Soft-Softer Handoff

Assignment will disrupt the link. During soft handoff the new base station must allocate the same frame offset to the mobile as assigned by the primary base station. If that particular frame offset is not available, a hard handoff may be required. Frame offset is a network resource and can be used up

HANDOFF INITIATION

A hard handoff occurs when the old connection is broken before a new connection is activated. The performance evaluation of a hard handoff is based on various initiation criteria [1, 3, 13]. It is assumed that the signal is averaged over time, so that rapid fluctuations due to the multipath nature of the radio environment can be eliminated. Numerous studies have been done to determine the shape as well as the length of the averaging window and the older measurements may be unreliable. Figure 1.2 shows a MS moving from one BS (BS1) to another (BS2). The mean signal strength of BS1 decreases as the MS moves away from it. Similarly, the mean signal strength of BS2 increases as the MS approaches it. This figure is used to explain various approaches described in the following subsection.

1.3.1 RELATIVE SIGNAL STRENGTH

This method selects the strongest received BS at all times. The decision is based on a mean measurement of the received signal. In Figure 1.2, the handoff would occur at position A. This method is observed to provoke too many unnecessary handoffs, even when the signal of the current BS is still at an acceptable level.

1.3.2 RELATIVE SIGNAL STRENGTH WITH THRESHOLD

This method allows a MS to hand off only if the current signal is sufficiently weak (less than threshold) and the other is the stronger of the two. The effect of the threshold depends on its relative value as compared to the signal strengths of the two BSs at the point at which they are equal. If the threshold is higher than this value, say T1 in Figure 1.2, this scheme performs exactly like the relative signal strength scheme, so the handoff occurs at position A. If the threshold is lower than this value, say T2 in Figure 1.2, the MS would delay handoff until the current signal level crosses the threshold at position B. In the case of T3, the delay may be so long that the MS drifts too far into the new cell.

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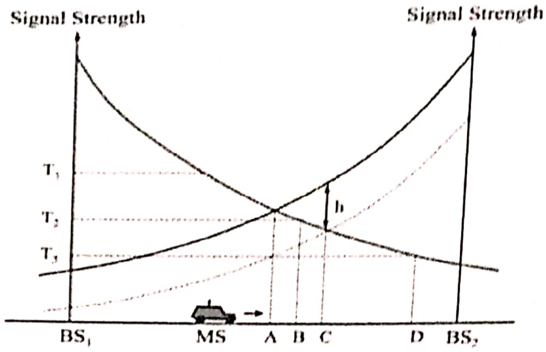

Figure 1.2 Signal strength and hysteresis between two adjacent BSs for potential handoff.

This reduces the quality of the communication link from BS1 and may result in a dropped call. In addition, this results in additional interference to cochannel users. Thus, this scheme may create overlapping cell coverage areas. A threshold is not used alone in actual practice because its effectiveness depends on prior knowledge of the crossover signal strength between the current and candidate BSs.

1.3.3 RELATIVE SIGNAL STRENGTH WITH HYSTERESIS

This scheme allows a user to hand off only if the new BS is sufficiently stronger (by a hysteresis margin, h in Figure 1.2) than the current one. In this case, the handoff would occur at point C. This technique prevents the so-called ping-pong effect, the repeated handoff between two BSs caused by rapid fluctuations in the received signal strengths from both BSs. The first handoff, however, may be unnecessary if the serving BS is sufficiently strong.

1.3.4 RELATIVE SIGNAL STRENGTH WITH HYSTERESIS AND THRESHOLD

This scheme hands a MS over to a new BS only if the current signal level drops below a threshold and the target BS is stronger than the current one by a given hysteresis margin. In Figure 1.2, the handoff would occur at point D if the threshold is T3

1.3.5 PREDICTION TECHNIQUES

Prediction techniques base the handoff decision on the expected future value of the received signal strength. A technique has been proposed and simulated to indicate better results, in terms of reduction in the number of unnecessary handoffs, than the relative signal strength, both without and with hysteresis, and threshold methods.

CONCEPT OF DELAYING A HANDOFF

In many cases, a two-handoff-level algorithm is used. The purpose of creating two request handoff levels is to provide more opportunity for a successful handoff. A handoff could be delayed if no available cell could take the call. A plot of signal strength with two request handoff levels and a threshold level is shown in Fig.3. The plot of average signal strength is recorded on the channel received

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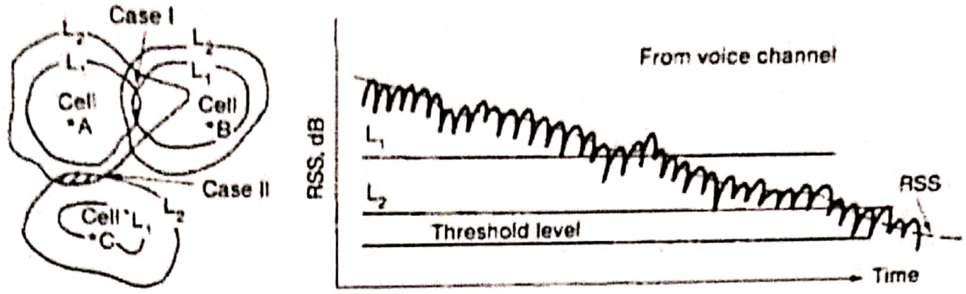

Fig.3. A two level handoff scheme

Signal strength indicator (RSSI), which is installed at each channel receiver at the cell site. When the signal strength drops below the first handoff level, a handoff request is initiated. If for some reason the mobile unit is in a hole (a weak spot in a cell) or a neighboring cell is busy, the handoff will be requested periodically every 5 s. At the first handoff level, the handoff takes place if the new signal is stronger. However, when the second handoff level is reached, the call will be handed off with no condition. The MSO always handles the handoff call first and the originating calls second. If no neighboring calls are available after the second handoff level is reached, the call continues until the signal strength drops below the threshold level; then the call is dropped. In AMPS systems if the supervisory audio tone (SAT) is not sent back to the cell site by the mobile unit within 5 s, the cell site turns off the transmitter.

ADVANTAGES OF DELAYED HANDOFF

1. Consider the following example. The mobile units are moving randomly and the terrain contour is uneven. The received signal strength at the mobile unit fluctuates up and down. If the mobile unit is in a hole for less than 5 s (a driven distance of 140 m for 5 s, assuming a vehicle speed of 100 km/h), the delay (in handoff) can even circumvent the need for a handoff. If the neighboring cells are busy, delayed handoff may take place. In principle, when call traffic is heavy, the switching processor is loaded, and thus a lower number of handoffs would help the processor handle call processing more adequately. Of course, it is very likely that after the second handoff level is reached, the call may be dropped with great probability.
2. The other advantage of having a two-handoff-level algorithm is that it makes thehandoff occur at the proper location and eliminates possible interference in the system. Figure 3, case I, shows the area where the first-level handoff occurs between cell A and cell B. If we only use the second-level handoff boundary of cell A, the area of handoff is too close to cell B. Figure 3, case II, also shows where the second-level handoff occurs between cell A and cell C. This is because the first-level handoff cannot be implemented.

POWER DIFFERENCE HANDOFF

A better algorithm is based on the power difference (_) of a mobile signal received by two cell sites, home and handoff. _ can be positive or negative. The handoff occurs depending on a preset value of _.

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_ = the mobile signal measured at the candidate handoff site

- The mobile signal measured at the home site

For example, the following cases can occur.

_> 3 dB request a handoff

1dB <_< 3 dB prepare a handoff

−3dB <_< 0 dB monitoring the signal strength

_< −3 dB no handoff

Those numbers can be changed to fit the switch processor capacity. This algorithm is not based on the received signal strength level, but on a relative (power difference) measurement. Therefore, when this algorithm is used, all the call handoffs for different vehicles can occur at the same general location in spite of different mobile antenna gains or heights.

FORCED HANDOFF

A forced handoff is defined as a handoff that would normally occur but is prevented from happening, or a handoff that should not occur but is forced to happen.

MOBILE-ASSISTED HANDOFF

In a mobile-assisted handoff process, the MS makes measurements and the network makes thedecision. In the circuit switched GSM (global system mobile), the BS controller (BSC) is in charge of the radio interface management. This mainly means allocation and release of radio channels and handoff management. The handoff time between handoff decision and execution in such a circuit-switched GSM is approximately 1 second.

SOFT HANDOFF

SOFT HANDOFF (FORWARD LINK)

In this case all traffic channels assigned to the mobile are associated with pilots in the active set and carry the same traffic information with the exception of power control subchannel. When the active set contains more than one pilot, the mobile provides diversity by combining its associated forward traffic channels.

SOFT HANDOFF (REVERSE LINK)

During intercell handoff, the mobile sends the same information to both base stations. Each base station receives the signal from the mobile with appropriate propagation delay. Each base station then transmits the received signal to the vocoder/selector. In other words, two copies of the same frame are sent to the vocoder/selector. The vocoder/selector selects the better frame and discards the other.

SOFTER HANDOFF (REVERSE LINK)

During intersector handoff, the mobile sends the same information to both sectors. The channel card/element at the cell site receives the signals from both sectors. The channel card combines both inputs, and only one frame is sent to the vocoder/selector. It should be noted that extra channel cards are not required to support softer handoff as is the case for soft handoffs. The diversity gain from soft handoffs is more than the

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diversity gain from softer handoffs because signals from distinct cells are less correlated than signals from sectors of the same cell.

10.2.4 BENEFIT OF SOFT HANDOFF

A key benefit of soft handoff is the path diversity on the forward and reverse traffic channels. Diversity gain is obtained because less power is required on the forward and reverse links. This implies that total system interference is reduced. As a result, the average system capacity is improved. Also less transmit power from the mobile results in longer battery life and longer talk time. In a soft handoff, if a mobile receives an up power control bit from one base station and a down control bit from the second base station, the mobile decreases its transmit power. The mobile obeys the power down command since a good communications link must have existed to warrant the command from the second base station.

INTERSYSTEM HANDOFF

Occasionally, a call may be initiated in one cellular system (controlled by one MSO) and enter another system (controlled by another MSO) before terminating. In some instances, intersystem handoff can take place; this means that a call handoff can be transferred from one system to a second system so that the call is continued while the mobile unit enters the second system. The software in the MSO must be modified to apply this situation. Consider the simple diagram shown in Fig.7. The car travels on a highway and the driver originates a call in system A. Then the car leaves cell site A of system A and enters cell site B of system B. Cell sites A and B are controlled by two different MSOs. When the mobile unit signal becomes weak in cell site A, MSO A searches for a candidate cell site in its system and cannot find one. Then MSO A sends

The handoff request to MSO B through a dedicated line between MSO A and MSO B, and MSO B makes a complete handoff during the call conversation. This is just a one-point connection case. There are many ways of implementing intersystem handoffs, depending on the actual circumstances. For instance, if two MSOs are manufactured by different companies, then compatibility must be determined before implementation of intersystem handoff can be considered.

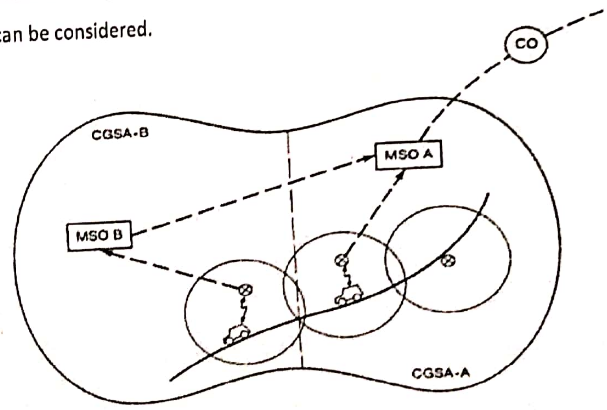

Fig.7. Intersystem handoffs

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Unit - 5

Hand off Strategies

- → Concept of Handoff
- → Types of Handoff
- → Hand off Initiation
- → delaying Handoff
- → Forced Hand off
- → Mobile Assigned Handoff (MAHO)
- → Inter System Hand off
- → Vehicle locating Methods
- → Dropped call rates and their evaluation

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Unit - V

HAND OFF STRATEGIES

Concept of Handoff :-

→ During a call, if the mobile unit is moving from one cell site to the other cell site then it must be moved from existing voice channel to a new voice channel pair.

→ This process is called "Hand off".

→ Hand off is required at different conditions (or) situations such as

(i) Moving the mobile unit from one cellsite to other cell site.

(ii) Mobile unit is moving from one sector to the another sector.

(iii) Mobile unit is moving from underlay region to overlay region.

(iv) Mobile unit entering into coverage hole

(v) Mobile unit assigned with a poor channel.

(2m)

Coverage hole:-

A low signal Strength area with in the coverage area of cellsite (or) sector is called as "Coverage hole."

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→ In coverage hole, signal strength is less than normal (or) threshold level for few channels.

Types of Hand off's :-

→ As per the procedure & function, handoff's are classified as (i) Forced hand off
(ii) Power difference hand off
(iii) Mobile Assisted handoff
(iv) Soft hand off
(v) Inter system handoff
(vi) Cell site hand off

(i) Forced hand offs :-

→ If the mobile unit is reading to the handoff threshold then the process of initiation handoff must be initiated.

→ If load on the reference cellsite is high then to create free channels, handoff may be given for the mobile units present in the common coverage areas.

→ This is called forced hand off.

→ A handoff that should not occur but is forced to happen is forced hand off.

→ TO execute forced hand off, handoff threshold must be changed accordingly.

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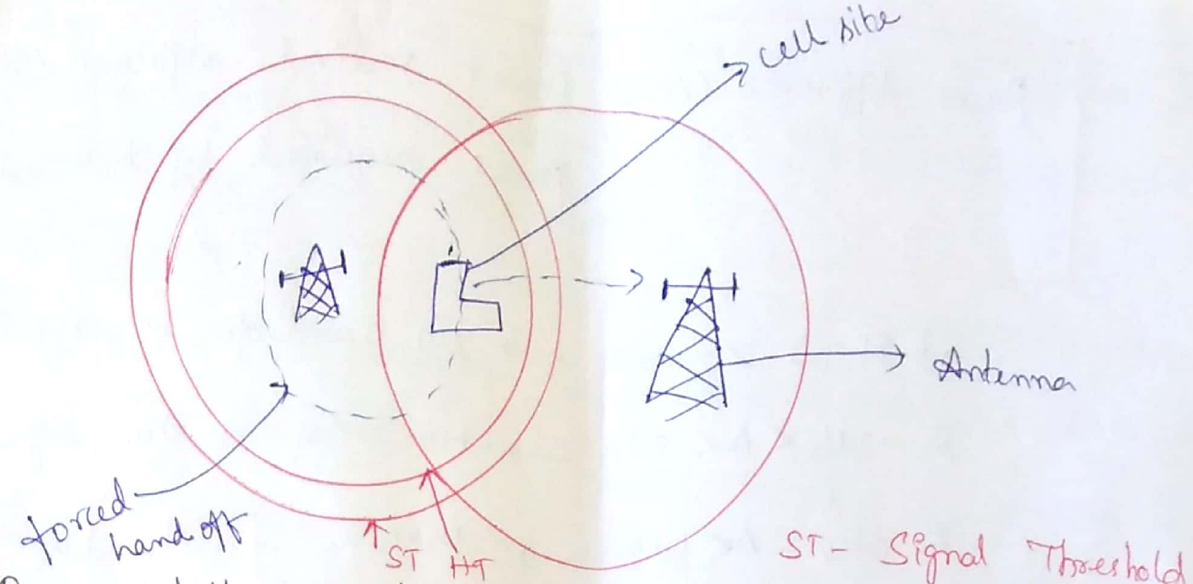
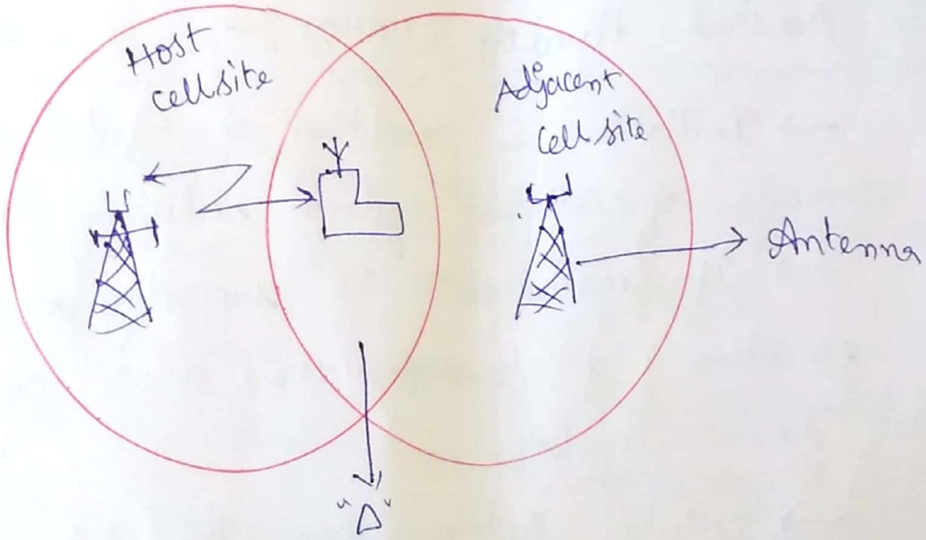


(ii) Power difference hand off :-



→ During a call, if the mobile unit is entering into common coverage area of host and adjacent cellsite then the signal transmitted by mobile unit is received by both cellsites.

