UNIT - III :- Interference

* **Introduction:**

→ The frequency reuse method is useful for increasing the efficiency of spectrum usage but results in cochannel interference because the ~~channel~~ same frequency channel is used repeatedly in different co-channel cells.

→ when customer demand increases, the channels which are limited in number, have to be repeatedly reused in different areas. which provides many cochannel cells, which increases the system capacity. But co-channel interference may occur.

→ In this situation, the received voice quality is affected by both the grade of coverage & the amount of cochannel interference.

→ For detection of serious channel interference areas in cellular system two tests are suggested

a) Co-channel interference at the mobile unit

b) Co-channel interference at the cell site.

a) Co-channel Interference at the mobile unit : [Co-channel Interference area from a mobile receiver : -

→ Cochannel interference which occurs in one channel will occur equally in all other channels in given area. we can then measure cochannel interference by selecting one channel & transmitting all co-chan sites on it while the mobile is travelling in one of co-channel cells

→ while performing the test we ~~measure~~ watch for any change detected by a field strength recorder in the mobile unit & compare the data with the condition of no cochannel sites being transmitted.

→ This test must be repeated as the mobile unit travels in every co-channel cell.

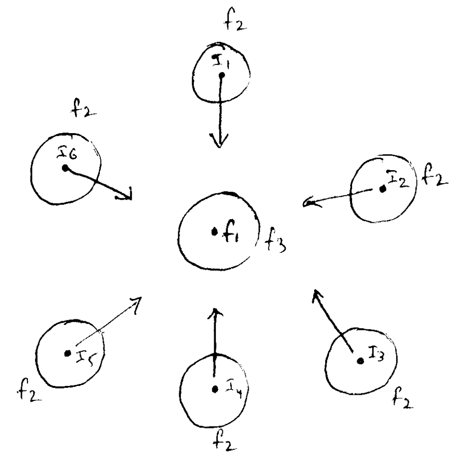
→ The channel scanning receiver scans the signal level (no-cochannel condition) in one channel as f_1 and records the interference level (six cochannel condition) in another channel as f_2 and records the noise level in third channel as f_3.

(i) If the $\frac{C}{I} > 18$ dB, then the system is properly designed

(ii) If $\frac{C}{I} < 18$ dB, $\frac{C}{N} > 18$ dB then there is cochannel interference

(iii) If $\frac{C}{I}, \frac{C}{N} < 18$ dB & $\frac{C}{I} \approx \frac{C}{N}$ then there is coverage problem

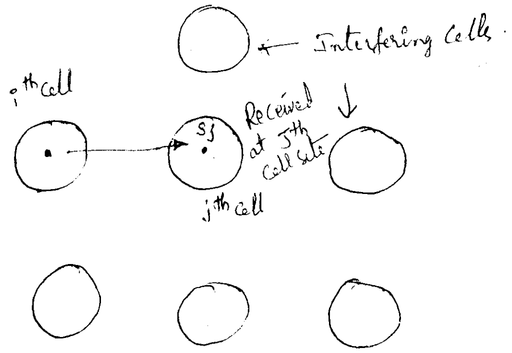
(iv) If $\frac{C}{I}, \frac{C}{N} < 18$ dB & $\frac{C}{N} > \frac{C}{I}$ then there is coverage problem & cochannel interference.



use f_2 for Interference level (I,
use f_1 for Signal level (S.
use f_3 for Noise level (N

fig: Cochannel interference at the Mobile unit

b) Cochannel Interference at the Cell site : [The Cochannel interference area which effects a cell site -



→ First we find the areas in an interfering cell in which the top 10 % level of signal transmitted from the mobile unit in those areas.

→ The average value of top 10 % level signal strength is used as the interference level from that particular interfering cell. Then we can re establish the C/I ratio received at a desired cell then

$$\frac{C_J}{I} = \frac{C_j}{\sum_{\substack{i=1 \\ i \neq j}}^{6} I_i}$$

* Real Time Cochannel interference Measurement in Mobile Radio Transcei

→ when the carriers are angularly modulated by the voice signal and the RF frequency difference between them is much higher than the fading frequency. Measurement of the signal C/I reveals that the signa

$$e_1 = s(t) \sin(\omega t + \phi_1) \quad — ①$$

and the interference is

$$e_2 = I(t) \sin(\omega t + \phi_2) \quad — ②$$

The received signal is $e(t) = e_1(t) + e_2(t)$

$$= R \sin(\omega t + \psi) \quad — ③$$

where $R = \sqrt{[s(t)\cos\phi_1 + I(t)\cos\phi_2]^2 + [s(t)\sin\phi_1 + I(t)\sin\phi_2]}$

and $\Psi = \tan^{-1} \dfrac{S(t)\sin\phi_1 + I(t)\sin\phi_2}{S(t)\cos\phi_1 + I(t)\cos\phi_2}$ — (5)

