UNIT – VI

HANDOFF & DROPPED CALLS

why Handoffs: once a Call is Established, the setup channel is not used again during the Call period; therefore handoff is always implemented on the Voice channel.

→ The Value of handoff is dependent on the size of the cell.

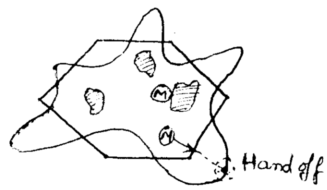
→ Handoff is needed in two situations 1) where the cell site receives weak signals from the mobile unit i.e at the cell boundary
2) when the mobile unit is reaching the signal strength holes within the cell site

Two Types of Handoffs: The types of handoffs is based on
a) Signal strength
2) Carrier to Interference Ratio.

→ The signal strength threshold level for handoff is −100 dBm in noise limited system and −95 dBm in interference limited system.

→ The value of C/I at the cell boundary for handoff should be 18 dB for having good voice quality.

In type 1: 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



$$RSS = C + I$$

Here C is Carrier signal power
I is the interference

→ Handoffs can be controlled by using the carrier to interference ratio C/I which can be obtained as

$$\frac{C+I}{I} \approx \frac{C}{I}$$

→ In todays cellular system; it is hard to measure C/I during a call because of analog modulation. Sometimes we measure the level of I before the call is connected & the level of C+I during the call. Thus (C+I)/I can be obtained.

* Probability of Requirement :

→ To find the probability of requiring a handoff we can carry out the following simulation

i,e 1) Suppose that a mobile unit randomly initiates a call in 10 mi cell

2) The vehicle speed is also randomly choosen as 5 to 60 mi/h

3) The direction is randomly choosen to be between 0° to 360°

then the chance of reaching the boundary is dependent on the call holding time.

→ If the call holding time is 1.76 min the only chance of reaching the boundary is 11 %. i,e there is a chance of handoff will occur for a call is 11%.

Handoff probability	Call length, in min
11.3	1.76
18	3
42.6	6
59.3	9

Number of handoffs per call : The number of handoffs per call is relative to cell size

0.2	handoffs	per call	in	16 - 24 km cell
1 - 2	"	"		3.2 - 8 km
3-4	"	"		1.6 to 3.2 km cell.

i,e the smaller the cell size, the implementing of handoffs will be greater.

Initiation of a Handoff : when the signal strength reaches the level of a handoff, then the cell site sends a request to the MTSO for a handoff on the call.

→ Suppose that -100 dBm is a threshold level at the cell boundary at which a handoff would be taken.

If we set up a level higher than -100 dBm i,e -100 dBm + ΔB and when the received signal reaches this level, a handoff request is initiated

→ Let the value of Δ be 10 dB i,e a level of -90 dBm as the threshold level for requesting a handoff.

→ The Δ should be varied according to the path loss slope of the received signal strength (γ) & the velocity of vehicle v. so that the number of unnecessary handoffs can be reduced and the required handoffs can be completed successfully

→ we have to calculate the velocity v of the mobile unit based on the predicted LCR (Level Crossing rate of signal strength) at a $-10\,dB$ level w.r.t the rms level which is at $-90\,dBm$ thus

$$v = \begin{cases} \dfrac{n\lambda}{\sqrt{2\pi}\,(0.27)} & ft/sec \\ n\lambda & mi/h \end{cases} \quad \text{at } -10\,dB \text{ level}$$

where n is the LCR counting positive slopes
λ is the wavelength in feet then the equation can be simplified as

$$v\,(mi/h) = n \text{ at } 850\,MHz \text{ and a } -10\,dB \text{ level}$$

→ There are two circumstances where handoffs are necessary but cannot be made that they are

1) when the mobile unit is located at a signal strength hole within a cell but not at the boundary
2) when the mobile unit approches a cell boundary but no channel in the new cell are available

→ Incase ① the call must be kept in old frequency channel untill it is dropped as the result of an unacceptable signal level
Incase ② the new cell must reassign one of its frequency channels within a reasonably short period or the call will be dropped

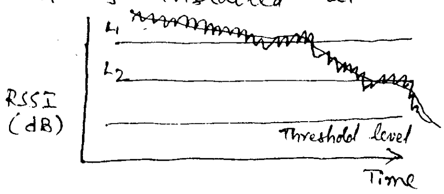
→ The MTSO usually controls the frequency assignment in each cell and can rearrange channel assignments or split cells when they are necessary.

Delaying Handoff :

Two handoff level algorithem :

→ The purpose of creating two request handoff levels is to provide more opportunity for a sucessful handoff. A handoff could be delayed if no available cell could take the call.