→ Based on this, a better algorithm can be desired to execute hand off process by means of power difference.

→ Host cellsite is used to execute various steps of hand off process, it is called as "power difference hand off."

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Power difference (Δ) = Power received adjacent cell site for / Power required by host cell site for

→ i) If Δ < -3dB → No hand off is required

ii) -3dB < Δ < 0dB → Monitoring of the signal strength

iii) 0dB < Δ < 1dB → prepare for hand off

iv) 1dB < Δ < 3dB → hand off must be given

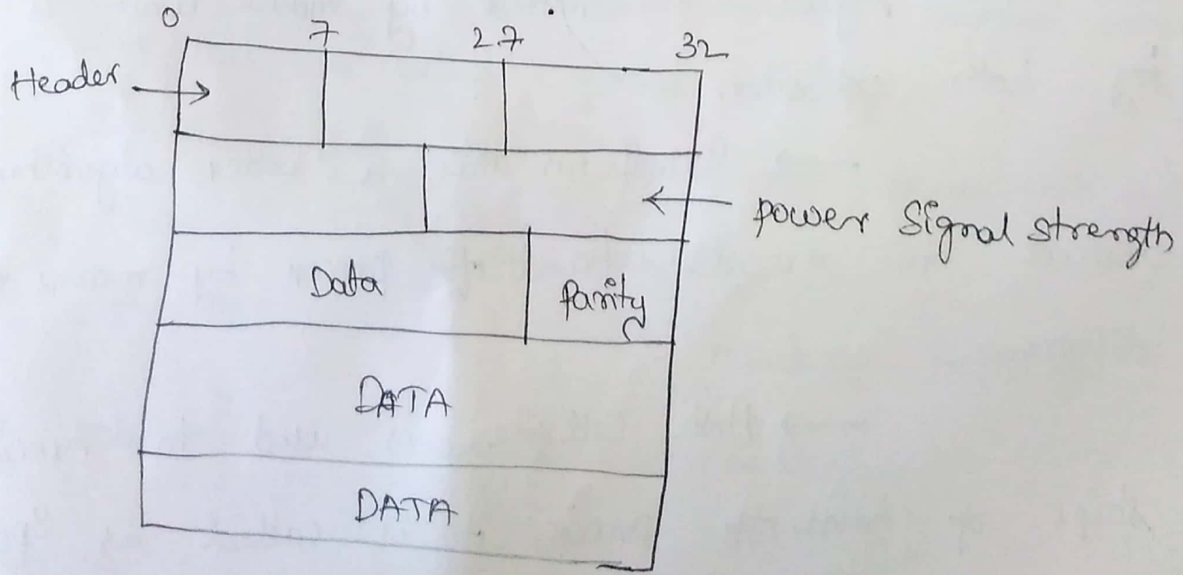
iii) Mobile Assisted Hand off (MAHO) :-

→ Initiation & execution of handoff is carried out by elements of cellular system excluding the mobile unit.

→ If mobile unit is supporting or participating in the execution of handoff then it is considered as Mobile Assisted handoff.

→ Cellular system then the data transmission may follow frame format.

Data frame @ mobile unit



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→ Different fields are present in the frame, in which one field is reserved to accomodate power information by the mobile unit.

→ After receiving this frame MTSO extracts the power (or) signal strength information & maintains a record.

→ Based on the power profile, the process of hand-off is executed by MTSO.

→ As this power information provided by mobile unit, it is called mobile assisted handoff.

(iv) Soft hand off :-

→ Hand off involves change of frequency at mobile unit, if it enters into adjacent cellsite.

→ In CDMA technology, all the mobile units operate with a single carrier frequency.

→ CDMA technology uses a single carrier but different coding schemes.

→ Therefore, change of existing code to a new code at mobile unit is called soft hand off.

v) Inter System hand off :-

→ If a call is initiated by the mobile unit in the last cellsite of CGSA, & if it is entering into a cell site, which belongs to CGSA of other system

→ Then call may be terminated at the boundary.

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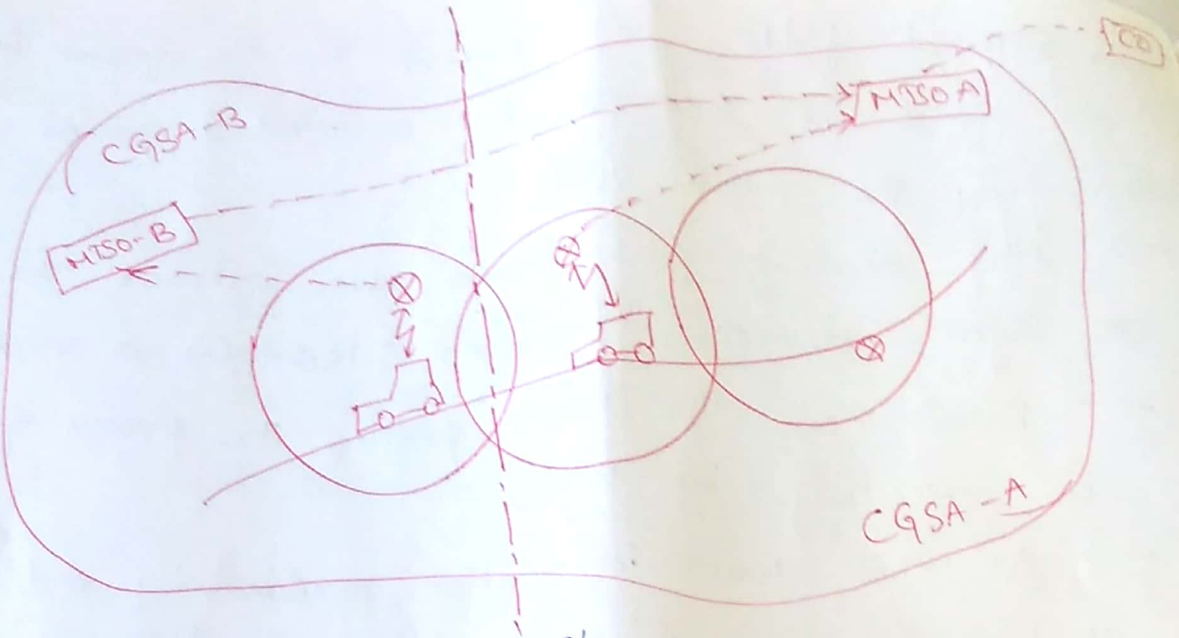

→ If the mobile unit is accepted by the adjacent cell site of other system.

→ Then it is considered as inter system handoff.

→ As communication link must be established between MTSO's of different systems to execute inter system handoff.

Vi, Cell site hand off :-

→ If the mobile unit is moving from one cell site to the other a new voice channel is assigned to that mobile unit by removing the existing channel.

→ Usually handoff is given ~~by~~ to the mobile unit by following the procedure.

→ If the mobile unit is leaving the host cellsite and entering into adjacent cell site if the mobile unit is accepted by the adjacent cell sites with same channel then it is considered as cell site handoff

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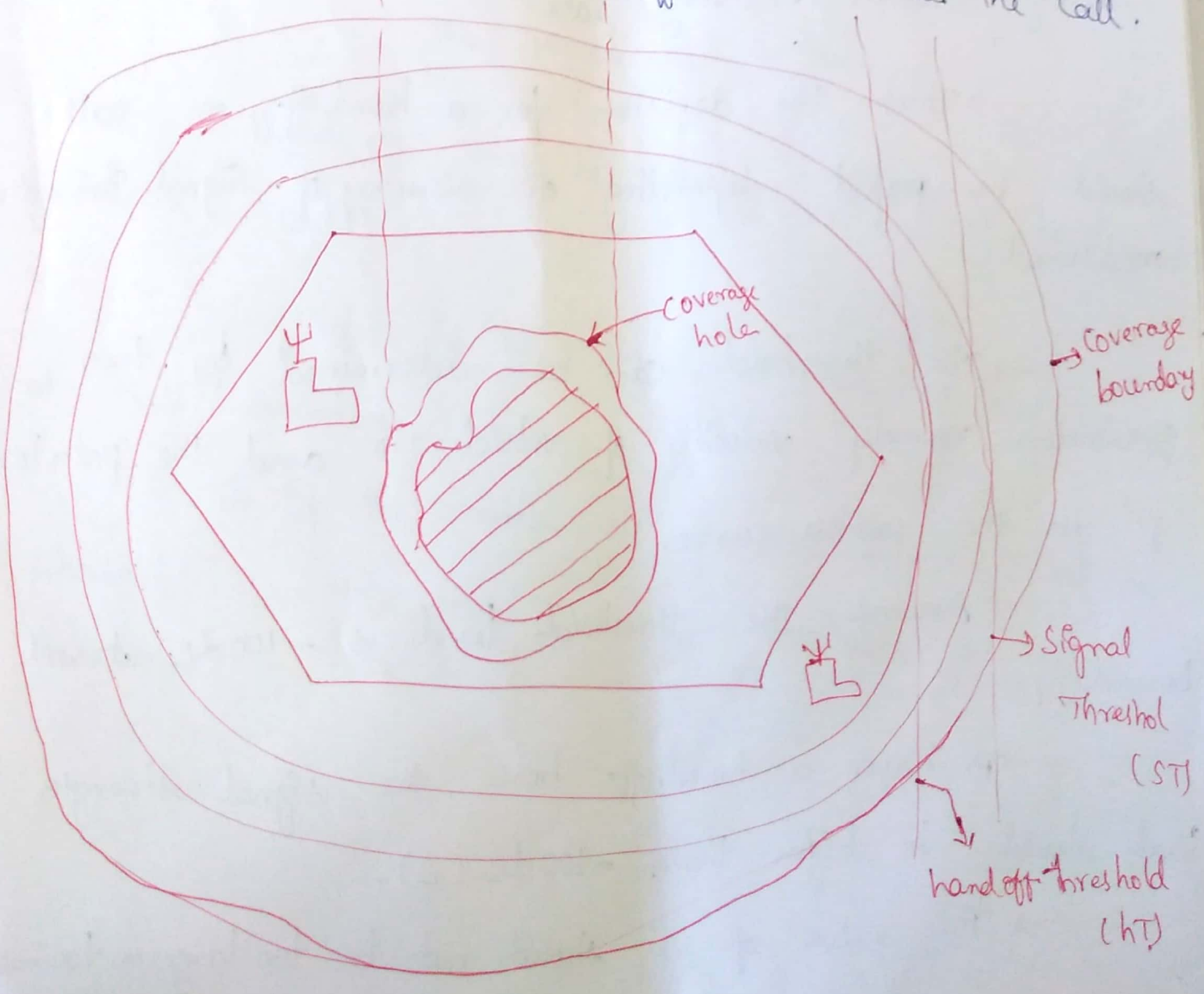
(H)and off Initiation :-

→ In the cell site the signal strength is (c)ontinuously monitored using a reverse voice channel.

→ Depending on the signal strength the decision for hand off is made.

→ whenever this strength is reducing to threshold level, hand off request will be placed.

→ If the signal strength reaches a level that is higher than the threshold level set for minimum voice quality, cell site will request the Switching office (MTSO) for handoff to continue the call.



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→ occurance of hand off either earlier (or) later be determined by intelligence within the call site.

→ If the mobile unit is reaching the handoff threshold (or) coverage hole then the handoff must be initi-

→ Handoff threshold can be determined from signal threshold.

→ Now, we have considered the two points, and the should be avoided.

(i) An unnecessary handoff will be required the handoff decision is very early.

(ii) A failure handoff would result of the handoff decision is very late.

→ Thus, the decision for a handoff on call should be perfect depending on accuracy of signal strength measured.

→ The threshold can be determined by two parameters namely velocity of vehicle 'V' and the path loss 'γ' in the pathloss curve.

→ Assume the threshold level is −100 dB at cell boundary.

→ To have a handoff here the signal strength level should be higher than −100 dB (Δ).

→ The value of 'Δ' should not be too large (or) too small

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→ we can calculate the velocity 'v' of the mobile unit based on the predicted level-crossing rate (LCR), at a -10dB level with respect to the root mean square (rms), level which is at -90 dB.

Thus,

$$V = \begin{cases} \dfrac{\eta \lambda}{\sqrt{2\pi}(0.27)} \; ft/s \\ \eta \lambda \quad mi/h \end{cases} \quad \text{at } -10dB \text{ level}$$

where,

η - is the LCR counting positive slopes

λ - is the wavelength in feet.

→ Hand off may be necessary, but can't be done at following cases.

(i) Mobile is at signal strength hole and not to at cell boundary.

(ii) If the mobile is at cell boundary but no channel in the new cell is available to make hand offs.

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Delaying Hand off :-

When a base station wants to hand over the [call] to the base station of new cell where the subscribers entered the new base station will accept it and takes call control. This smooth hand off is possible only if the new cell is free to take it. If there the call not available then the hand-off will be delayed. This is known as the "delayed handoff."

Advantages of delayed hand offs:-

① If the neighbouring cells are busy delayed handoff helps to continue the call in progress smootly till the new cell gets free.

② In two handoff level algorithm only after the second handoff the call will be dropped. Thus probability of call blocking is very less.

③ This algorithm also makes handoff to take place at correct location.

④ ~~Tha~~ It also eliminates the possible interference.

⑤ It avoids insignificant handoffs.

⑥ It helps in identifying the exact location, where the handoff should occur.

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Two-hand off level algorithm :-

→ The purpose of creating two request handoff level is to provide more opportunity for a succesful hand off.

→ Two level handoff scheme is used to avoid interference in the system.

→ In this hand off scheme the cell is divided into two sub cells.

That is

(i) Underlaid cell

(ii) Overlaid cell.

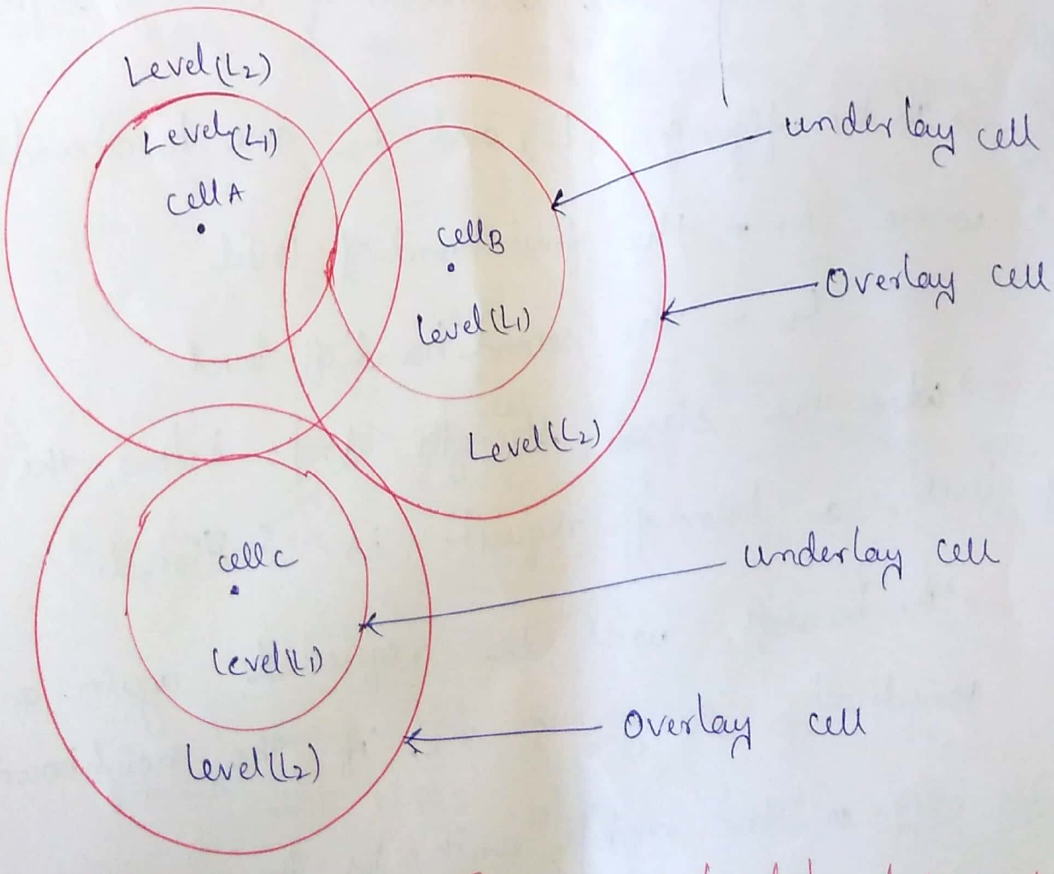

Fig - Two Level hand off scheme using different cells

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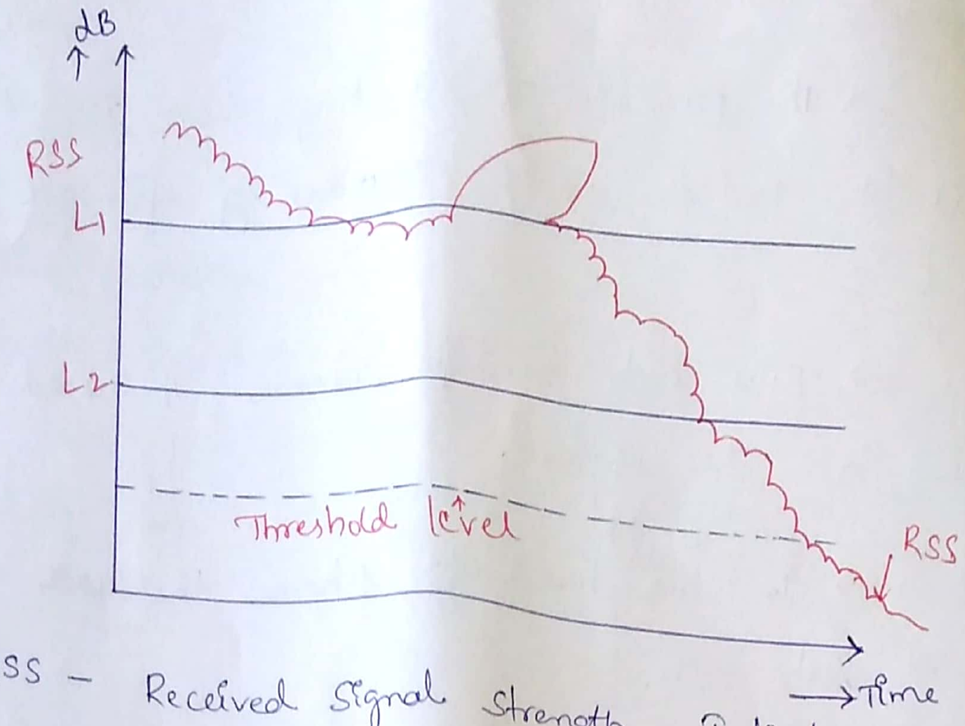

→ RSS – Received Signal Strength Indicator.