The 'R' can be simplified and R^2 becomes

$$R^2 = \underbrace{S^2(t) + I^2(t)}_{X} + \underbrace{2\,S(t)\,I(t)\cos(\phi_1 - \phi_2)}_{Y} \quad (6)$$

Assume that the Random Variables $S(t)$, $I(t)$, ϕ_1, ϕ_2 are independent then the average process on X & Y are

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

$$\overline{Y^2} = 4\,\overline{S^2(t)\,I^2(t)}\left(\tfrac{1}{2}\right) = 2\,\overline{S^2(t)\,I^2(t)}$$

∴ The Signal to Interference ratio Γ becomes

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

where $K = \dfrac{\overline{X^2}}{\overline{Y^2}} - 1$

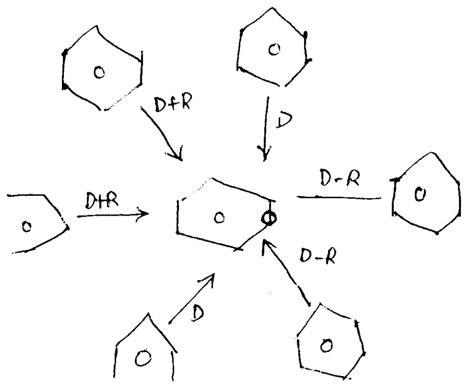
Since X, Y can be separated, the preceeding computation of Γ could have been accomplished by means of Envelope detector & A-D Converter & Microcompter. The Sampling Delay time Δt should be small enough to satisfy

$$\therefore\ S(t) = S(t + \Delta t)$$
$$I(t) = I(t + \Delta t)$$

∴ Determining the Delay time Δt, & Preceeding Calculation is difficult & it is drawback to this measurement technique.

∴ The real time Cochannel interference is difficult to achive in practice

→ Design of an Omnidirectional antenna System



→ we proved that the value of $q = 4.6$ is valid for a normal case interference in a $K = 7$ cell pattern. Now we have to prove that $K = 7$ cell pattern does not provide a sufficient frequency-reuse distance separation even when an ideal condition of flat terrain is assumed.

→ The worst case is at the location where the mobile unit would recei[ve] the weakest signal from its own cell site but strong interference from all other interfering cell sites.

→ In the worst case the mobile unit is at the cell boundary R and the distances from all six cochannel interfering sites as two distance $D-R$, two distances of D and two distances of $D+R$

→ we already known that in the mobile Radio environment

$$C \propto R^{-4}$$

$$I \propto D^{-4}$$

Then the Carrier to Interference Ratio is

$$\frac{C}{I} = \frac{R^{-4}}{2(D-R)^{-4} + 2(D)^{-4} + 2(D+R)^{-4}} \quad \text{— (1)}$$

$$= \frac{1}{2(q-1)^{-4} + 2q^{-4} + 2(q+1)^{-4}} \quad \text{— (2)}$$

In normal case $q = 4.6$ is substituted then

$\frac{C}{I} = 54$ or $17\ dB$ which is lower than $18\ dB$

For worst case we may use the shortest distance $D-R$ for all six interferers then the equation is replaced by

$$\frac{C}{I} = \frac{R^{-4}}{6(D-R)^{-4}} = \frac{1}{6(q-1)^{-4}} = 28 = 14.47\ dB$$

In reality because of the imperfect site locations & rolling nature of terrain configuration, the C/I received is always worse than 17 dB & 14 dB & lower in a heavy traffic situation. then $q = 4.6$ is insufficien[t]

→ In that worst case a co-channel interference reduction factor of $q = 4.6$ is insufficient. In an omni directional cell system $K=9$ & $K=12$ would be correct choice then the q values are

$$q = \begin{cases} D/R = \sqrt{3K} \\ 5.9 \quad K=9 \\ 6 \quad K=12 \end{cases}$$

Substituting them then we obtain

$$\frac{C}{I} = 84.5 = 19.25 \text{ dB} \rightarrow K=9$$

$$\frac{C}{I} = 179.33 = 22.54 \text{ dB} \rightarrow K=12$$

The $K=9$ & $K=12$ cell patterns are used when the traffic is light. Each cell covers an adequate area with adequate number of channels to handle the traffic.