→ The plot of average signal strength is recorded on the channel received 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 neighbouring cell is busy, the handoff will be requested periodically every 5 sec.

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 handedoff with no condition.

→ The MTSO always handles the handoff calls first & the originating calls second

→ If no neighbouring calls are available after the second handoff level is reached, the call continues untill the signal strength drops below the threshold level, then the call is dropped.

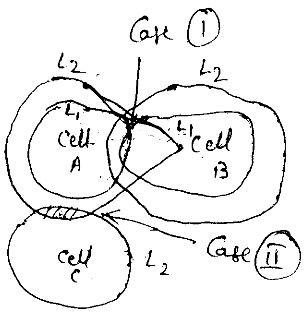
Advantages of Delayed Handoffs:

→ The mobile units are randomly moving and the terrain contour in uneven the received signal strength at the mobile unit fluctuates up & down. If the mobile unit is in a hole for less than 5 sec, the delay can circumvent the need for a handoff.

→ If the neighbouring cells are busy, delayed handoff may take place

→ The other advantage of having a two handoff level algorithm is that it makes the handoff occur at the proper location & eliminates possible interference in the system.

→ In the fig: shows the areas where the first handoff level occurs between cell A & B. If we only use the second level handoff boundary of cell A, the area of handoff is too close to cell B



→ Case II shows where the second level handoff occurs between cell B & cell C. This is because the first level handoff cannot be implemented.

* Forced Handoffs :-

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

→ Controlling a Handoff : The MTSO also can control a handoff by making either a handoff earlier or later, after receiving a handoff request from a cell site.

→ Creating a Handoff : In this case, the cell site does not request a handoff but the MTSO finds that some cells are too congested. then the MTSO can request cell sites to create early handoffs for those congested cells.
In otherwords a cell site has to follow the MTSO's order and increase the handoff threshold to push the mobile unit at the new boundary & to handoff earlier.

*→ Power Difference Handoffs : A better algorithm is based on the power difference (Δ) of a mobile signal received by two cell sites home and handoff.

→ Δ can be positive or negative. The handoff occurs depending on a preset value of Δ

$$\Delta = \text{The mobile signal measured at the candidate handoff site} - \text{The mobile signal measured at the home site}$$

→ If

$\Delta > 3dB$: Request a handoff

$1dB < \Delta < 3dB$: Prepare a handoff

$-3dB < \Delta < 0dB$: Monitoring the signal strength

$\Delta < -3dB$: no handoff.

→ This algorithm is not based on the received signal strength level but on a relative (Power difference) measurement.

→ when this algorithm is used, all the cell handoffs for different vehicles can occur at the same general location inspite of different mobile antenna gains & heights.

→ Queuing of Handoffs :

→ Queuing of handoff is more Effective than two threshold level handoffs. The MTSO will queue the requests of handoffs Calls instead of rejecting them if the new cell sites are busy.

→ A queuing Scheme is Effective only when the requests for handoffs arrive at the MTSO in batches or bundles.

If handoff requests arrive at the MTSO uniformly, then the queuing Scheme is not needed.

→ For defining the Equations we have to know the parameters

$\frac{1}{\mu}$ = Average Calling time in Seconds, including new Calls and handoff Calls in Each Cell

λ_1 = Arrival rate (λ_1 Calls per second) for originating Calls

λ_2 = Arrival rate (λ_2 handoff Calls per Second) for handoff Calls

M_1 = Size of queue for originating Calls

N = number of Voice channels

$a = (\lambda_1 + \lambda_2)/\mu$

$b_1 = \lambda_1/\mu$

$b_2 = \lambda_2/\mu$

To See the Improvement the following analysis Can be given in 3 (

1) <u>No queuing on either the originating Calls or the handoff Calls</u>

The blocking for either an originating Call or a handoff Call is

$$B_c = \frac{a^N}{N!} P(0) \quad \text{--- (1)}$$

where

$$P(0) = \left(\sum_{n=0}^{N} \frac{a^N}{n!} \right)^{-1} \quad \text{--- (2)}$$

2) <u>Queuing the originating Calls but not the handoff Calls :</u>

The blocking probability for originating Calls is

$$B_{oq} = \left(\frac{b_1}{N}\right)^{M_1} P_q(0) \quad \text{--- (3)}$$

where

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

The blocking probability for handoff Calls is

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

3) Queuing the handoff Calls but not the originating Calls :

The blocking probability for handoff Calls is

$$B_{hq} = \left(\frac{b_2}{N}\right)^{M_2} P_q(0) \quad — \quad (6)$$

where $$P_q(0) = \left[N! \sum_{n=0}^{N-1} \frac{a^{n-N}}{n!} + \frac{1-(b_1/N)^{M_1+1}}{1-(b_1/N)} \right]^{-1} \quad — \quad (7)$$

The blocking probability for originating calls is

$$B_{ho} = \left[\frac{1-(b_2/N)^{M_2+1}}{1-(b_2/N)}\right] P_q(0) \quad — \quad (8)$$

Problem: If $N = 70$, Call holding Time is 101 sec $= 0.028$ h.