→ Received signal strength Indicator is installed at each channel receiver at the cell site.

→ It records the scenario of average signal strength.

→ In the figure L_1 and L_2 are two handoff Levels, where L_1 – the first hand off level

L_2 – the second hand off level.

→ When the signal strength drops below the first hand off level, a handoff request is initiated.

→ The handoff will be requested again and again periodically every 5 sec; if the neighbouring cell is busy or the mobile unit is in a weak location in a cell.

→ At the first handoff level, the handoff takes place

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if the new signal is stronger.

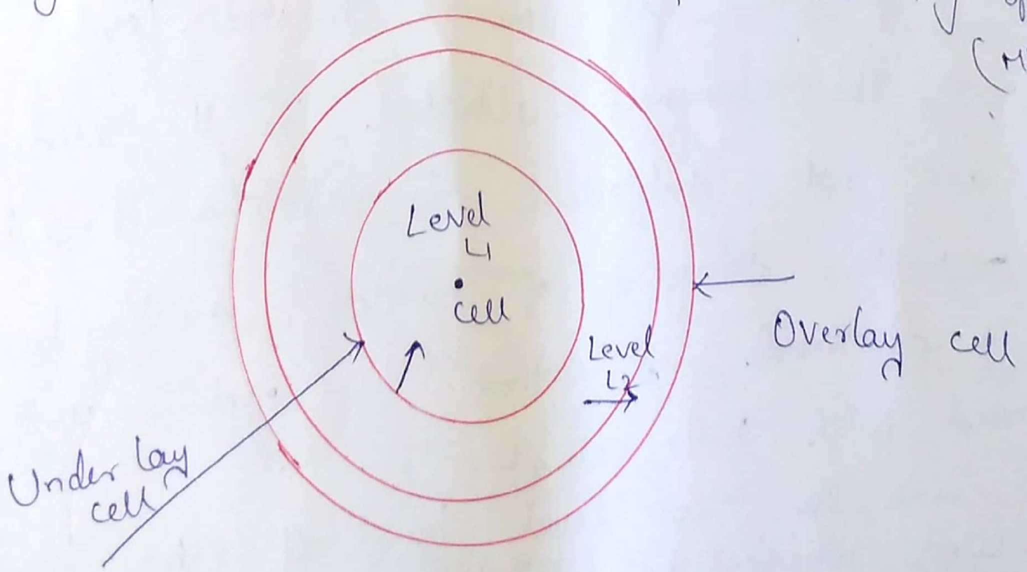
→ If the signal is strong enough at the first handoff level, then hand-off occurs.

→ The call will be handed off, as the signal touches second hand-off level.

→ when the second handoff level is reached, the call will be handed off with no condition.

→ After reaching second handoff level, if no calls are available from neighbouring cells, the call will be continued till the signal strength drops below the threshold level, then call is dropped.

→ The handoff calls are given priority over originating calls at the Mobile Telephone Switching office (MTSO).



Two level handoff scheme

→ The MTSO always handles the handoff call first and the originating calls second.

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→ If the Supervisory Audio Tone (SAT) sent back to the cell site by the mobile unit with in the 5 sec the cell site turns off the transmitter.

→ The inner circle represents the underlaid cell.

→ The outer circle represents the overlaid cell.

→ These two cells are assigned with different threshold levels L_1 and L_2.

→ L_1 is the highest threshold level.

→ L_2 is the lowest threshold level.

→ The channels allocated in the underlaid cell are not subjected to co-channel Interference

→ In delaying of handoff, existing handoff level is decreased so that the mobile unit is continued with host cell site.

→ In two level hand off, two handoff levels are used where level-1 is active if free channels are available in the adjacent cell site.

→ The level-2, is active, if all channels are occupied in the adjacent cell site.

→ If both levels are active, then the repetition rate of handoff request is different

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between level-1 & level-2 and level-2 & Signal threshold.

Controlling & creating hand-off :-

→ Either cell site (or) MTSO can assign new (or) lower threshold levels for hand-offs to control its occurance, this is referred as controlling a hand-off.

→ MTSO can create a hand-off irrespective of the hand-off threshold levels depending on channel availability and requirement.

2m(or 5m)

Advantages of Hand off :-

→ Hand off's are required to reduce the no. of dropped calls and dropped call rate in cellular system.

→ Hand offs are required to continue the call if the mobile unit is moving from one sector to the other sector.

→ If the mobile unit is entering into coverage hole then the call may be continued if hand off is given

→ Hand offs are useful to improve the quality of service during underlay - overlay arrangement at cell site.

→ To ensure the performance and Quality of cellular system, hand off may be given to the stationary mobile units which are not given.

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→ Availability of channels in the cell site be optimized by delayed (or) forced handoff's

Queuing of hand off's :-

→ Thousands of cell sites and a large numb of mobile units are associated to the cellular system.

→ Therefore huge number of hand off requests are placed at MTSO for execution per second.

→ Queuing of handoffs is the most effective technique for execution of handoff based on loading in the adjacent cell site.

→ If hand off requests are reaching to MTSO in large number then Queuing is required.

→ If Queuing is implemented and handoffs are executed properly by the MTSO then no blocking and number of dropped calls in the system.

→ Based on Queuing of handoffs, the following '3' conditions are considered in cellular system.

i) No queuing on Either the originating calls or the hand off calls

→ Non-availability of channels leads to blocking of originating calls.

→ It is given by,

$$B_0 = \frac{A^N}{N!} P(0) \quad \text{——— (1)}$$

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where,

$$P(0)_{oq} = \left[\sum_{n=0}^{N} \frac{A^N}{n!} \right]^{-1} \longrightarrow (2)$$

where A = Total number of calls

N = Number of voice calls

$A = \frac{\lambda_1 + \lambda_2}{\mu}$

here,

$\frac{1}{\mu}$ = Average calling time (sec)

λ_1 = Arrival rate for originating calls

λ_2 = Arrival rate for handoff calls

(ii) Queuing the originating calls but not handoff calls:-

→ Blocking reduces if originated calls are queued

→ The blocking probability for originating calls is given by,

$$B_{oq} = \left[\frac{b_1}{N} \right]^{M_1} P_q(0) \longrightarrow (3)$$

where,

b_1 = Total number of originating calls

$b_1 = \frac{\lambda_1}{\mu}$

$$P_q(0) = \left[N! \sum_{n=0}^{N} \frac{A^N}{n!} + \frac{1-(b_1/N)^{M_1+1}}{1-(b_1/N)} \right]^{-1} \longrightarrow (4)$$

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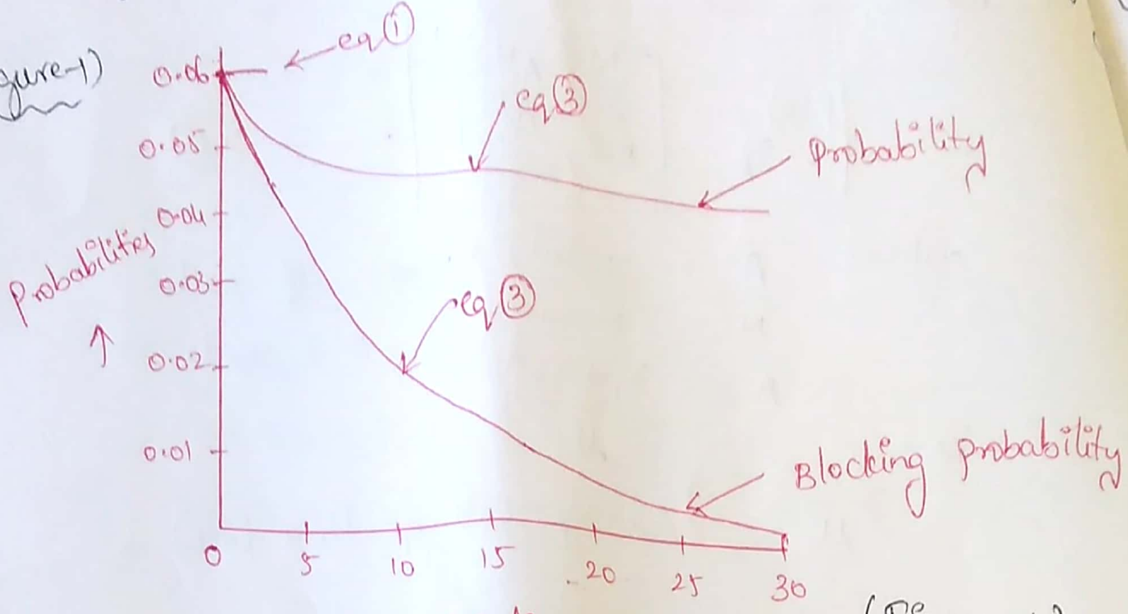
→ Fig-1 shows the plot for blocking probability of Originating Queue

(Figure-1)



(Figure-1)

→ As hand off calls are not Queued.

→ The blocking probability for hand off calls is given by,

$$B_{oh} = \frac{1-(b_1/N)^{M_1+1}}{1-(b_1/N)} P_q(0) \quad \rightarrow ⑤$$

where,

M_1 = Size of queue for originating calls

→ Fig-2 Shows the plot for blocking probability of handoff calls

(Figure-2)

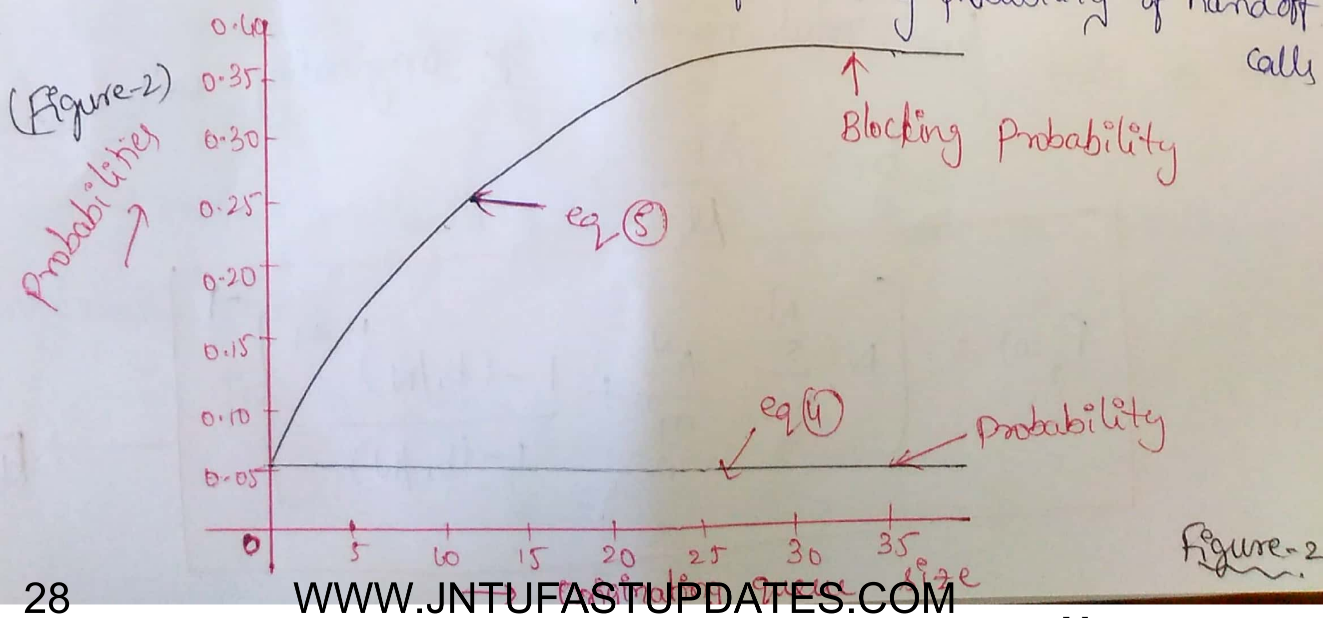


Figure-2

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Queuing the handoff calls but not the originating calls

→ If handoff calls are Queued then the blocking reduces when compared to case (ii).

→ The blocking probability for the handoff calls is given by,

$$B_{hq} = \left[\frac{b_2}{N}\right]^{M_2} P_q(0) \rightarrow (6)$$

where,

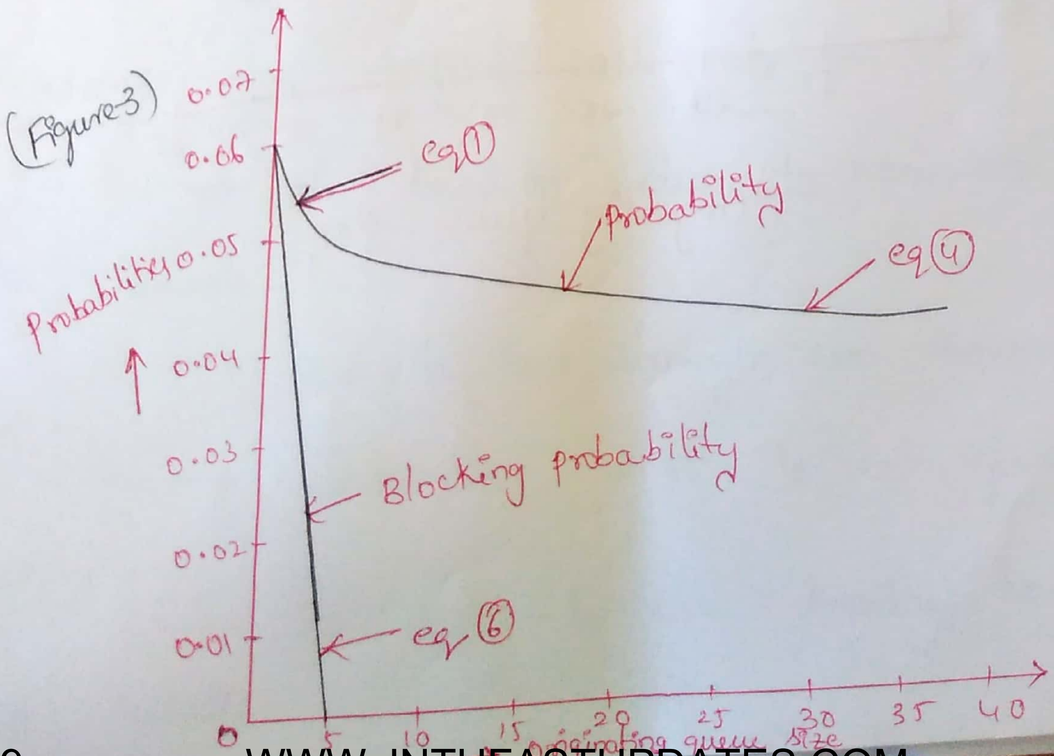
M_2 = Sizes of queue for handoff calls

b_2 = Total number of handoff calls

$$b_2 = \frac{\lambda_2}{\mu}$$

→ Figure-3, shows the plot for blocking probability of hand off calls

(Figure-3)