★ Design of a Directional antenna System :

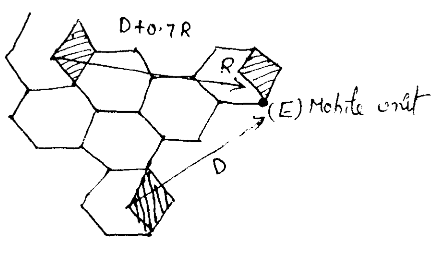
→ When the call traffic begins to increase, we need to use the frequency spectrum efficiently and avoid the increasing number of cells K in a seven cell frequency reuse pattern.

→ Instead of increasing the number K in a set of cells, let us keep $K=7$ and introduce a directional antenna arrangement.

→ The cochannel interference can be reduced by using directional antennas. This means that each cell is divided into 3 & 6 sectors and uses 3 & 6 directional antennas at a base station. Each sector is assigned a set of frequencies (channels).

Directional antennas in $K=7$ cell patterns :

a) 3 Sector Case :



→ The mobile unit at position E will experience greater interference in the lower shaded cell sector than in the upper shaded cell sector because the mobile receiver receives the weakest signal from its own cell ~~but~~ fairly strong interference from the interfering cell.

→ In a 3 sector case the interference is effective in only direction because the front to back ratio of cell site directional antenna is atleast 10 dB or more in mobile radio environment.

→ Because of the use of directional antennas, the number of principal interferers is reduced from six to two then the value of $\frac{C}{I}$ can be obtained by the following expression

$$\frac{C}{I} = \frac{R^{-4}}{(D+0.7R)^{-4} + D^{-4}} = \frac{1}{(q+0.7)^{-4} + q^{-4}}$$

Let $q = 4.6$

$$\frac{C}{I} = 285 \text{ or } 24.5 \text{ dB}.$$

→ Here the C/I is received by mobile unit from the 120° directional antenna Sector System. is greatly Exceed 18 dB in a worst Case.

→ The using of directional antenna Sectors Can improve the SNR, that is reduce the Cochannel interference.

→ But in reality the C/I Could be 6 dB weaker than in worst Ca. in a heavy traffic area as a result of irregular terrain Configurations and imperfect Site locations. then the remaining 18.5 is still adequate

b). Six Sector Case: we have to divide a Cell into Six sectors by using 60° beam directional antennas as shown in figure.

In this Case only one instance of interference Can occur in Each Sector

$$\frac{C}{I} = \frac{R^{-4}}{(D+0.7R)^{-4}} = (q+0.7)^{4}$$

For $q = 4.6$ then $\frac{C}{I} = 794 \simeq 29 \text{ dB}$.

→ which shows a further reduction of Cochannel interference.

If we Subtract 6 dB from the result like 3 Sector Case, then the remaining 23 dB is still more than adequate

→ when heavy traffic occurs, the 60° Configuration Can be used to reduce Cochannel interference

Directional antennas in K=4 Cell patterns:

3 Sector Case: For $K=4$ $q = \sqrt{3K} \Rightarrow 3.46$

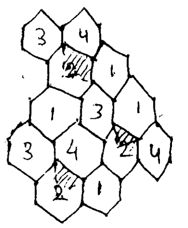
$$\frac{C}{I}(\text{worst Case}) = \frac{1}{(q+0.7)^{-4} + q^{-4}} = 97 = 20 \text{ dB}$$

If we Subtract that 6 dB, the remaining is unacceptable

Six Sector Case: There is only one interfer at a distance of D+R with $q = 3.46$ then we obtain

$$\frac{C}{I}(\text{worst Case}) = \frac{R^{-4}}{(D+R)^{-4}} = \frac{1}{(q+1)^{-4}} = 355 \simeq 26 \text{ dB}$$

If we Subtract that 6 dB, the remaining 21 dB is adequate. under heavy traffic Conditions, we Can use 60° sector at K=4 Cell pattern



Interference with K = 4.