$\lambda_1 = 2270$, $\lambda_2 = 80$ then

$$A = \frac{\lambda_1 + \lambda_2}{\mu} = (2270 + 80)\, 0.028 = 65.80$$

$$b_1 = \frac{\lambda_1}{\mu} = 2270 \times 0.028 = 63.60$$

$$b_2 = \frac{\lambda_2}{\mu} = 80 \times 0.028 = 2.24$$

→ with Queuing of originating Calls only, the Probability of blocking is reduced and increased blocking probability on hand off Calls This is a draw back.

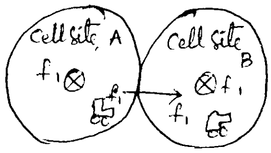
→ with Queuing of handoff Calls only, the blocking probability is reduced from 5.9 to 0.1 percent by using one queue space Therefore it is worthful to implement a simple queue for H.O Calls.

→ However we should always be aware that Queuing for the handoff is more important than queuing for those initiating Calls on assigned voice channels because Call drops upset Customers more than Call blockings.

* Cell site Handoff only : This Scheme is used in non cellular System

→ The mobile unit has been assigned a frequency and talks to its home Cell site while it travels

→ when the mobile unit leaves its home Cell and Enters a new Cell, its frequency doesnot change. rather the new Cell must tune into the frequency of the Mobile Unit



→ Inthis Case only the Cell site needs the frequency information of the mobile unit. Then the aspects of mobile unit Control Can be greatly Simplified & there will be no need to provide H.O at the mobile unit. & the Cost will also be lower.

→ This Scheme Can be recomended only in areas of Very low traffic when the traffic is dense, frequency Coordination is necessary for the Cellular System. Then if the mobile unit does not change frequen on travel from Cell to Cell, other mobile units then must change the frequency to avoid interference.

→ That is if the channels assigned to one Cell will not reuse frequency in other Cells, then it is Possible to implement the Cell site handoff feature as it is applied in Military Systems

* Mobile Assisted Handoff (MAHO) & Soft Handoff :

→ In a normal handoff procedure, the request for a handoff is based on the Signal Strength

→ In the digital Cellular System, the mobile receiver is Capable of monitoring the Signal Strength of the Setup channels of the neighbouri Cells while Serving a Call.

→ In TDMA System, one time Slot is used for Serving a Call, the rest of the time slots Can be used to monitor the Signal strength of Setup channels.

→ when the Signal Strength of its Voice channel is weak, the mobile unit, Can request a handoff and indicate to the MTSO which neighbouring Cell Can be , Candidate for handoff.

→ Now the Switching offices has two pieces of information the Signal Strengths of both forward & reverse setup channels, of a neighbouring cell or two different neighbouring cells

* **Soft Handoff :**

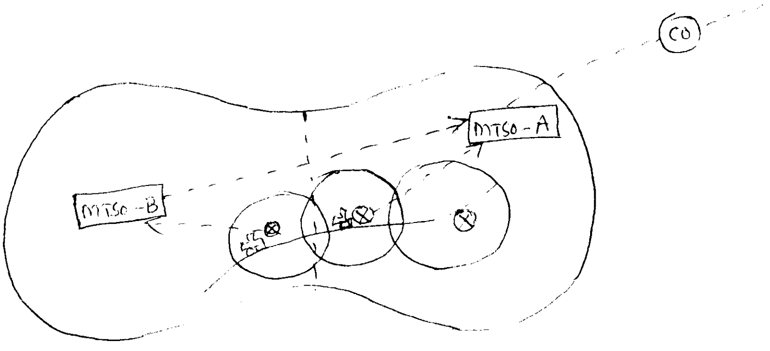
→ The Soft handoff is applied to one kind of Digital Cellular System named CDMA In CDMA Systems, all Cells Can use the Same radio Carrier therefore the frequency reuse factor K approaches one i,e no need to change from one frequency to another frequency but change from one Code to another Code Thus there is no hard handoff

→ If Sometimes there are more than one CDMA radio Carrier operating in a Cell. and if the soft handoff from one Cell to another is not possible for Some reason, then the intra cell hard handoff may takes place first, then go to the inter Cell Soft handoff.