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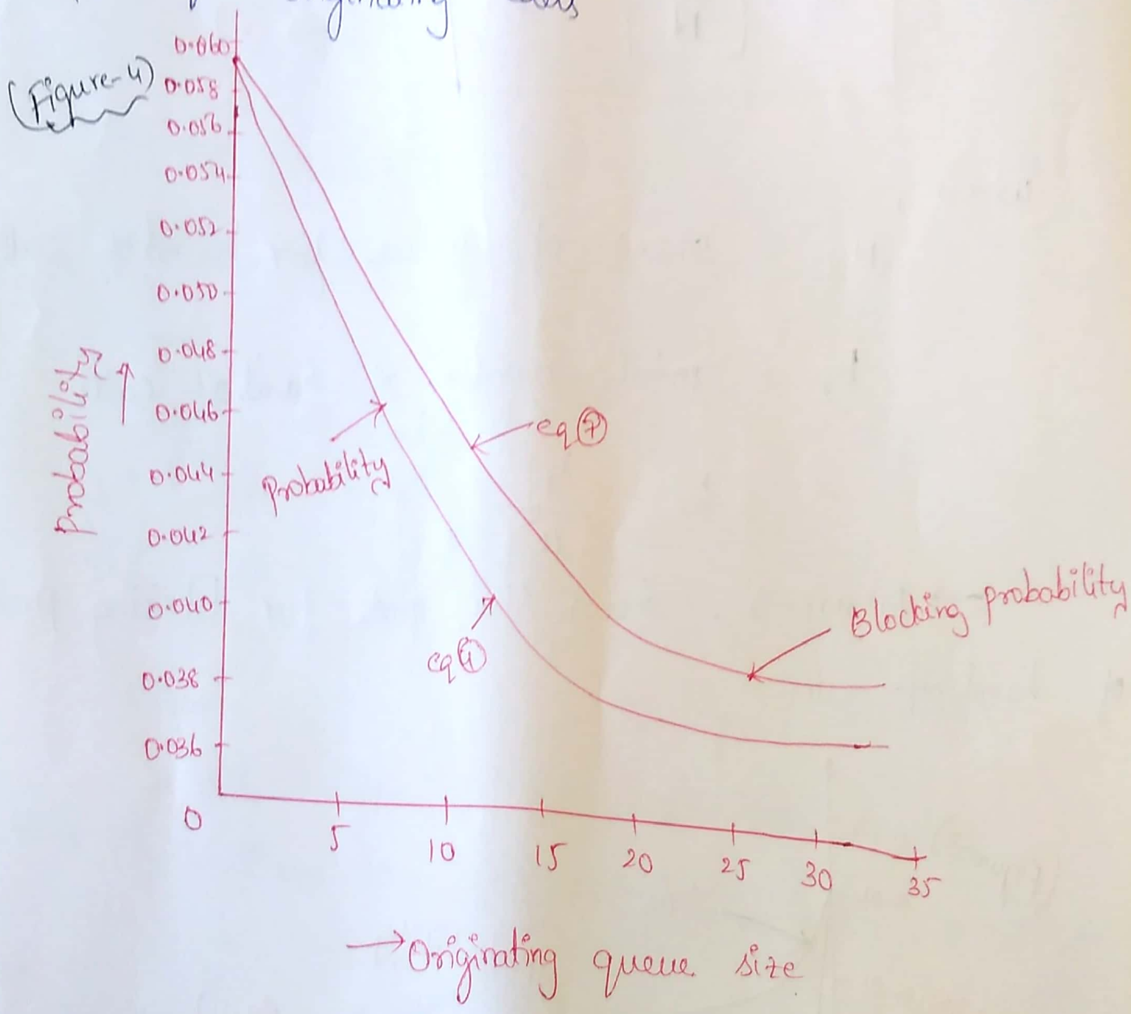
→ The blocking probability for originating calls given by,

$$B_{ho} = \frac{1-(b_2/N)^{M_2+1}}{1-(b_2/N)} P_q(0) \quad \rightarrow (7)$$

→ figure-4 shows the plot for blocking Probability of originating calls

(Figure-4)



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Dropped call rate :-

→ At the end of conversation, if the call is terminated by the user then it is considered as a completed call.

→ During the conversation, if the call is terminated due to network issues (or) other then it is considered as dropped call

→ Termination of call with out users intention (or) knowledge is a dropped call.

→ If Q calls are placed during the busy hour & Q-1 calls are completed then the no. of dropped calls are $Q-(Q-1) = 1$.

→ Therefore the dropped call rate is defi[ned] as the ratio of no. of dropped calls to no. of calls placed & $1/Q$ is the dropped call rate.

Reasons for dropped call rate :-

→ No hand off due to non-availability of voice channels.

→ Due to low strength (or) coverage hole a[rea]

→ Subscriber unit is not functioning properly.

→ The user is not knowing, how to get best results.

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→ Poor voice quality

→ No Queuing of hand-off's at MTSO.

Reduction (or) minimization of dropped call rate:-

→ Hand off must be given at appropriate time to reduce dropped calls.

→ Each cellsite must be provided with desired no. of voice channels for successful handoff.

→ All channels must be good performing to work in the coverage hole areas.

→ If coverage holes are filled by proper repeater mechanism then dropped call rate can be minimized.

→ By proper training (or) Knowledge on equipment usage, dropped calls due to improper use can be minimized.

→ If dropped calls are due to hardware limitations, then the equipment must be replaced (or) repaired.

→ Queuing of handoff request must be done at MTSO to minimize dropped call rate.

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Relationship among capacity, voice quality & dropped call rate :-

→ The relationship between capacity, voice quality, dropped call rate can be expressed using a common C/I parameter.

→ The capacity of the cellular system is denoted by "m".

→ Capacity depends on number of channels in the system.

→ Then it is given by,

$$m = \frac{B_T / B_c}{\sqrt{\frac{2}{3} (C/I)_s}} \longrightarrow eq^n (1)$$

where,

B_T/B_c is total number of voice channels in the system.

$(C/I)_s$ is the required parameter to design a system (or) the required C/I ratio.

→ Eq^n (1) is acquired by taking six co-channel interferes that occur during busy hour that is the equation is acquired in worst case conditions

→ Squaring on both sides of eq^n(1),

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Then we get,

$$m^2 = \left(\frac{(B_T / B_c)^2}{\sqrt{\frac{2}{3} (C/I)_s}} \right)^2$$

$$m^2 = \frac{(B_T / B_c)^2}{\left(\sqrt{2/3 \, (C/I)_s}\right)^2}$$

$$m^2 = \frac{(B_T / B_c)^2}{2/3 \, (C/I)_s}$$

$$2/3 \, (C/I)_s = \frac{(B_T / B_c)^2}{m^2}$$

$$(C/I)_s = \frac{(B_T / B_c)^2}{2/3 \, m^2}$$ → desired C/I ratio

(or)

$$(C/I)_s = \frac{3}{2} \left(\frac{B_T}{B_c}\right)^2 \cdot \frac{1}{m^2}$$

→ The voice quality of the system is dependent on the value of $(C/I)_s$.

→ If $(C/I)_s$ decreases the system capacity increases.

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Controlling a handoff :-

The cell site can assign a low handoff threshold in a cell to keep a mobile unit in a cell longer (or) assign a high handoff threshold level to request a handoff earlier. The MTSO also can control a handoff by making either a handoff earlier (or) later receiving a handoff request from cell site.

Creating a handoff :-

The cell site does not request a handoff but the MTSO finds that some cells are too congested while others are not. Then MTSO request cell sites to create early handoffs for these congested cells.

A cell site has to follow the MTSO's order and increase the handoff threshold to push the mobile units at the new boundary and to handoff earlier.

Thus handoff threshold level in cell site may be high (or) low according to the order to MTSO given to cell sites.

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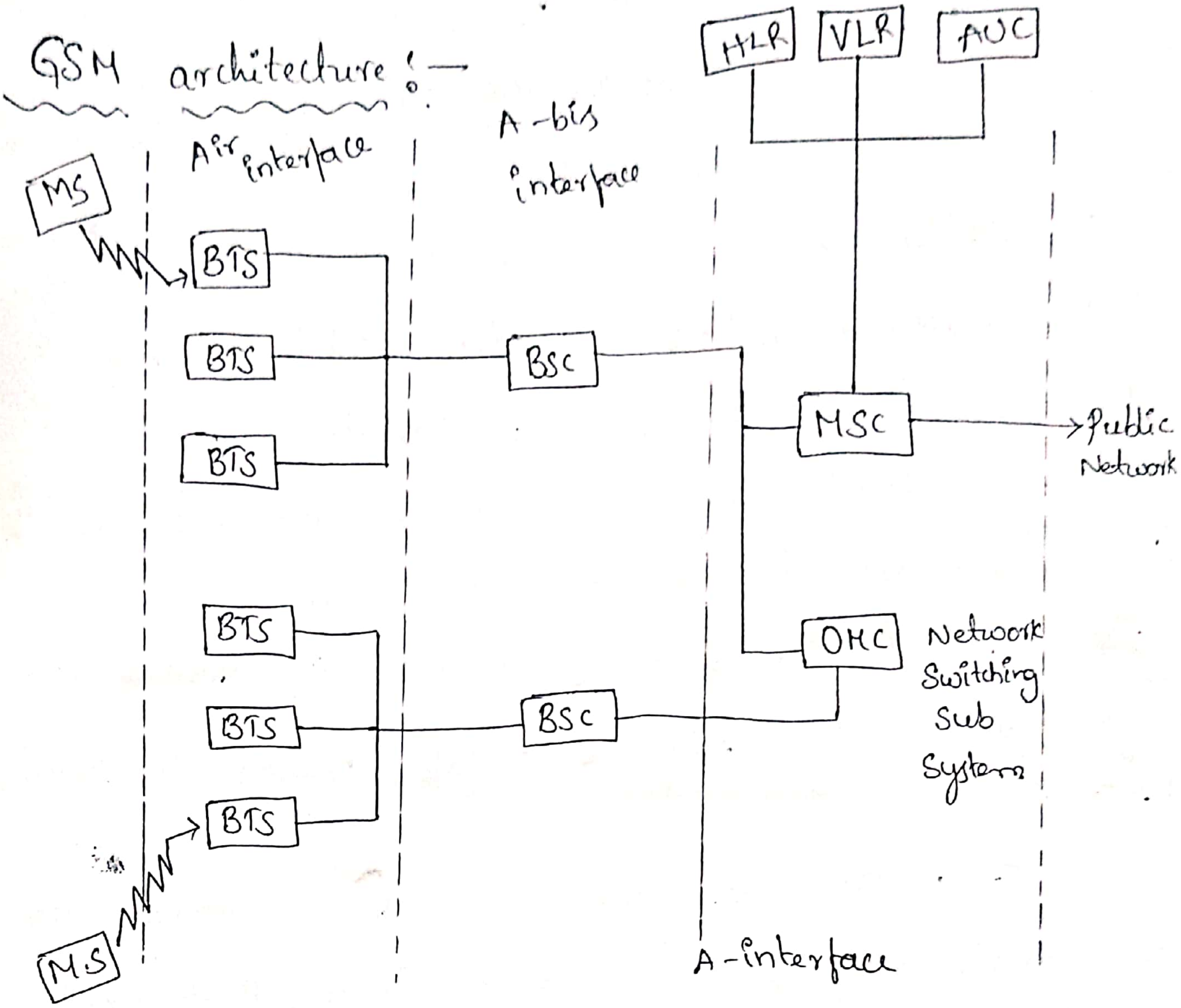
UNIT- VI

Digital Cellular Networks

GSM architecture :-



MS - Mobile station

GSM- Global System for mobile Communications

BTS - Base Transceiver System

BSC - Base Station Controller

MSC - Mobile Switching center

OMC - operation & Maintainence Controller

HLR - Home location register

VLR - Visitor location register

AUC - Authentication Center

→ GSM consists of many subsystems, such

1. Mobile Station (MS)
2. Base Station Sub system (BSS)
3. Network & Switching SubSystem (NSS)
4. Operation Sub System (OSS)

) Mobile Station (MS):—

→ Mobile Station includes mobile equipment (ME) and Subscriber Identity module (SIM).

→ Mobile equipment (ME) does not need to be personally assigned to one Subscriber.

→ Subscriber Identity module (SIM) is a subscriber module which stores all the subscriber related information.

→ when a subscribers SIM is inserted into the mobile equipment of a mobile Station, that mobile-Station belongs to the subscriber and call is delievered to that mobile station.

→ The mobile equipment is not associated with a called number, it is linked to the SIM.

Base station SubSystem :—

→ The Base Station Subsystem connects to the mobile station through a radio interface (or) air interface and also connects to the NSS.

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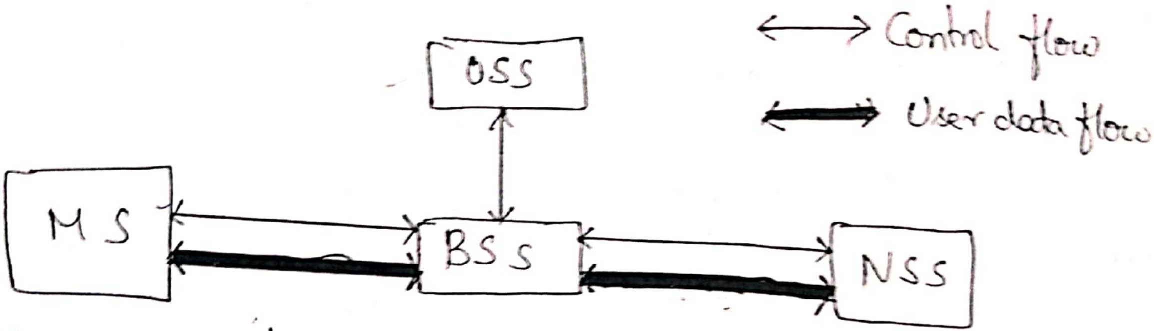
→ The BSS consists of a base transceiver station (BTS) located at the antenna site to the mobile equipment (ME) in an mobile station (MS). ②

→ A Transcoder rate adaption Unit (TRAU) Carries out encoding and speech decoding and rate adaption for transmitting data.

→ As a subpart of the BTS, the TRAU may be sited away from the BTS, usually at the MSC.



External environment of BSS

→ GSM uses the open System inter Connection (OSI).

→ There are three common interfaces based on OSI

(i) Interface between MS & BTS is called "Air interface" (or) Radio interface

(ii) Interface between BTS & BSC is called "A-bis interface"

(iii) Interface between MSC & BSC is called "A-interface"

→ The difference between interface and protocol is interface represents the point of contact between two adjacent

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equipment and a protocal provides information through the interfaces

Network and Switching System :- (NSS)

→ NSS manages the common between GSM users and Telecommunication Users.

→ NSS management consists of MSC.

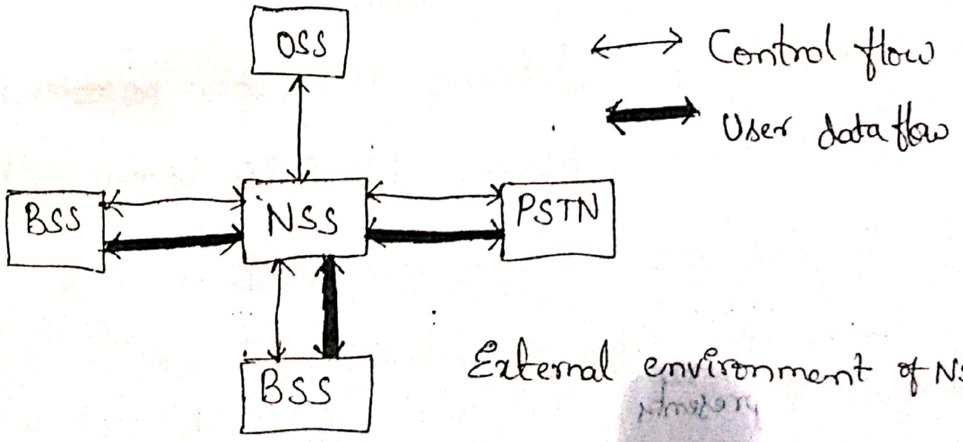
→ MSC which coordinates call setup to and from GSM users.

→ An MSC controls several BSC.

Inter working Function (IWF) :-

→ A gate way for MSC to interface with external Network's for Communication with user outside GSM such as packet - switched public data N/w (Network) (PSPDN) or Circuit - Switched public data Network (CSPDN)

→ The role of the IWF depends on the type of user data and the N/w to which it interfaces.