★ Comparing K = 7 and K = 4 Systems

K = 7	K = 4
1) In K = 7 System has total of 42 sectors	1) In K = 4 System has total of 24 Sectors.
2) when traffic increases, 3 sector system provide less Cochannel interference	2) It is difficult and unacceptable
	3) Advantage: 60° Sectors with K = 4, require fewer Cell sites than 120° sectors with K = 7
	4) Disadvantage: a) They require more antennas to be mounted on antenna mast b) They often require more frequent hand off for travel across the six Sectors of cell.

Lowering the antenna Height:

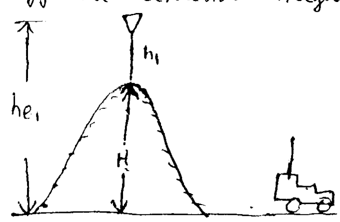
→ It doesnot always reduce the Cochannel interference but in Some Circumstances like fairly flat ground or in a valley situation it will be very Effective for reducing the Cochannel & adjacent channel interference

→ There are Three Cases where lowering the antenna height may or maynot Effectively help to reduce the interference

a) on a high hill or high Spot:

→ The Effective antenna height, rather than the actual antenna height varies according to the location of mobile unit.

→ when the antenna site is on a hill then the Effective antenna height is $h_1 + H$



If we reduce the actual antenna height to $0.5h_1$ then the new Effective antenna hight becomes $0.5h_1 + H$ then the gain reduction is

$$G = 20 \log \frac{0.5h_1 + H}{h_1 + H} \quad \text{— (1)}$$

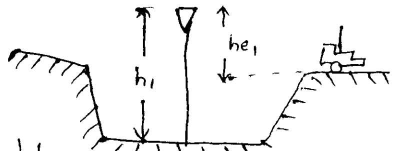
$$= 20 \log \left(1 - \frac{0.5h_1}{h_1 + H}\right) \quad \text{— (2)}$$

If $h_1 << H$ then $G = 20 \log_{10}(1) = 0 \text{ dB}$

This proves that the lowering antenna height on the hill does not reduce the received power at either cell site or the mobile unit.

In a Valley :

→ The Effective antenna height as seen from the mobile unit as h_{e_1} which is less than actual antenna height h_1.



→ If $h_{e_1} = \frac{2}{3} h_1$ and the antenna is lowered to $\frac{1}{2} h_1$ then the new Effective antenna height is

$$h_{e_1} = \frac{1}{2} h_1 - \left[h_1 - \frac{2}{3} h_1 \right]$$

$$= \frac{1}{6} h_1$$

Then the antenna gain is reduced by

$$G = 20 \log \frac{\frac{1}{6} h_1}{2/3 h_1} = -12 \text{ dB}$$

This Simply proves that the lowerd antenna height in a Valley is Very Effective in reducing the radiated power.

→ However in the area adjacent to the cell site antena, the effective antenna is the Same as the actual antenna height.

The power reduction Caused by decreasing antenna height by half is only

$$20 \log \frac{1/2 h_1}{h_1} = -6 \text{ dB}.$$

In a Forested area :

→ In a forested area, the antenna hight must be higher than all of trees ~~the locality~~ because Excessive attenuation of desired Signal will occur in the vicinity of the antenna & in its Cell boundary if the antenna were below the treetop level.

Reduction of Cochannel Interference in a cellular System :

→ The methods to be Considered for reducing the interference are

1) Increasing the Separation between two Cochannel Cells
2) lowering the antenna heights at the base station
3) Using Directional antennas at the base station

→ Method ① is not advisable because as the number of frequency re Cells increase, the number of channels per cell decreases which is directly propotional to decreasing of System Efficiency.

→ Method ② is not recommended because Such an arrangement weaken the reception level at the mobile unit.

Method ③ is a good approch ~~often~~ Especially when the number of frequency Reuse cells is fixed.

- The use of directional antennas in each cell can have two purposes
  1) Further reduction of cochannel interference if the interference cannot be eliminated by a fixed separation of cochannel cells
  2) Increasing the channel capacity when the traffic increases.

* Reduction of Cochannel Interference by Means of Notch in the Tilted Antenna pattern :

- The cochannel interference can exist even when a directional antenna is used, as the serving site can interfer with the cochannel cell.