* **Intersystem Handoff :**

→ Occasionally a Call may be initiated in one Cellular System (Controlled by one MTSO) and Enter another System (Controlled by another MTSO) before Terminating

→ Intersystem Handoff means that a Call H.O Can be transferred from one System to a Second System So that the Call be Continued while the mobile unit Enters the Second System



→ The Software in the MTSO must be modified to apply this Situation. If 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 & B are Controlled by two different MTSO's when the mobile unit Signal becomes weak in Cell site A then MTSO A Sends the handoff request to MTSO B through a dedicated line b/w MTSO A & B.

and MTSo B takes a Complete handoff during the Call Conversation

→ If two MTSo's are manufactured by different Companies, then Compatibility must be determined before implementation of intersystem handoff Can be Considered.

There are four Conditions of intersystem handoff that they are

1) A long distance Call becomes a local Call while a home mobile unit becomes a roamer

2) A long distance Call becomes a local Call while a roamer becomes a home mobile unit

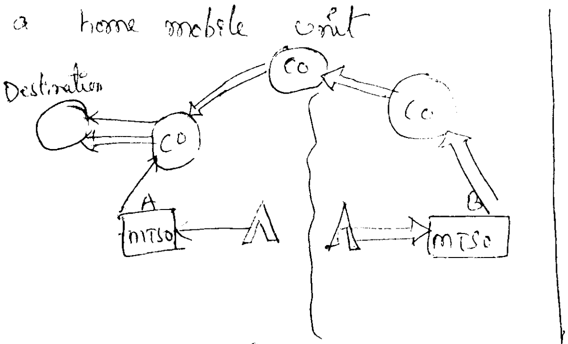


fig (1)

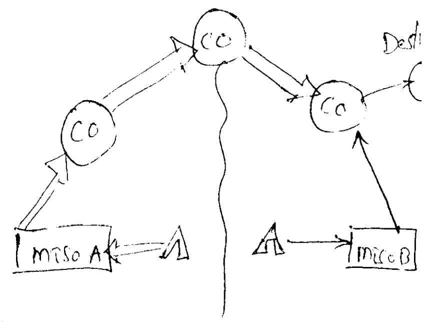


fig (2)

3) A local Call becomes a long distance Call while a home mobile unit becomes a roamer

4) A local Call becomes a long distance call while a roamer becomes a home mobile unit

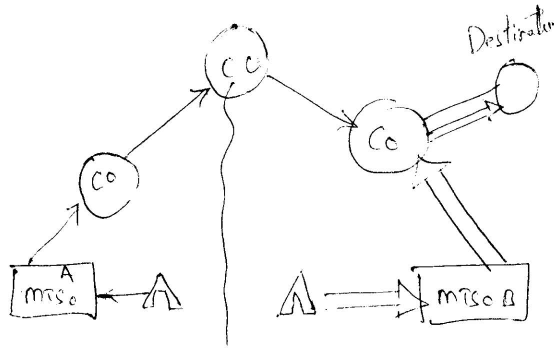


fig (3)

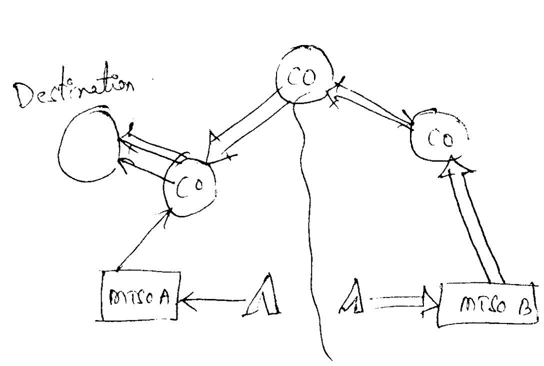


fig (4)

Introduction to Dropped Call Rate :

→ The definition of a dropped call is after the call is established but before it is properly terminated.

→ If there is a possibility that a call will drop due to the poor signal of the assigned voice channel, this is considered as a dropped call.

→ The Relationship among Capacity, voice quality, Dropped call rate :

we already know
$$\frac{C}{I} = \frac{1}{6}\left[\frac{D}{R}\right]^4 = \frac{1}{6}\left[(\sqrt{3K})^4\right]^2$$

$$\frac{C}{I} = \frac{3}{2}K^2$$

$$M = \frac{B_t}{B_c} \quad \text{— (a)} \qquad K = \sqrt{\frac{2}{3}\frac{C}{I}} \qquad \boxed{M = mK}$$

$$\boxed{m = \frac{B_T/B_c}{\sqrt{2/3\,(C/I)_s}}} \quad \text{— (1)}$$

where
- m = number of voice channels (Radio capacity)
- K = number of frequency reuse cells
- B_t = total Bandwidth
- B_c = Channel Bandwidth

Here B_T/B_c is the total number of voice channels. $(C/I)_s$ is required c/i for designing a system.