External environment of NSS

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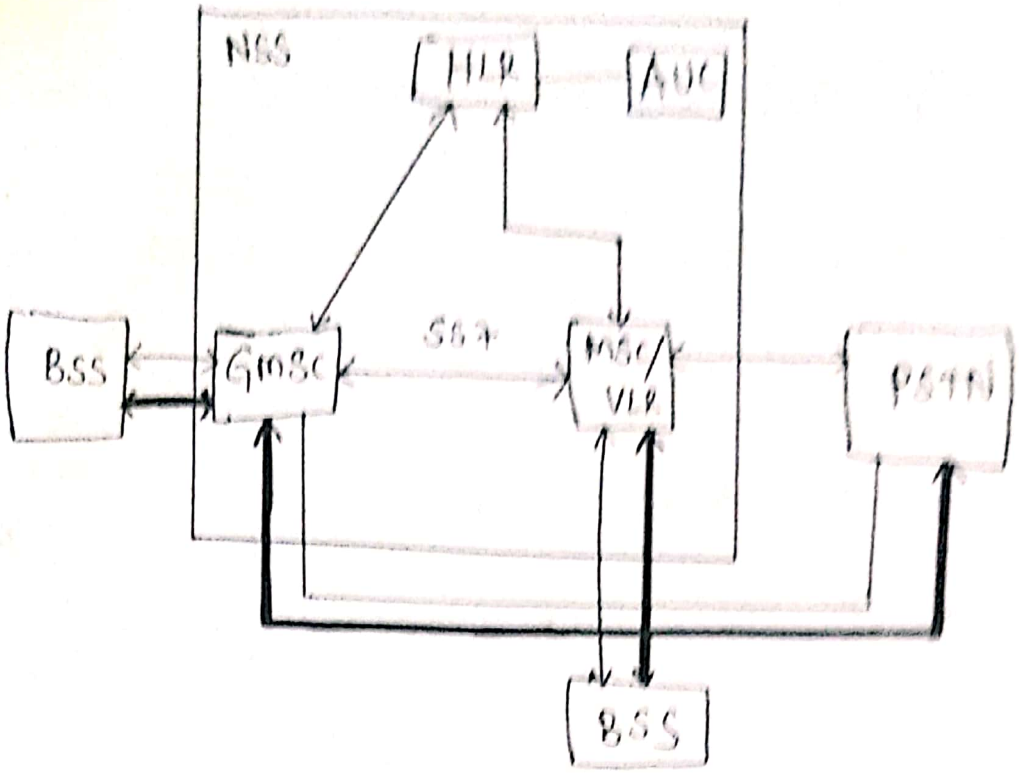

→ It consists of 3 parts

(i) HLR

(ii) VLR

(iii) AUC

Home Location register :-

→ It contains the subscriber information related to subscribers current location.

→ A Subdivision of HLR is the authentication ~~center~~ center.

Authentication center:-

It manages the security data for subscriber authentication. It contains Equipment Identify Register (EIR) which stores the data of mobile equipment (ME).

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Visitor Location register :- (VLR)

→ It contains the information of roaming subscribers.

→ Here, the information is stored temporarily.

The

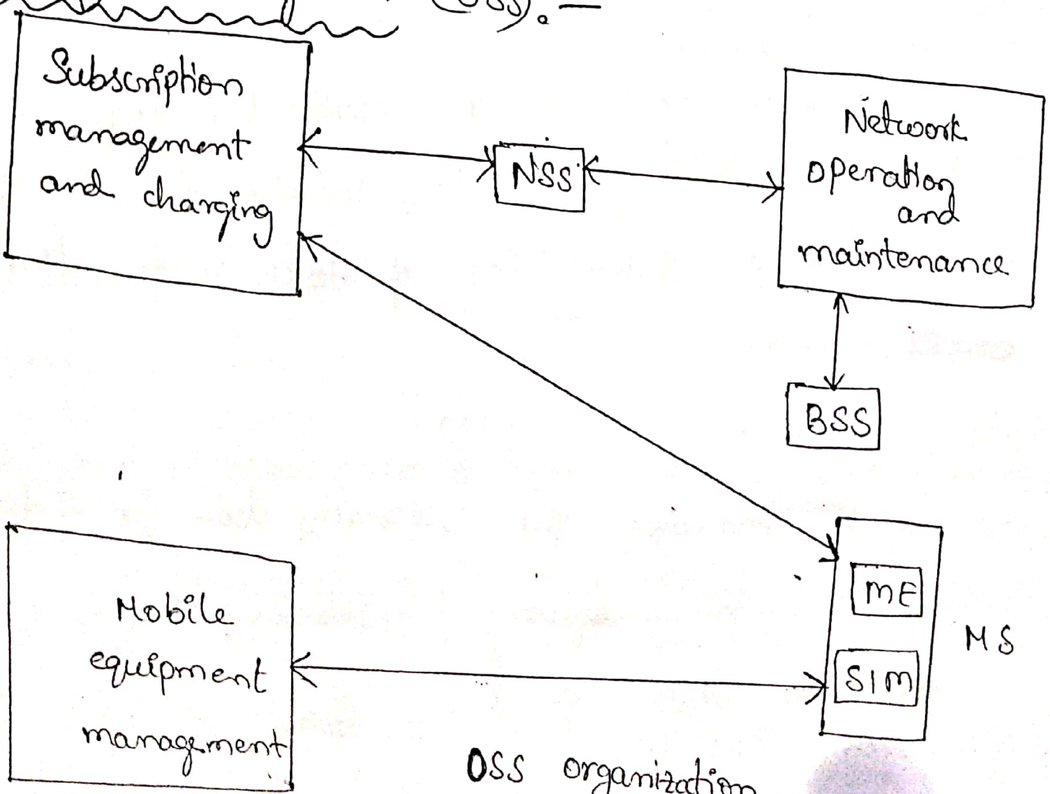
Signaling Transfer point (STP) :-

STP optimizes the cost of the signaling transport among MSC /VLR, GMSC and HLR.

Gateway mobile Switching center :- (GMSC)

The GMSC has an interface with the external Network for gate waying, and the network also operates the full signaling system 7 (SS7) signaling between NSS machies.

Operating Sub System (OSS) :-



OSS organization

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(4)

→ There are 3 areas of OSS.

(i) Network operation and maintance functions

(ii) Subscription management, including charging and billing

(iii) mobile equipment management

→ These tasks require interaction between some (or) all of the infrastructure equipment.

→ OSS is implemented in any existing Network.

Layer modeling (OSI model) :-

The open System Interconnection (OSI) of GSM consists of five layers

(i) Transmission

(ii) Radio resource management (RR)

(iii) Mobility Management (MM)

(iv) Communication Management (CM)

(v) Operation Administration and Maintenance (OAM)

→ The lower layers correspond to short-time-scale functions.

→ The Upper layers correspond to long-time scale functions.

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i) Transmission layer :-

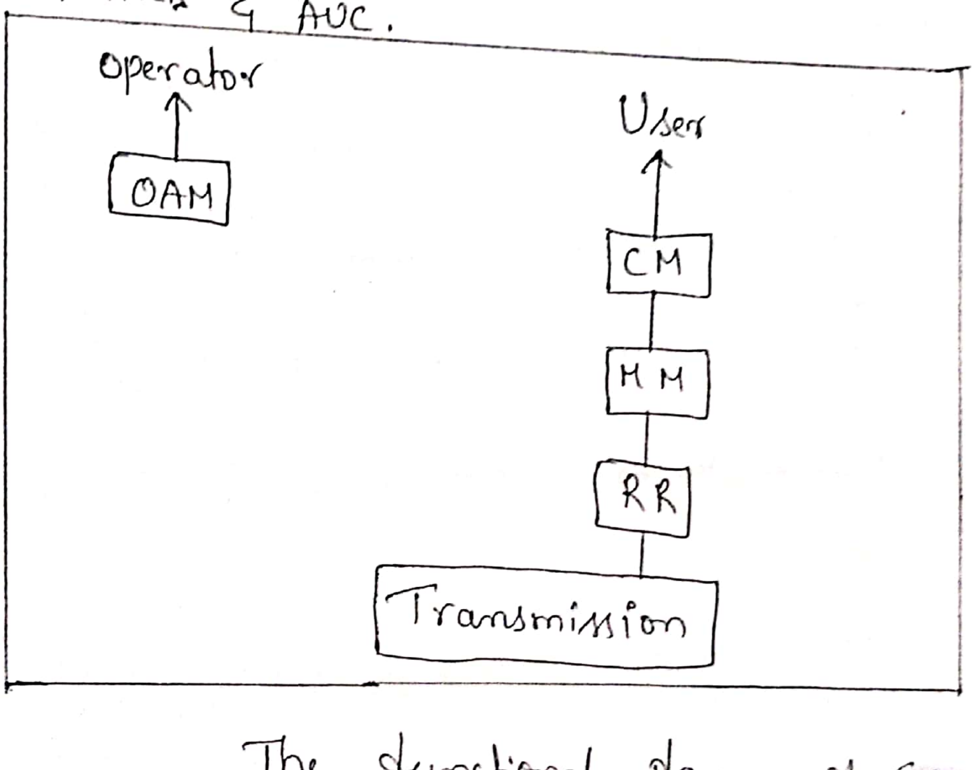
Transmission layer set up a connection between Mobile Station (MS) and Base Transceiver System (BTS).

ii) RR Layer :-

It refers to the protocol for management of the transmission over the radio interface and provides a stable link between mobile station (MS) and Base station Controller (BSC).

iii) MM layer :-

It manages the subscriber's basis which includes location data & manages, authentication activities SIM, HLR & AUC.



The functional planes of GSM

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CM layer :-

The following functions are parts of the CM layer.

a) Call control
b) Supplementary Services Management
c) Short message service (SMS)

a) Call control :-

The CM Layer setup calls, maintains calls, and releases calls.

The CM layer interacts among the MSC/VLR, GMSC, IWF, and HLR for managing circuit-oriented service, including speech and circuit data.

b) Supplementary Services Management :-

It allows users to have some control of their calls in the network, and has specific variations from the basic service.

c) Short Message Service (SMS) :-

→ It is related to point-to-point SMS.

→ A SMS service center (SMS-SC) may connect to several GSM networks.

→ Short message transmission requires setting up

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a signaling connection between the mobile (MS) and mobile switching center (MSC).

→ The two functions of SMS are

(i) mobile - originating short message

(ii) mobile - terminating short message

1) OAM layer:-

→ OSS is an integral part of the OAM layer.

→ All the subsystems, such as BSS and NSS, contribute to the OAM operation and maintenance functions.

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GSM channels :-

GSM channels are of
(i) physical channels
(ii) Logical channels
(iii) Signalling channels

(i) physical channels :-

There are three kinds of physical channels, which are also called as "TRAFFIC CHANNEL" (TCH).

These carry digitally encoded user speech or user data & have identical functions and both the forward & reverse link.

TCH's may be either full rate or half rate.

When transmitted as full-rate, user data is contained within one transmission per frame.

When transmitted as half-rate, user data is mapped onto the same time slot, but is sent in alternate frames.

a) Full rate TCH (or) TCH/F :-

① Full-rate Speech channel (TCH/FS) :-

The full rate speech channel carries user speech which is digitized at a raw data rate of 13 kbps.

The full rate speech channel carries 22.8 kbps

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② Full - rate data channel for 9600 bps (TCH / F9.6):—

The full rate traffic data channel carries raw user data which is sent 9600 bps, additional forward error correction coding applied by the GSM standard, the 9600 bps data is sent at 22.8 kbps.

③ Full rate data channel for 4800 bps (TCH / F4.8):—

This carries user data is sent at 4800 bps additional forward error correction coding applied by the GSM standard, the 4800 bps is sent at 22.8 kbps.

④ Full rate data channel for 2400 bps (TCH / F2.4):—

This carriers user data which is sent at 2400 bps additional forward error correction coding applied by the GSM standard, the 2400 bps is sent at 22.8 kbps.

Half Rate TCH:—

① Half rate Speech channel (TCH / HS):—

The half rate speech channel has been designed to carry digitized speech which is sampled at a rate half, that of the full rate channel, the half-rate speech channel will carry 11.4 kbps.

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② Half rate data channel for 4800bps (TCH/H4.8):-

The H4.8 data channel carries 4800bps, additional forward error correction coding applied by the GSM standard, the 4800bps data is sent at 11.4 kbps.

③ Half rate data channel for 2400bps (TCH/H2.4):-

It carries raw user data, which is sent at 2400 bps, will additional forward error correction coding applied by GSM standard, the 2400 bps data is sent at 11.4 kbps

ii. Logical channels:-

→ These are divided into 3 channels.

→ They are

a) Broadcast channel (BCH)

b) Common Control channel (CCCH)

c) Dedicated Control channel (DCCH)

a) Broad cast channel (BCH):-

The broad cast channel operators on the forward link, and transmitts data only first time slot (TS0).

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→ Unlike TCH's which are duplex, BCH, [illegible] the forward link.

→ BCH provides synchronization for all [illegible] within the cell & is occasionally monitored by mobile[illegible] neighbouring cells.

→ BCH's are of three types, namely

1. Broadcast control channel (BCCH)
2. Frequency correction channel (FCCH)
3. Synchronization channel (SCH)

① Broadcast Control channel (BCCH):—

It is a forward control channel.

It is used to broadcast information such as cell and network identity and operating characteristics of the cell.

This is also broadcasts the list of channels that are currently in use within the cell.

) Frequency correction channel (FCCH):—

The FCCH allows each subscriber unit to synchronize its internal freq standard to the exact frequency of the base station.

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Synchronization channel (SCH):—

It is used to identify the serving base station while allowing each mobile to frame synchronize with the base station.

(b) Common Control Channels (CCCH's):—

CCH consists of three different channels, they are

1. Paging channel (PCH) [Forward link channel]
2. Random Access channel (RACH) [Reverse link channel]
3. Access Grant channel (AGCH) [Forward link channel]

(1) Paging channel (PCH):—

The paging channel provides paging signals from the base station to all mobiles in the cell. The PCH may be used to provide cell broadcast ASCII text messages to all subscribers.

(2) Access Grant channel (AGCH):—

The AGCH is used by the base station to provide forward link communication to the mobile, and carries data which instructs the mobile to operate in a particular physical channel with

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a particular dedicated control channel.

3) Random Access channel (RACH):—

This is a reverse link channel used by a subscriber unit to acknowledge page from the base and is also used by mobiles to originate a call.

c) Dedicated Control channels (DCCHs):—

In this there are three types of dedicated control channels which are bidirectional & have the same format & function on both forward & reverse link.

The three types are

1. Stand-alone dedicated control channel (SDCCHs)
2. Slow Associated control channel (SACCH)
3. fast Associated control channel (FACCH)

1. Stand-alone Dedicated control channel (SDCCHs):—

This carries signalling data following the connection of the mobile with the base station, and just before a TCH assignment is issued by the base station.

The SDCCH ensures that the mobile station and base station remain connected while the base station & MSC verify the subscriber unit & allocate resources for the mobile. This is used to send authentication

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nd alert messages.

Slow - Associated control channel (SACCH):-

This is always associated with a traffic channel or a SDCCH & maps onto the same physical channel. It is used to send slow but regularly changing control information to the mobile, such as transmit power level instructions, & specific timing advance instructions for each user.

③ Fast - Associated control channels (FACCH):-

The FACCH carries urgent messages and contains essentially the same type of information as the SDCCH.

A FACCH is assigned whenever a SDCCH has not been dedicated for a particular user & there is an urgent message such as a hand off request.

ii) Signalling channels:-

All the signaling channels have chosen one of the physical channels, and the logical channels names are based on their logical functions.

———— o ————

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Multiple Access Scheme:-

→ Generally GSM is a combination of FDMA and TDMA.

→ The total number of channels in FDMA is 124, and each channel is 200 kHz.

→ Both the 935 - 960 MHz uplink and 890 - 915 MHz downlink have been allocated 25 MHz for a total 50 MHz.

→ If the TDMA is used within 200 kHz channel, 8 time slots are required to form a frame.

→ Frame duration is 4.615 ms & the time slot burst period is 0.577 ms.

→ The downlink is 1805 - 1880 MHz & the uplink is 1700 - 1785 MHz.

→ The numbering of the uplink slots is derived from the downlink slots by a delay of 3 time slots.

→ This allows the slots of one channel to bear the same time slot number in both directions.

Frequency Hopping:-

→ GSM has a slow frequency hoping radio interface. The slow hopping is defined in bits per hop.

→ The slow hopping is 217 hops/second.

Different types of time slots:-

→ Each cell provides a reference clock from which the time slots are defined. Each time slot is given a number (TN) which is known by the base station and the mobile station.

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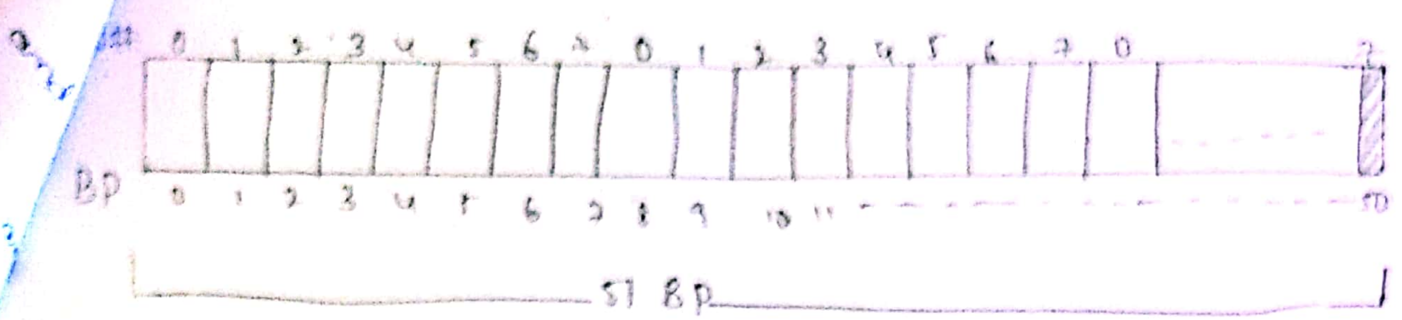

Bursts & training Sequences:-

→ In TDMA, the signaling transmitts in bursts. The time interval of the burst brings the amplitude of a transmitted signal up from a starting value of 0 to its normal value.

→ There are tail bits and training sequence bits within a burst.

→ The tail bits are three 0 bits added at the beginning and at the end of each burst which provide the guard time.

→ The training sequence bits are inserted in the middle of time slot sometimes called a midamble,

→ There are several kinds of bursts

1. The normal burst used in TCH:

Tail	Information	Flag	Training sequence	Flag	Information	Tail
3	57	1	26	1	57	3

The 1-bit binary information indicating data or signalling is called "Stealing Flag"

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i) The access burst used on the RACH in the uplink direction flag

Tail	Training sequence		Information	Tail
7	41	1	35	3

i) The F & S bursts. The F burst is used on the frequency correction channel (FCCH) has the simplest format. All of the 148 bits are zero, producing a pure sinewave. Five S bursts in each 51×8 BP cycle are used on the SCH.

→ One S burst is shown as

Tail	Information	Flag	Training sequence	Flag	Information	Tail
3	38	1	64	1	38	3

GSM's strengths:— GSM is the first to apply the TDMA scheme developed for mobile radio system. It has several distinguishing features

1. Roaming in European countries
2. Connection to ISDN through RA box
3. Use of SIM cards
4. Control of transmission layer
5. Frequency hoping
6. Discontinuous transmission
7. Mobile - Assisted handover.

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Time division Multiple Access (TDMA):-

(or)

North American TDMA:- TDMA architecture

→ The NA-TDMA architecture is similar to GSM architecture

→ The only difference is that in NA-TDMA, there is only one common interface, which is the radio interface.

→ The NA-TDMA uses the intelligent network.

→ All the components such as HLR, VLR, AUC and EIR are the same as used in GSM.

→ In developing the NA-TDMA system, there were two phases.

First phase:-

TO commonly share the 21 setup channels, ~~that~~ which are used for the analog system. The first-phase system is only for voice transmission.

Both modes, AMPS and digital, are built in the same unit.

The handoff procedure has to take care of the following features

1. AMPS cell to AMPS cell
2. TDMA cell to TDMA cell
3. AMPS cell to TDMA cell
4. TDMA cell to AMPS cell.

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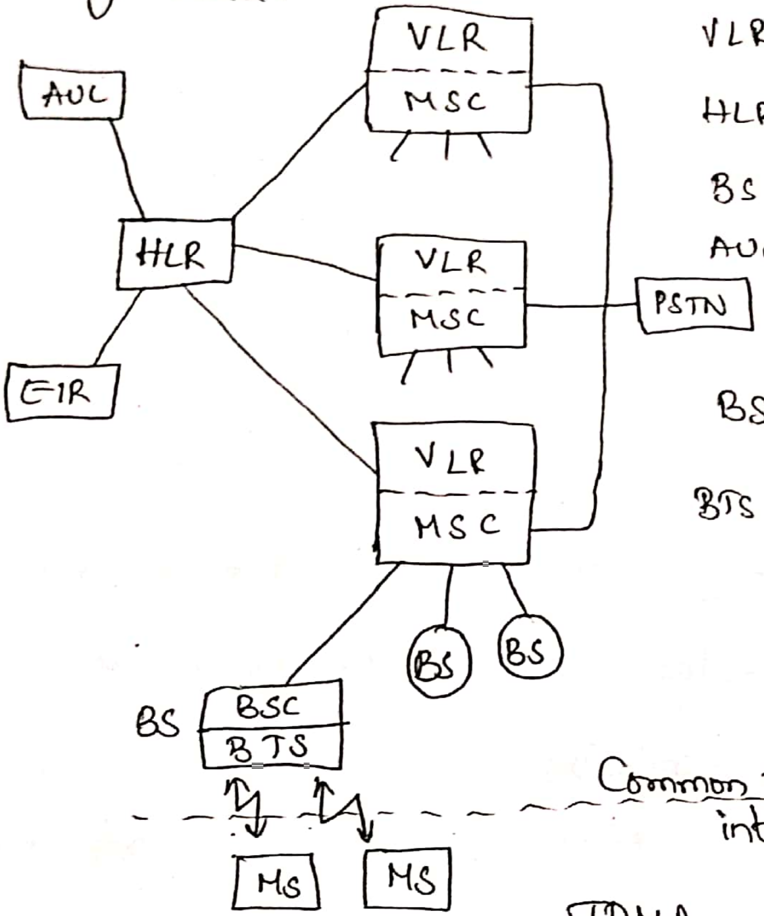
Second phase :-

→ Generate new digital set-up channels (that were in the voice band) to access to TDMA voice channels so that a digital stand-alone unit can be provided.

→ Specify a data-service signal protocol for transmitting data.



VLR – Visitor location registration

HLR – Home location registration

BS – Base station

AUC – Authentication center

EIR – Equipment Identity register

BSC – Base station Controller

BTS – Base transceiver Station

TDMA architecture

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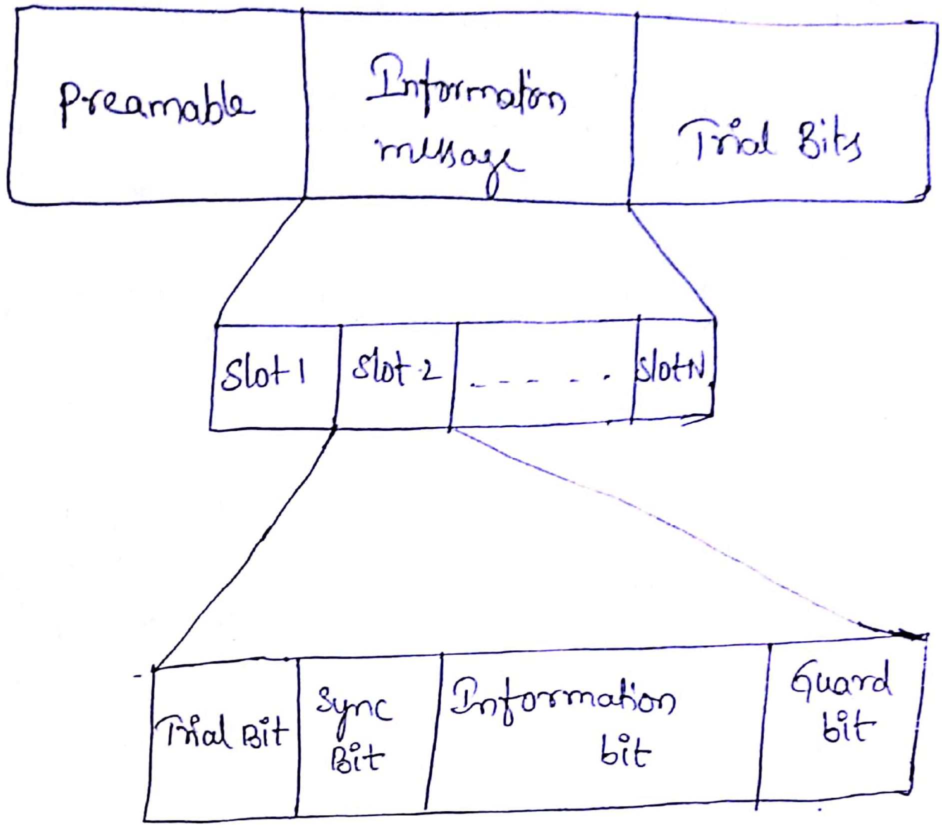
(12)

TDMA Structure :-



TDMA frame Structure

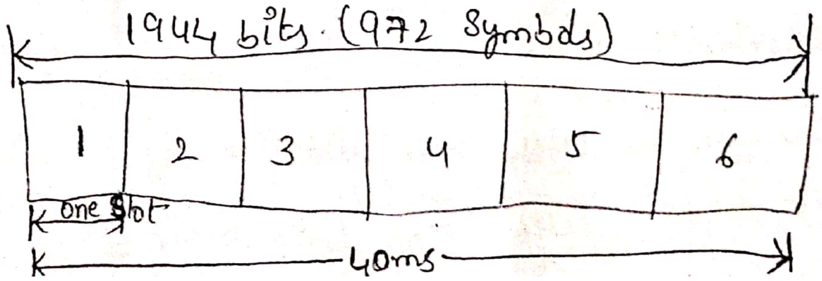
→ In NA-TDMA, the set-up channels are analog channels shared with the AMPS system.

→ One digital channel contains 25 frames per second.

→ Each frame is 40-ms long and has 6 time slots.

→ Each time slot is 6.66 ms long.

→ One frame contains 1944 bits (972 symbols).



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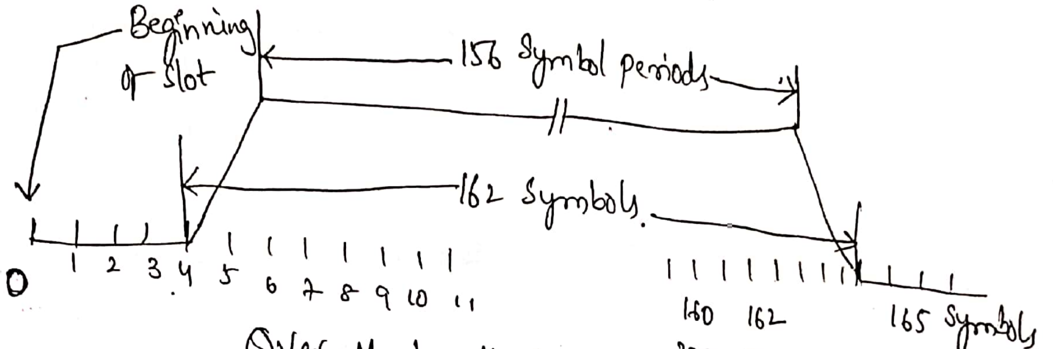
→ Each slot contains 324 bits (162 symbols) and the duration between bits is 20.57 us.

→ One radio channel is transmitted at 48.6 kbps but only 24,000 symbols per second over the radio path.

→ Each frame consists of 6 time slots.

→ The maximum effect on the signal for a forward time slot is one-half full symbol period and for a reverse time slot is 6 symbol periods.



Overall length in each slot

→ Preamable contains the address & synchronization information that both base station and subscriber use to identify each other.

Frame length:-

→ There are two frame lengths, fullrate and halfrate. Each full rate traffic channel shall use two equally spaced time slots of the frame. The overall length in each slot.

Channel 1 uses time slots 1 and 4.

Channel 2 uses time slots 2 and 5.

Channel 3 uses time slots 3 and 6.

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→ Each half rate traffic channel shall use one time slot of the frame. (2)

Channel 1 uses time slot 1

channel 2 uses time slot 2

channel 3 uses time slot 3

channel 4 uses time slot 4

channel 5 uses time slot 5

channel 6 uses time slot 6

Frame offset :-

→At the mobile station, the offset between the reverse and forward frame timing is

Forward frame = reverse frame + (1 time slot + 44 symbols)

= reverse frame + 206 Symbols.

→The time slot (TS) 1 of frame N (in forward link) occurs 206 Symbol periods after TS 1 of frame N in the reverse link.

Modulation Timing :-

Modulation Timing with in a forward time slot :-

The first modulated symbol used by the mobile unit shall have maximum effect on the signal (156 Symbols) transmitted from the base antenna, one-half symbol (1 bit) period after beginning the time slot.

Modulation Timing with in a reverse time slot :-

The first modulated Symbol has a maximum effect

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on the signal transmitted at the mobile unit symbol periods after the beginning of the reverse-time

NA-TDMA Channels:-

In NA-TDMA there are no common channels such as those used in GSM. The digital call set-up uses the 21-setup channels which are shared with the analog system.

Fast associated control channel:- (FACCH)

FACCH is a blank and burst channel equivalent to a signaling channel for the transmission of control and supervision messages between the base station and the mobile station. It consists of 260 bits. mostly FACCH is used for handoff messages.

Slot associated control channel (SACCH):-

SACCH is a signaling channel including twelve code bits present in every time slot transmitted over the traffic channel whether these contain voice (or) FACCH information.

Mobile-assisted handoffs:-

The mobile station performs signal quality measurements on two types of channels:

1) Measure the RSSI (Received Signal Strength Indicator) and the BER (Bit error rate) information

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of the current forward traffic channel during a call.

2). Measures the RSSI of any RF channel which is identified from the measurement order message from the base station.

→ MAHO consists of three messages

(i) Start Measurement Order

(ii) Stop Measurement order

(iii) Channel quality message.

Signalling format and Message structure in TDMA :-

Signalling format in different channels :-

A reverse digital traffic channel (RDTC) is used to transport user information and signalling.

A forward digital traffic channel (FDTC) has same format as the RTDC (reverse digital traffic channel).

Two control channels are used : the FACCH is a blank and borst channel, the SACCH is a continuous channel, and interleaving is on the SACCH.

The signalling formats of these two channels are shown below.

FACCH :-

Continuation flag	Contents	Error detection
1 bit	48 bits	16 bits
Signalling word header	message	CRC

0 - First word
1 - Subsequence word

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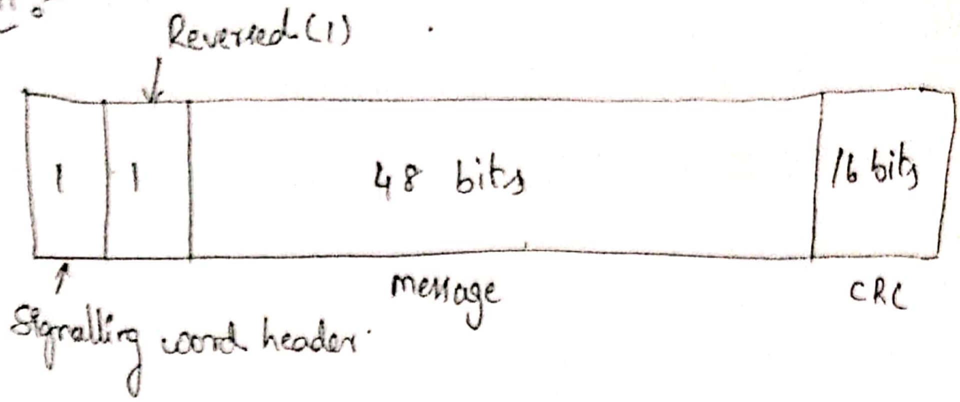
SACCH :-



Signalling formats of FACCH & SACCH

Message structure :-

All messages contain

1. An application message header
2. Mandatory fixed parameters
3. Mandatory Variable parameters
4. Remaining length
5. Optional Variable parameters

purpose ↓ which protocal ↓

Message type (8 bits)	Protocal Discriminator (2 bits)	Mandatory fixed Parameters	Mandatory Variable parameters	Remaining length 6 bits	optinum Variable Parameters

Hand off action :-

when a handoff order is received, the mobile-Station is at high state and stays at that state.

Hand off to a digital traffic channel is described as follows :

① Turn on signaling tone for 50 ms, turn off signaling tone, turn off transmitter which was operating on the old frequency.

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② Adjust power, tune to new channel, set stored (15)
vcc field of the received message.

③ Set the transmitter and receiver to digital mode set the transmitt and receive rate based on the message type field

④ Set time slot based on the message-type field

⑤ Set the time alignment offset to the value basec on the field.

⑥ Once the transmitter is synchronized, enter the conversion task to the digital traffic channel.

Features of TDMA :-

→ TDMA shares a single carrier frequency with several users, where each other makes use of non-overlapping time slots.

→ The number of time slots per frame depends on several factors like modulation Techniques, available Bandwidth etc.

→ Data transmission for TDMA System is not continuous, but occurs in bursts.

→ This results in ~~loss~~ low battery consumption, since subscriber transmitter can be turned off when not in use.

→ TDMA uses different time slots for transmission and reception, thus duplexes are not required.

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→ Adaptive equalization is usually necessary in systems, since the transmission rates are generally very as compared to FDMA channels.

→ In TDMA, guard time should be minimised

→ High Synchronization overhead is required in TDMA systems because of burst transmissions.

→ TDMA transmissions are slotted, and this requires the receivers to be synchronized for each data burst.

→ TDMA has an advantage in that it is possible to allocate different numbers of time slots per frame to different users.

→ Thus Bandwidth can be supplied on demand to different users by concatenating or reassigning time slots based on priority.

Efficiency of TDMA:—

→ It is a measure of the percentage of transmitted data that contains information as opposed to providing overhead for the access scheme.

→ The frame efficiency "η_f" is the percentage of bits per frame which contain transmitted data.

→ The transmitted data may include source and channel coding bits, so the raw end-user efficiency of a system is generally less than "η_f".