The Equation (1) can be changed as

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

→ The voice quality is based on $(C/I)_s$

→ when the specified $(C/I)_s$ is reduced the radio capacity increased. when the measured (C/I) is less than the specified $(C/I)_s$ then both poor voice quality & Dropped calls can occur.

Formula of Dropped Call Rate :

δ = probability that the Signal is below the specified receive threshold (In noise limited System)

μ = probability that the Signal is below the Specified Cochannel interference level (In an interference limited System)

γ = Probability that no traffic channel is available upon handoff attempt when moving into a new cell.

θ = Probability that the Call will return to the original cell

β = Probability of blocking ckts between BSC & MSC during Handoff.

α_n = The weighted value for those Calls having n handoffs &

$$\sum_{n=0}^{N} \alpha_n = 1$$

N = N is highest number of handoffs for those Calls.

→ The general formula of dropped call rate P in a whole System Can be Expressed as

$$P = 1 - \sum_{n=0}^{N} \alpha_n x^n$$

$$= \sum_{n=0}^{N} \alpha_n \cdot P_n \quad \text{— (3)}$$

where

$$\boxed{P_n = 1 - x^n} \quad \text{— (4)}$$

Here

$$x = (1-\delta)(1-\mu)(1-\theta\gamma)(1-\beta)^{\gamma} \quad \text{— (5)}$$

→ In a Commonly used formula ~~formula~~ of dropped call rate, the values of γ, θ, β are assumed to be very small & neglected. then the Equation (5) becomes

$$x = (1-\delta)(1-\mu)$$

In noise limited system, $\mu \to 0$ then Equation (3) becomes.

$$P_A = \sum_{n=0}^{N} \alpha_n \cdot P_n = \sum \alpha_n \left[1 - (1-\delta)^n\right] \quad \text{— (6)}$$

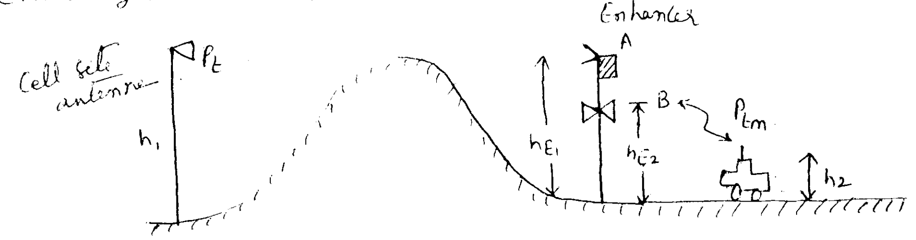
In Interference limited system $\delta \to 0$ then Equation (3) becomes

$$P_B = \sum_{n=0}^{N} \alpha_n P_n = \sum \alpha_n \left[1 - (1-\mu)^n\right] \quad \text{— (7)}$$

* **Coverage Hole Filler:** The ground is not flat, so many holes (weakspots) are created in a general area during antenna radiation.

Enhancers (Repeaters): An enhancer is used in an area which is a hole in the serving cell site. There are two types of enhancer.

a) wideband enhancer
b) Channelized Enhancer.



Wideband Enhancer: It is a repeater. It is designed for either Block A or block B channel implementation. All the signals will be amplified.

→ Sometimes it creates an intermodulation products. So implementation of an enhancer is an appropriate place to fill the hole without creating interference is a challenging job.

→ The signal is transmitted from the cell site and received at the enhancer site by a higher directional antenna which is mounted at a high altitude.

→ The mobile units in the vicinity of the enhancer site will receive the signal. The mobile unit uses the reverse channel to respond to calls through the enhancer to the cell site.

→ However the amplifier amplifies both the signal and noise. Therefore the enhancer cannot improve the SNR. The function of enhancer is actually a relay, receiving at a lower hight h_2 & the transmitting to a higher hight h_1 or vice versa.

→ The gain of enhancer can be adjusted from 10 to 70dB & the range is from 0.5 to 3km

→ The received signal at the mobile units and at the cell site with an enhancer placed in the middle can be expressed as.

$$P_{RM} = P_{tc} + g_c - L_a + (G + g_{E_1} + g_{E_2}) - L_b + g_m \quad \text{--- (1)}$$ and

$$P_{RC} = P_{tm} + g_m - L_b + (G + g_{E_1} + g_{E_2}) - L_a + g_c \quad \text{--- (2)}$$

where
P_{tc} = Transmitted power at cell site
P_{tm} = Transmitted power at mobile unit

P_{Rc}, P_{Rm} → Received power at cell site & at mobile unit respectively

G → Amplification gain at Enhancer

g_c → Antenna gain at cell site

g_m → " " at Mobile unit

g_{E_1}, g_{E_2} → Antenna gain at enhancer.

h_1 → Antenna height at cell site.

h_2 → " " at mobile unit

h_{e_1}, h_{e_2} → " " at Enhancer

L_a → path loss between cell site and Enhancer.