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→ The frame efficiency can be calculated as (16) follows

$$B_{OH} = N_r b_r + N_t b_p + N_t b_g + N_r b_g$$

where,

N_r = no. of reference bursts per frame

N_t = no. of traffic bursts per frame

b_r = no. of overhead bits per reference burst

b_p = no. of overhead bits per preamble in each slot

b_g = no. of equivalent bits in each guard time interval

→ The total no. of bits per frame

$$b_T = T_f R \quad (\cdot b_T = T_f R)$$

T_f = frame duration

R = Channel bit rate

→ The frame efficiency η_f is

$$\eta_f = \left(1 - \frac{b_{OH}}{b_T}\right) \times 100\%$$

Number of channels in TDMA System:—

→ The number of TDMA channel slots =

No. of TDMA slots / channel × No. of channel available

i.e., $N = \frac{m(B_{tot} - 2B_{guard})}{B_c}$

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where,

m = maximum no. of TDMA users supported on a radio channel

Examples:-

① Consider Global system for mobile, which is a TDMA/FDD system that uses 25MHz for the forward link, which is broken into radio channels of 200kHz. If 8 speech channels are supported on a single radio channel, and if no guardband is assumed, find the number of simultaneous users that can be accomodated in GSM.

Sol The number of simultaneous users that can be accomodated in GSM is given as

$$N = \frac{25MHz}{(200kHz)/8} = 1000$$

Thus GSM can accomodate 1000 simultaneous users.

Example ② If GSM uses a frame structure where each frame consists of eight time slots, and each time slot contains 156.25 bits, and data is transmitted at 270.833 Kbps in the channel, find

a) The time duration of a bit

b) The time duration of a slot

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c) The time duration of a frame

d) how long must a user occupying a single time slot wait between two successive transmissions.

Sol

a) The time duration of a bit,

$$T_b = \frac{1}{270.833\ kbps} = 3.692\ \mu sec$$

b) The time duration of a slot,

$$T_{slot} = 156.25 \times T_b$$

$$= 156.25 \times 3.692\ \mu sec = 0.577\ ms$$

c) The time duration of a frame,

$$T_f = 8 \times T_{slot}$$

$$= 8 \times 0.577\ ms$$

$$T_f = 4.615\ ms$$

d) A user has to wait 4.615 ms, the arrival time of a new frame, for its next transmission.

Example (3) If a normal GSM time slot consists of six trailing bits 8.25 guard bits, 26 training bits, and two traffic burst of 58 bits of data, find the frame efficiency.

Sol^n → A time slot has

$$6 + 8.25 + 26 + 2(58) = 156.25\ bits$$

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→ A frame has, $8 \times 156.25 = 1250$ bits / frame

→ The number of overhead bits per frame is given by,

$$b_{OH} = 8(6) + 8(8.25) + 8(26)$$

$$= 322$$

$$b_{OH} = 322 \text{ bits}$$

→ Thus, the frame efficiency,

$$\eta_f = \left[1 - \frac{322}{1250}\right] \times 100$$

$$\boxed{\eta_f = 74.24\%}$$

TDMA advantages & Disadvantages:–

Advantages:–

1. Better suited for digital
2. Gets higher capacity

Disadvantage:–

Strict synchronization & guard time needed

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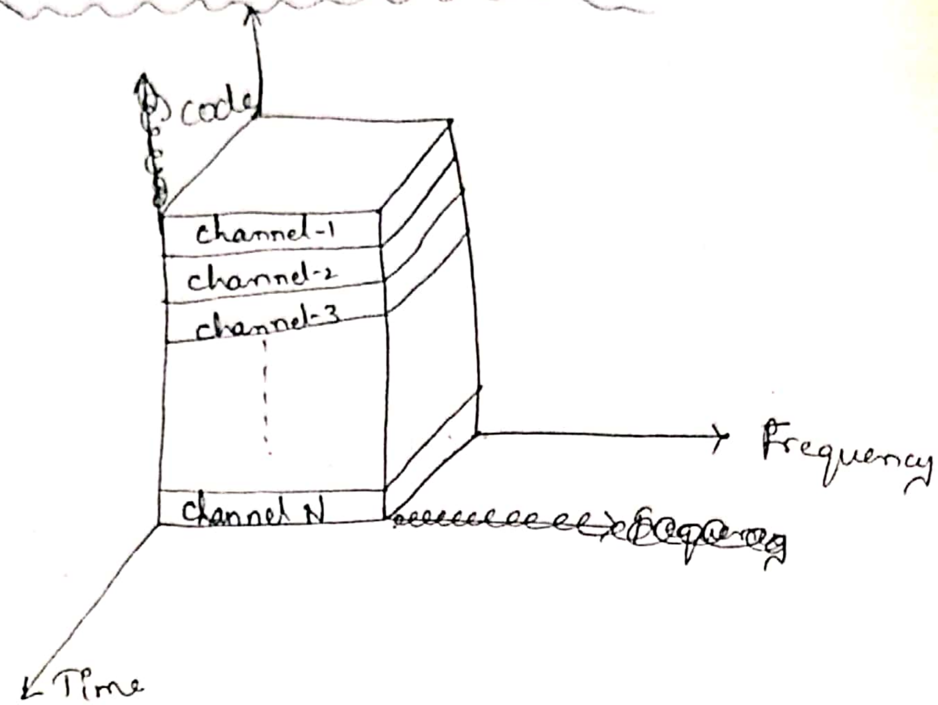
Code Division Multiple Access (CDMA) :—



→ In CDMA System, the narrowband message signal is multiplied by a very large signal called spreading signal.

→ The spreading signal is a pseudo noise code sequence that has a orders of magnitudes greater than the data rate of the message.

→ All users in a CDMA System, use the same Carrier frequency and may transmitt simultaneously

→ For detection of message signal it is essential that receiver must know the code word used by the Transmitter.

→ Each user operates independently without the knowledge of other users.

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→ CDMA gives good protection against Interference.

→ CDMA receiver has to know the background noise composed of other signals due to which designing of receiver is complex.

CDMA forwards: Channels :-

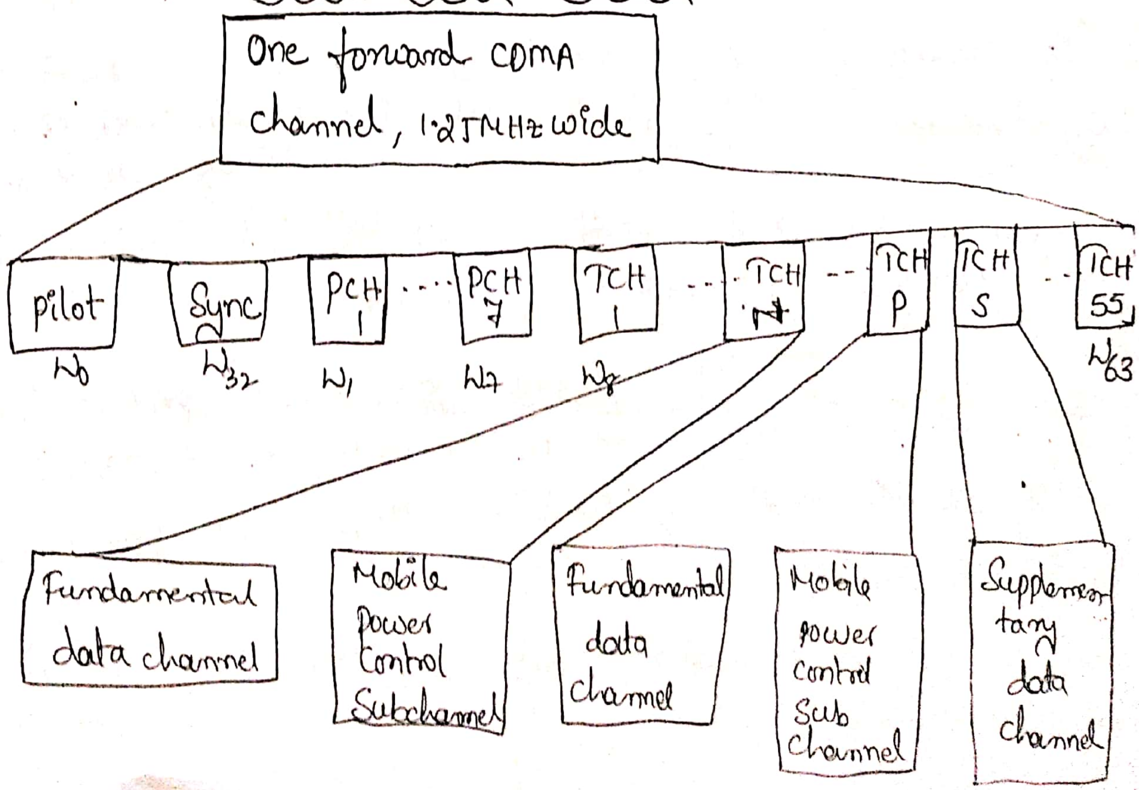
CDMA forward channels have 4 types of logical channels. They are

1) Pilot channel
2) Synchronization channel
3) Paging channel
4) Forward traffic channel.

→ Every forward channel carrier consists of a pilot channel, synchronization channel, seven paging channels and several forward traffic channel.

→ The structure of CDMA forward channel is below,

Forward channel Structure



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→ From the figure, it can be observed that the channels are separated from each other using different spreading codes.

→ Based on the picture of signaling and data traffic a channel carries, it is named as fundamental data channel, supplementary data channel or mobile power control sub channel.

Pilot channel :-

→ It is a reference channel used by Base station (BS) in downlink for synchronizing and tracking all the MSS (Mobile Station SubSystems).

→ This channel compares signal strengths of all the channels in system and locks channels having (RF) Radio frequency carrier.

→ It is the strongest channel with combined power transmitted from base station & capable of supporting soft handover and coherent deflection.

→ This channel use the walsh code i.e., W0 containing all zeros.

Synchronization Channel :-

→ It performs all the synchronizing functions and configures information to the mobile phones.

→ The synchronization channel present in CDMA forward channel helps mobile users in decoding the other logical channels by providing them with precise timing information.

→ Walsh code W_{32} is assigned to synchronization channel.

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Paging channel :-

→ The control information and paging message are sent to mobile users in a system using paging channel.

→ There are seven paging channels in forward channel that are used to sent short message like, broad cast messages, registration procedure details, traffic channel information, response to access requests, list of parameters of neighbouring cell sites etc.

→ The walsh code w_1 to w_7 are assigned to seven paging channels.

Forward traffic channel :-

→ It primarily carries data an establish link between cell site and mobile users to enable communication, that is data transfer.

→ In CDMA forward channel out of 64 channels 55 channels are used for traffic channel which are assigned with walsh codes from w_8 to w_{31} and w_{33}.

→ In case when huge data traffic arrives which can't be handled using the default traffic channel then some extra supplementary traffic channels are dynamically added to meet the desired data rates.

CDMA Reverse channel :-

→ All the mobiles in coverage area of a cell use reverse CDMA channel for sending signals to the base station.

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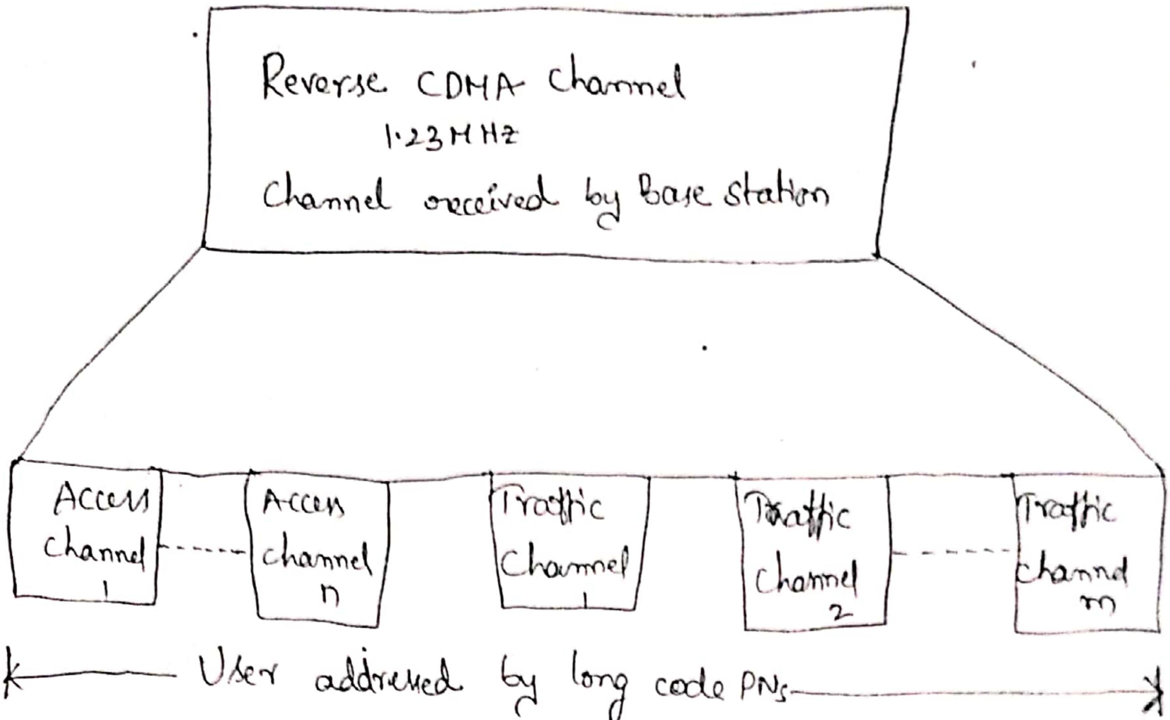
→ The structure of CDMA reverse channel is below



CDMA Reverse channel Structure

→ At any given point of time, there is always a possibility of 'X' mobiles busy in call & 'Y' mobiles trying to access the system.

→ In order to access to as many mobiles as possible.

→ CDMA reverse channel uses 62 distinct traffic channels & 32 distinct access channels in system.

→ There are two types of reverse channels in CDMA. They are

1) Access channels

2) Reverse Traffic channels

1) Access channels :-

It allows a mobile to communicate with the system for registration, call origination & sending

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response signals to receiving on a paging channel. (21)

→ It configurable one (or two access channels are generally configured for 1 paging channel with data rate of 4.8 kbps.

2) Reverse Traffic channel :—

→ The voice (or data traffic from a mobile to the Base station is transmitted using reverse traffic channel that are paired with their respective forward traffic channels.

→ During call signaling, information is transfered again using blank & burst by dim & burst mode.

CDMA Advantages :—

→ CDMA technique enables the users to communicate in a secured network environment.

→ It provides secured communication

→ It allows the use of small antennas with no interference problem.

→ It strongly rejects the noise and other unwanted signals.

→ CDMA technique permits individual stations to access the complete bandwidth irrespective of time limit.

→ It eliminates the time synchronization activity of cell stations.

→ It is highly resistant to interference and Jamming.

→ It provides user privacy by employing random walsh codes.

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→ CDMA provides an improved call quality by cross talk, interference noise etc.

→ It supports soft hand-offs due to the presence of multiple diversities.

→ It provides higher coverage quality with fewer cells.

→ It increases the talk-time & battery life for mobile phones.

CDMA disadvantages :-

→ CDMA technique has low through put efficiency.

→ As the number of subscribers increases, the total performance of the system decreases to a low level.

→ CDMA is a bit complex system.

→ It suffers from self-Jamming & near-far problems.

→ The backward compatibility techniques used in CDMA are not economical

→ The cost of the equipment is high.

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Difference between TDMA, FDMA, CDMA :—

S.No	Parameters	TDMA	FDMA	CDMA
1.	Modulation (Process of encoding information to be transmitted)	QPSK (Quadrature phase shift keying)	QPSK	QPSK and OQPSK
2.	FEC coding	In this, redundancy offered by FEC coding requires higher transmission rate & greater bandwidth	In this also FEC coding requires higher transmission rate & greater bandwidth	In this also FEC coding requires higher transmission rate & greater bandwidth.
3.	Diversity	Multiple receivers are necessary to achieve diversity	Multiple receivers are necessary to achieve diversity.	It supports soft handoffs due to the presence of multiple diversity

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	Parameters	TDMA	FDMA	CDMA
	System Complexity	In order to share the available time slots, mobile subscribers must improve their level of co-operation	In FDMA, the function of mobile users is not dependent	CDMA system may suffers with a limitation reffered to as self Jamming that occurs when non-orthogonal PN sequences are allocated to the CDMA subscriber
5.	Multiple Access interference (MAI)	Interference effect is reduced by the fixed assignment of frequency groups to specific cells	Interference effect is reduced by the fixed assignment of frequency groups to specific cells	A CDMA System suffers from other limination referred to as near-far problem that occurs when a single channel is being shared by different subscribers

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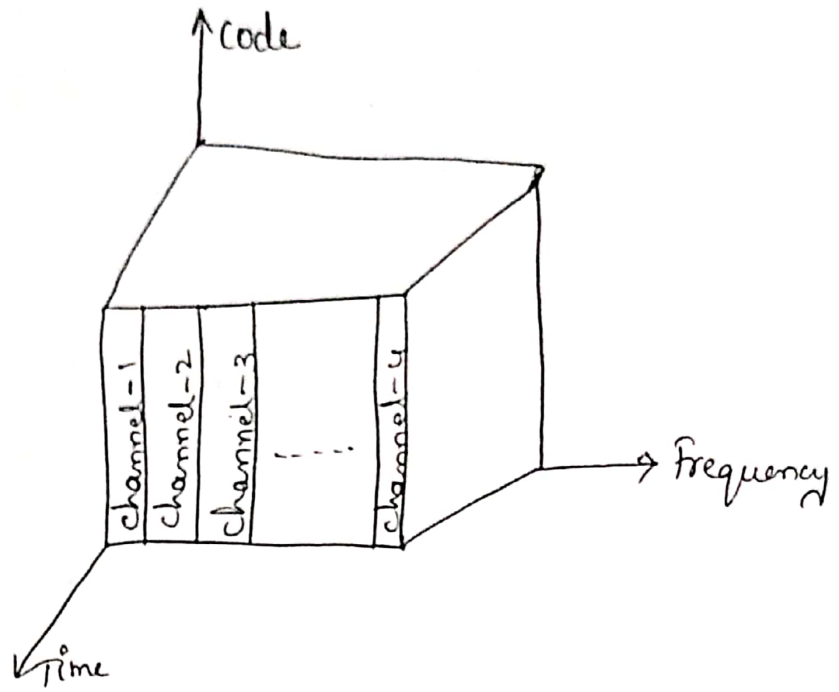
(Fre)quency Division Multiple Access (FDMA):—

→ FDMA assigns individual channels to individual users.



→ These channels are assigned to on demand to users request service

→ During the period of the call, no other user can share the same channel.

→ In FDD (frequency division duplexing) systems, the users are assigned a channel as a pairs of frequencies, one frequency for forward channel while the other for the reverse channel

Features of FDMA:—

→ FDMA channel carries only one phone circuit at a time.

→ If an FDMA channel is not in use, then it sits idle and cannot be used by other users to increase capacity.

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→ After the assignment of a voice channel, Base station and the mobile transmit simultaneously and continuously.

→ The bandwidths of FDMA channels are relatively narrow (30 kHz in AMPS) as each channel supports only one circuit per carrier.

→ FDMA is usually implemented in narrow band systems.

→ The symbol time of a narrow band signal is large as compared to the average delay spread.

→ No equization is required in FDMA narrow band systems.

→ The complexity of FDMA mobile systems is lower when compared to TDMA systems.

→ FDMA systems have higher cell site system cost compared to TDMA.

→ The FDMA mobile unit uses duplexes since both the transmitter and receiver operate at the same time.

→ FDMA requires tight RF filtering to minimize adjacent channel reference.

Example of FDMA:—

AMPS (Advanced Mobile phone System)

→ It is based on FDMA/FDD.

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(21)

→ A single user occupies a single channel while the call is in progress, and the single channel is actually two simplex channels, which are frequency duplexed with a 45Hz split.

→ Multiple users are accomodated in AMPS by giving each user a unique channel.

→ Voice signals are sent on the forward channel from the Base station to mobile unit, on the reverse channel from the mobile unit to the Base Station

→ In AMPS, analog narrow band frequency modulation (NBFM) is used to modulate the carrier.

→ The number of channels that can be simultaneously supported in a FDMA system is given by,

$$N = \frac{B_t - 2B_{guard}}{B_c}$$

where,

B_t : total spectrum allocation

B_{guard} : guard band allocated at the edge of the allocated spectrum band

B_c : Channel Bandwidth

———— 0 ————

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Example

In US AMPS ; 416 channels are allocated to various cellular operators. The channel between them is 30kHz with the guard band of 10kHz. Calculate the spectrum allocation to each other.

Sol

Given that,

Number of channels (N) = 416

Guard band (B_{guard}) = 10kHz

channel bandwidth (B_c) = 30 kHz

We know that, Total spectrum allocation (B_t) = ?

$$N = \frac{B_t - 2B_{guard}}{B_c}$$

$$NB_c = B_t - 2B_{guard}$$

$$NB_c + 2B_{guard} = B_t$$

$$B_t = NB_c + 2B_{guard}$$

$$B_t = 416 \times 30 \times 10^3 + 2(10 \times 10^3)$$

$$B_t = 12.5\ MHz$$

So, 12.5 MHz is allocated for each simplex band

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Orthogonal Frequency Division Multiple Access (OFDMA):–

(or)

Orthogonal frequency Division multiplexing (OFDM):–

→ OFDM is similar to frequency division multiplexing (FDM)

→ In OFDM the subcarriers signal has orthogonal relation ship.

→ Orthogonality allows the OFDM subcarrier to overlap each other with out interference

→ In the OFDM the input information sequence is first converted into parallel data sequence and each serial / parallel converter output is multipled with spreading code.

→ Data from all subcarriers is modulated by FSK modulation and passes through ~~fast~~ Inverse Fast Fourier Transform (IFFT), which convert frequency domain to time domain and converted back to serial data.

→ The guard interval is inserted between symbols to avoid FSI (Floor space Index) by multipath fading.

→ At receiver (Rx) the subscriber comparing and corresponding to the received data is first coherently detected with FFT and frequency domain converted to time domain.

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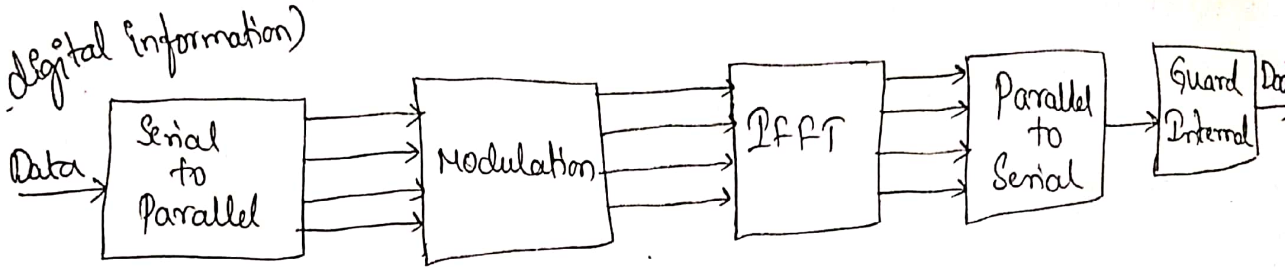
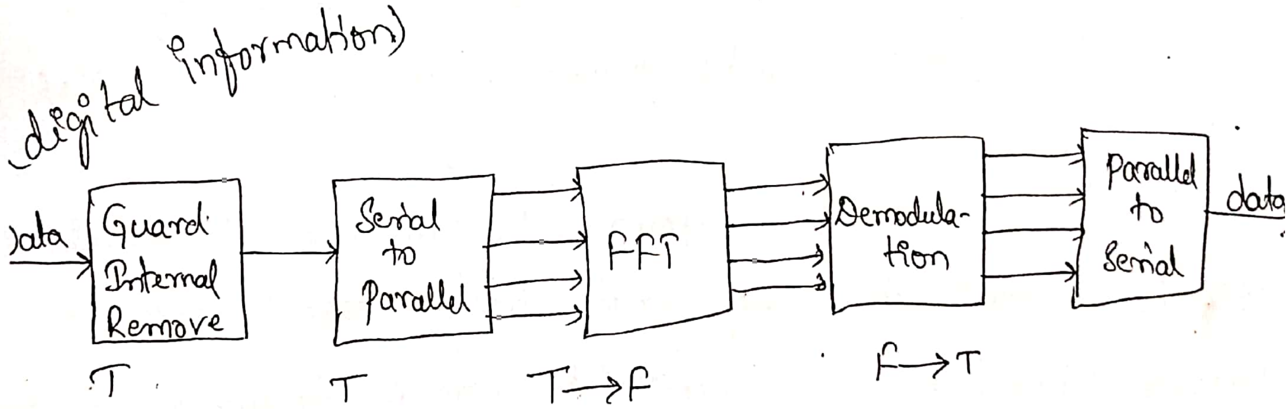
→ Then demodulation is done and converted back to serial data.

OFDM Transmitter



OFDM Receiver



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Code No: **R1642041** **R16** **Set No. 1**

IV B.Tech II Semester Regular/Supplementary Examinations, July - 2021

CELLULAR AND MOBILE COMMUNICATIONS

(Electronics and Communication Engineering)

Time: 3 hours **Max. Marks: 70**

Question paper consists of Part-A and Part-B
Answer ALL sub questions from Part-A
Answer any FOUR questions from Part-B
*****

PART–A *(14 Marks)*

1. a) Define frequency reuse ratio. [3]
   b) What is the significance of diversity receiver? [2]
   c) What are the functions of frequency management? [2]
   d) Explain in detail about the importance of cell-site antennas. [2]
   e) Discuss about handoff initiation [2]
   f) What are the different traffic channels of GSM [3]

PART–B *(4x14 = 56 Marks)*

2. a) Discuss about Trucking and GOS. [7]
   b) Explain about consideration of the components of Cellular system [7]

3. a) With neat sketch explain the effect of reduction of Antenna height on different terrains? [7]
   b) Explain the measurement of real time Co-Channel interference. [7]

4. a) Explain in detail about near-distance propagation. [7]
   b) Discuss about fixed channel and non-fixed channel assignment [7]

5. a) What is the minimum separation required for cell site antennas and discuss about high gain antennas. [7]
   b) Explain in brief about Roof Mounted antenna. [7]

6. a) With neat sketch explain the concept of Handoff. [7]
   b) Write short notes on vehicle locating methods [7]

7. a) Explain in detail the Code Division Multiple Access technique [7]
   b) What are the subsystems of GSM? Explain the functions of OSS sub system? [7]

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Code No: **R1642041** **R16** **Set No. 1**

IV B.Tech II Semester Regular Examinations, September - 2020

CELLULAR AND MOBILE COMMUNICATIONS

(Electronics and Communication Engineering)

Time: 3 hours **Max. Marks: 70**

Question paper consists of Part-A and Part-B
Answer ALL sub questions from Part-A
Answer any FOUR questions from Part-B
*****

PART–A *(14 Marks)*

1. a) Define cell sectoring. [2]
   b) What is co-channel interference? [2]
   c) What is channel sharing and borrowing in cellular systems? [3]
   d) List out the types of antennas used at cell site. [2]
   e) What are the various handoff initiation techniques? [2]
   f) Write the features of OFDMA. [3]

PART–B *(4x14 = 56 Marks)*

2. a) Explain the concept of frequency reuse with the help of a neat diagram. [7]
   b) The 2G GSM has 125 channels in the uplink and 125 channels in the down link. Each channel has a bandwidth of 200 kHz. What is the total bandwidth occupied in both uplink and down link. [7]

3. a) Derive the expression for carrier-to-interference ratio in a cellular system for normal case and worst-case scenario with an omni-directional antenna. [7]
   b) Explain the various types of non-cochannel interferences in a cellular environment? [7]

4. a) What are the various channel assignment strategies with respect to cell sites? Explain in detail. [7]
   b) Explain the effects of human made structures for mobile propagation in open area. [7]

5. a) Explain the role of directional antennas for interference reduction if cellular systems. [7]
   b) Write short notes about Roof mounted antennas in cellular systems. [7]

6. a) What type of handoff is used when a call initiated in one cellular system and enters another system before terminating? Explain how it works? [7]
   b) Explain the various vehicle locating methods in detail. [7]

7. a) What are the different types of channels for GSM? Explain. [7]
   b) Explain the basic architecture of 3G cellular system with a neat sketch. [7]

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Code No: **R1642041** **R16** **Set No. 2**

IV B.Tech II Semester Regular Examinations, September - 2020

CELLULAR AND MOBILE COMMUNICATIONS

(Electronics and Communication Engineering)

Time: 3 hours **Max. Marks: 70**

Question paper consists of Part-A and Part-B
Answer ALL sub questions from Part-A
Answer any FOUR questions from Part-B

*****

PART–A ***(14 Marks)***

1. a) Write the differences between macro and micro cellular structures? [3]
   b) Write the different types of non co-channel interference. [2]
   c) Describe the major factors causing propagation loss in cellular systems. [3]
   d) Write the features of omni directional antennas? [2]
   e) What is forced handoff? Describe. [2]
   f) Write the features of CDMA. [2]

PART–B ***(4x14 = 56 Marks)***

2. a) Explain the principle of operation of cellular mobile system and its components with a neat diagram. [7]
   b) Determine the number of cells in clusters for the following values of the shift parameters *i* and *j* in a regular hexagon geometry pattern:
      (i) i=2 and j=4
      (ii) i=3 and j=3. [7]

3. a) What is cochannel interference in cellular systems? Explain the different methods of reducing the co-channel interference. [7]
   b) Explain the various functions of diversity receiver with a neat diagram. [7]

4. a) What are the set-up channels? Explain, how set-up channels acts as control channels in a cellular system? [7]
   b) Describe the various steps involved in finding antenna height gain in a mobile environment. [7]

5. a) Explain the principle and advantages of umbrella pattern antennas in cellular systems. [7]
   b) Write short notes about Glass mounted antennas in cellular systems. [7]

6. a) What is different handoff strategies based on algorithms of handoff? Explain. [7]
   b) What is dropped call rate? Explain how it is evaluated? [7]

7. a) Describe the various features and services of GSM system. [7]
   b) Explain the principle of TDMA and its frame structure with a neat diagram. [7]

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Code No: **R1642041** **R16** **Set No. 3**

IV B.Tech II Semester Regular Examinations, September - 2020

CELLULAR AND MOBILE COMMUNICATIONS

(Electronics and Communication Engineering)

Time: 3 hours **Max. Marks: 70**

Question paper consists of Part-A and Part-B
Answer ALL sub questions from Part-A
Answer any FOUR questions from Part-B
*****

PART–A *(14 Marks)*

1. a) Write the differences between pico and femto cellular structure. [3]
   b) Define co-channel interference reduction factor. [2]
   c) What is the importance of frequency management chart? [3]
   d) List out the types of antennas used at cell site. [2]
   e) Define the dropped call rate. [2]
   f) Write the features of TDMA. [2]

PART–B *(4x14 = 56 Marks)*

2. a) What is co-channel reuse ratio? Prove that for a hexagonal geometry, the co-channel reuse ratio is $\sqrt{3N}$, where $N = i^2 + ij + j^2$. [7]
   b) List the various techniques used to expand the capacity of a cellular system. Explain in detail. [7]

3. a) What is non-cochannel interference? Explain the various types of non-cochannel interference? [7]
   b) Determine the minimum cluster size for a cellular system designed with an acceptable value of C/I =18 dB. Assume the path loss exponent as 4 and co-channel interference at the mobile unit from six equidistant cells in the 1st tier. [7]

4. a) What are the various channel assignment strategies with respect to mobile units? Explain in detail. [7]
   b) Explain the point-to-point path loss prediction model and describe the factors that affect the accuracy of prediction. [7]

5. a) What are the different types of antennas used for mobile unit? Explain any one with neat diagram. [7]
   b) Write short notes about mobile high gain antennas in cellular systems. [7]

6. a) What are the various handoff initiation techniques? Explain. [7]
   b) What is intersystem handoff? Explain with necessary diagram. [7]

7. a) What are the various subsystems in GSM architecture? Explain the network switching subsystem. [7]
   b) Describe the basic principle and advantages of OFDMA. [7]

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Code No: **R1642041** **R16** **Set No. 4**

IV B.Tech II Semester Regular Examinations, September - 2020

CELLULAR AND MOBILE COMMUNICATIONS

(Electronics and Communication Engineering)

Time: 3 hours **Max. Marks: 70**

Question paper consists of Part-A and Part-B
Answer ALL sub questions from Part-A
Answer any FOUR questions from Part-B
*****

PART–A *(14 Marks)*

1. a) List the main features of 3G cellular systems. [2]
   b) What are the types of interferences in cellular system? [2]
   c) Describe the concept of overlaid cell. [3]
   d) Write the features of umbrella pattern antennas. [2]
   e) List out the different vehicle locating methods. [2]
   f) Compare the basic technological differences between GSM and CDMA. [3]

PART–B *(4x14 = 56 Marks)*

2. a) Explain the principle of cell splitting and cell sectoring in cellular systems. [7]
   b) Draw the frequency reuse pattern for a cluster size of N=3 and N=7. [7]

3. a) Derive the expression for C/I for worst case scenario in an omni directional antenna system. [7]
   b) If a signal to interference ratio of 15 dB is required for satisfactory forward channel performance of a cellular system, what is the frequency reuse factor and cluster size that should be used for maximum capacity if the path loss exponent is (a) n=4, (b) n=3? Assume that there are 6 co-channel cells in the first tier and all of them are at the same distance from the mobile. Use suitable approximations. [7]

4. a) What is the importance of frequency management chart? Explain. [7]
   b) Derive the expression for the path difference between the direct and reflected paths in a mobile environment. [7]

5. a) Explain the different types of antennas used for coverage and interference reduction in cellular systems. [7]
   b) Write short notes about Roof mounted antennas in cellular systems. [7]

6. a) Explain the differences between handoff initiation in analog and digital cellular systems. [7]
   b) How dropped call rate is defined using general formula? Explain. [7]

7. a) Explain the GSM architecture with a neat sketch. [7]
   b) Compare and contrast the various multiple access schemes. [7]

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