L_b → " " Enhancer and mobile unit.

→ If the undesired signal received by the antenna at height h_{E_1} is transmitted back to the cell site. This could also occur when an undesired signal is received by the antenna hight h_{E_1} because of poor design and is repeatedly transmitted by the antenna at hight h_{E_2}

Channalized Enhancer: It should amplify only the channels that it selected previously with a good design. Therefore it is a useful apparatus for filling the holes.

→ Three points could be noted in the installation of an Enhancer:

1) Ring oscillation might easily occur. If this separation b/w two antennas at the Enhancer is critical. If this separation is inadequate the signal from the lower antenna can be received by upper antenna and create a ring oscillation, thus jamming the system instead of filling the hole.

2) The distance between the Enhancer & serving cell site should be as small as possible to avoid spread of power into a large area

3) Terrain contour should be considered in enhancer installation.

Operational Techniques and Technologies

* Adjusting the parameters of the System :

1) Increasing the Coverage for a Noise limited System :

In noise limited system, there is no co channel interference or adjacent channel interference. This means that either i) no cochannels and adjacent channels are used in the system or 2) channel reuse distance is so large that the interference would be negligible.

The following approaches are used at the cell site to increase coverage

a) Increasing the transmitted power :

→ when the power level is doubled, the gain increases by 3dB. The received power P_r can be obtained from the transmitted power P_t. Let the received power P_r be the power received in an original cell of a radius r_1

$$\therefore \quad P_{r_1} = \alpha P_t r_1^{-4} \quad — \text{(1)}$$

Area covered then is $A_1 = \pi r_1^2$

Here α is a constant

P_{r_1} can be obtained from P_{t_1}

Case i) The transmitted power remains unchanged but the received power changes. If the received power is to be strong, the cell radius should be smaller.

The relation is

$$\frac{P_{r_1}}{P_{r_2}} = \frac{r_1^{-4}}{r_2^{-4}} = \frac{r_2^4}{r_1^4} \quad — \text{(2)}$$

&

$$r_2 = \left(\frac{P_{r_1}}{P_{r_2}}\right)^{1/4} r_1 \quad — \text{(3)}$$

If $P_{r_2} = 2P_{r_1}$ and the transmitted power remains the same, the radius reduces to

$$r_2 = (0.5)^{1/4} r_1$$

$$r_2 = 0.84\, r_1$$

and the area reduces to $\frac{A_2}{A_1} = \frac{\pi r_2^2}{\pi r_1^2} = \frac{r_2^2}{r_1^2} = \frac{(0.84 r_1)^2}{r_1^2} = 0.71$ — (4)

Case ii) The transmitted power changes but the received power doesn't then the imi reception level changes if the transmitted power changes then we obtain

$$P_{r_1} = \alpha P_{t_1} r_1^{-4}$$

$$P_{r_2} = \alpha P_{t_2} r_2^{-4}$$

In this case since

$$r_2 = \left(\frac{P_{t2}}{P_{t_1}}\right)^{1/4} r_1 \quad — (5)$$

If the transmitted power P_{t_2} is 3 dB higher than P_{t_1} then

$$r_2 = (2)^{1/4} r_1$$

$$= 1.19\, r_1$$

and the area increases is

$$\frac{A_2}{A_1} = \frac{r_2^2}{r_1^2} = (1.19)^2 = 1.42 \quad — (6)$$

∴ A General Equation should be expressed as

$$r_2 = \left(\frac{P_{r_1} P_{t2}}{P_{r_2} P_{t_1}}\right)^{1/4} r_1 \quad — (7)$$

$$A_2 = \left(\frac{P_{r_1} P_{t2}}{P_{r_2} P_{t_1}}\right)^{1/2} A_1 \quad — (8)$$

b) Increasing cell site antenna height

c) Using a high gain or a directional antenna at the cell site

d) A low noise receiver

e) Diversity Receiver

f) Selecting cell site locations

g) Using repeaters and Enhancers to Enlarge the coverage area or to fill in holes.

2) <u>Increasing the traffic capacity</u>:

a) Small Cell Size : If we can control the radiation pattern, we can reduce the size of cell & increase the traffic capacity.

b) Increasing the number of radio channels in each cell

c) Enhanced frequency spectrum

d) Queuing e) Dynamic channel assignment

3) Reducing the Interference :

a) A good frequency management chart
b) An intelligent frequency assignment
c) Design of an antenna pattern on the bases of direction
d) Tilting antenna pattern
e) Reducing the antenna height
f) Reducing the transmitted power.
g) Choosing the cell site location.

Passive Reflector :

→ Inorder to redirect the incident energy, the reflector system should be installed in a field far from both the Tx'ing antenna and the receiving antenna

→ The approximate separation b/w the antenna and the reflector is

$$d_1 > \frac{2A_T}{\lambda} + \frac{2A_1}{\lambda} \quad \text{and} \quad d_2 > \frac{2A_1}{\lambda} + \frac{2A_R}{\lambda} \quad —(1)$$

where A_T, A_R = effective aperture of Tx'ing & Rx'ing antennas
d_1, d_2 = distance from reflector to transmitting antenna and receiving antenna respectively.
λ = wavelength.

→ If the transmitting and receiving antennas are linear elements, then

$$d_1 > \frac{2L_T^2}{\lambda} + \frac{2A_1}{\lambda} \quad \text{and} \quad d_2 > \frac{2A_1}{\lambda} + \frac{2L_R^2}{\lambda} \quad —(2)$$

Here L_T & L_R are Tx'ed & Rx'ed lengths of elements.

→ Assume that 100% of incident power is reflected then the received power is

$$P_R = P_T \frac{A_T A_R A_1^2}{\lambda^4 d_1^2 d_2^2} \quad —(3)$$

But

$$A_T = \frac{G_T \lambda^2}{4\pi} \quad —(4)$$

$$A_R = \frac{G_R \lambda^2}{4\pi} \quad —(5)$$

Then

$$P_R = P_T G_T G_R \frac{A_1^2 \lambda^4}{(4\pi)^2 d_1^2 d_2^2 \lambda^4}$$

$$= \left[\frac{P_T G_T G_R}{(4\pi d/\lambda)^2} \cdot \frac{d^2 (A_1/\lambda)^2}{d_1^2 d_2^2}\right]$$

free space loss · Excessive loss

where $d = d_1 + d_2$

$$P_R = 10 \log (FSL) + 10 \log \left[\frac{d^2 \lambda^2}{d_1^2 d_2^2} \cdot \left(\frac{A_1}{\lambda^2} \right)^2 \right]$$

→ In a mobile radio environment, d_1 can be considered to be in free space and d_2 to be a mobile radio path from the reflector to the mobile unit

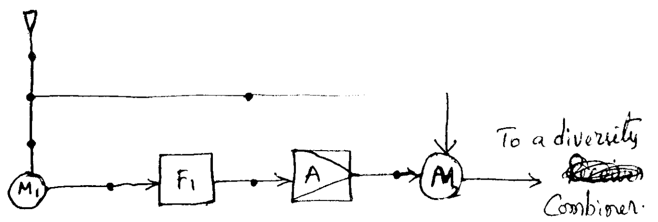
$\therefore \frac{d_1}{d_2} = 0.25$ at 850 MHz

* Cophase Technique: The cophase technique is used to bring all signal phases from different branches to a common phase point.

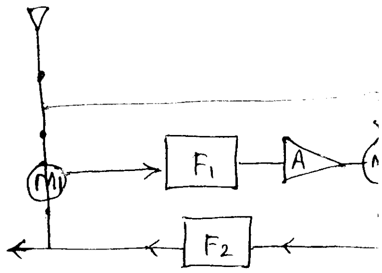
→ Here the common phase point is the point at which the random phase in each branch is reduced.

→ There are two kinds of cophase techniques
  a) Feed forward
  b) Feedback.

F: Filter
M: Mixer.
A: Limiting amplifier



a) Feed forward



b) Feedback.

→ The feed forward cophase technique has been used for satellite communication applications. It is simpler than phase locked loop

→ The outcome of the feedback technique is always better than that of the feed forward technique provided the two filters in the circuit have been properly designed to avoid any significant time delay. It is also called as Granlund Combiner.

* Leaky Feeder :

Leaky waveguides : The velocity of propagation of an Electromagnetic wave V_g in the waveguide is greater than the speed of light V_c i.e $V_g > V_c$

→ The Carrier frequency in Hz should be the same as in the waveguide & in free space. Thus if two waves have the same frequency, their wavelengths will be longer in the waveguide than in free space

$$\lambda_g = \frac{V_g}{f}$$

$$\therefore \quad \lambda_g > \lambda_c$$

→ If the waveguide structure supporting this mode is properly opened up, then the Energy will leak into the Exterior region.
The opening slots will usually be placed along the waveguide periodically

→ This leaky waveguide is different from a slot antenna
The slot antenna is designed to radiate all the Energy into the space at the slot, where as in leaky waveguide, fractional Energy will be leaking constantly. Because $V_g > V_c$. So the leaky waveguide may sometimes be Catagerorized as fast wave antenna

→ At frequencies below 1000 mHz, the use of Coaxial Cable is Universal because the attenuation per unit length is reasonable & the dimensions are practical for passing the principal modes of leaky waves

→ At higher frequencies above 3000 mHz, waveguides are generally used ~~to~~ if high attenuation may occur.

$$V = \frac{\omega}{\beta} = \frac{1}{\sqrt{LC}}$$

Leeky feeder Radio Communication :

→ In some areas, Such as Underground grages or Cell of less than 1mi radius, leaky feeder technique becomes increasingly important to provide adequate Coverage and reduce interference.

→ The leaky feeder is characterseized by Transmission & Coupling losses.

→ Transmission loss is Expressed in decibles per unit length.
Coupling loss is defined by the ratio of power recieved by a dipole antenna at a distanse s Equal to 1.5 m away from the Cable to the transmitted power in the Cable at given point.

→ The Smaller the ~~power~~ ratio, the greater the loss

→ If the distance is other than 1.5 m, the Coupling loss L increases as d ↑

$$L\,(s \text{ at } d) = (\text{Coupling loss at } 1.5\,m) + 10 \log \left(\frac{d}{1.5}\right)$$

→ The principal of leaky Cable operation is

1) use high Coupling loss (little Energy will leakout) Cables near the transmitter End. usually high Coupling loss Cables have a low transmission loss and are of greater length in use.
2) Radiation Can be distributed through joint points (or) boosters and by adjusting the Signal phases around phases as needed
3) Leaky Cables are open fields. The Electric field leaking out from the leaky Cable is reciprocally propotional to square of the distance from the leaky Cable. $L_r = 20 \log s$ dB.
4) Low temparature affects leaky Cable. Transmission loss levels Change with change in temparature. The lower the temparature, the less the Transmission loss
5) Snow accumalation around slots Causes an increase in transmission loss. Reflection and path loss due to Snow on leaky Cable Cause an increase of Coupling loss.
6) The boosters are power amplifiers. ∴ In many narrowband modulated Carriers passing through Common broadband amplifiers generate Intermodulation products power. Inorder to reduce the Im product to a specified level, the linear amplifiers should be operated at a reduced o/p level by backing them off from 1dB gain Compression point.

Narrowbeam Concept:

→ The narrowbeam Sector Concept is another method for increasing the traffic Capacity.

→ For a $K = 7$ frequency reuse pattern with $120°$ sectors Configuration

$$\frac{333 - 21}{3 \times 7} = 15 \text{ channels per } 120° \text{ sector}$$

→ For a $K = 4$ frequency reuse pattern with $60°$ sectors Configeration

$$\frac{333 - 21}{4 \times 6} = 13 \text{ channels per } 60° \text{ sector}.$$

→ In the K = 7 pattern there is a total of 21 sectors with 15 channels in each sector.

→ In the K = 4 pattern there is total of 24 sectors with 13 channels in each sector.

→ With a blocking probability of 2%, the offered load of 189 Erlangs for K = 7 and 177 Erlangs for K = 4.

→ This means that K = 7 pattern offers a 7% higher spectrum efficiency.

→ For customizing channel distribution; that is usage of the 120° & 60° sectors can be mixed. Some 120° sectors can be replaced by two 60° sectors in K = 7 pattern. Then the number of each channels can then be increased from 15 to 26.

→ This scheme is suitable for small cell systems. These sector mixed system follow a K = 7 frequency reuse pattern & the traffic capacity is dramatically increased as a result of customizing the channel distribution according to the real traffic conditions.

Important Questions

1) Explain the following types of Handoff
   1) forced H.O 2) MAHO 3) Intersystem H.O
2) Derive the formula for dropped call rate.
3) Explain the different approaches to increase the coverage of cellular system in a noisy environment.
4) write short notes on the following
   a) Diversity Receiver
   b) Leaky feeder
   c) Cophase techniques.
5) a) Explain the various parameters of a cellular system that can be adjusted to increase coverage
   b) Explain the principle of coverage hole filler.
6) a) write short notes on the following
   a) Digital cellular systems
   b) Cell splitting
   c) Foliage losses
   b) what is handoff & Explain how the handoff is initiated
   c) Derive the relationship b/w capacity, voice quality & dropped call rate
7) what do you mean by operational techniques? why are all these needed in cellular system. Explain briefly different operational techniques.
8) a) Explain clearly how to calculate δ & μ for single cell.
   b) Explain the phenomenon of waveguide.
   Explain the importance of leaky feeder in waveguides)