Let us assume that a seven cell cellular system $K=7$ & the cochannel interference reduction factor q becomes

$$q = \sqrt{3N} = 4.6$$

and the cochannel cell separation D can be found

$$D = qR = 4.6R$$

with a separation of $4.6R$, the area of interference at the interference receiving cell is illuminated by the central $19°$ sector of entire transmitting antenna pattern at the serving cell.

- If three directional antennas are implemented in every cell, with each antenna covering $120°$ sector, then every sector receives interferen in the central $19°$ sector of the entire $120°$ angle at the interfering cell. These all attempts should be made to reduce the signal strength of the interference in this $19°$ sector.

- There are two ways to tilt down the antenna patterns Electronically & Mechanically.

- The electronic downtilting is to change the phases among the elements of collinear array antenna

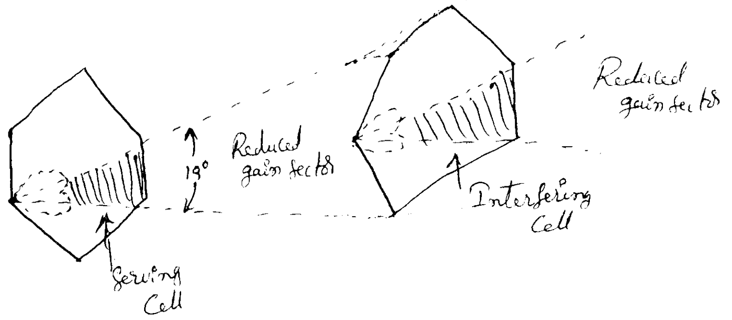
- The mechanical downtilting is to downtilt the antenna physically.

To acheive a significant gain of C/I in the interference receiving cell we should consider using a notch in the centre of the antenna pattern at the interfering cell.

- The new C/I $(\alpha C/\beta I)$ after tilting is significantly higher than C/I before tilting

$$\frac{\alpha C}{\beta I} \text{ (linear scale)} \Rightarrow \frac{C}{I} + (\alpha - \beta) \text{ (dB scale)}$$

Let us for $10°$ tilt, $\alpha = 3.75$ & $\beta = 4\,dB$ & Improved new C/I is $\frac{C}{I} + 0.25\,dB$

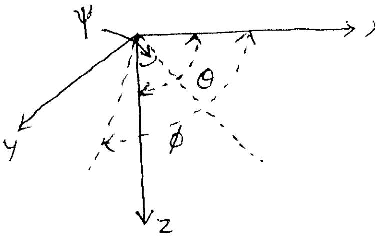


a) Reduced gain sector of two Cochannel Cells

→ The shape of the antenna pattern at the base station relates directly to the reception level of Signal strength at the Mobile unit
when the Centre beam is tilted downward by an angle θ, the o; Centre beam is tilted downward by only an angle ψ, the vary. angle in xy plane Considered as ϕ then they related as

$$\psi = \cos^{-1}\left(1 - \cos^2\phi\,(1-\cos\theta)\right)$$

If the physically Tilted angle is $\theta = 18^\circ$ then the off Centre beam ψ is tilted downward



$$\phi = \begin{cases} 0^\circ \\ 45^\circ \\ 90^\circ \end{cases} \qquad \psi = \begin{cases} 18^\circ \\ 12.7^\circ \\ 0^\circ \end{cases}$$

→ The antenna tilting angle θ may be between 22 to 24° inorder to increase the C/I by an additional 7 to 8 dB in the interfering c then we can reduce the Cochannel interference by an additional 7 to 8 d because of the notch in the mechanically tilted antenna patter

→ The Serving Cell and the interfering cell are separated by only 0.5° at most, then by tilting the antenna down by 10° the interference interfering Cell is reduced by an ~~angle~~ of additional of 0.25 dB i.e the Total Power received ~~power~~ is 4 dB less than in no tilt.

Umberella pattern:

→ The umberella pattern can be acheived by use of Staggered discon antenne. This pattern is applied to reduce Cochannel interference as the downward tilting of directional antenna pattern

In most Cellular Systems, the long distance interference due to tropospheric propagation Cause Crosstalk, interference problemes.

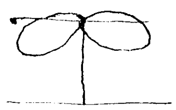
→ Elevation angle of long distance propagation in tropospheric layer Considered as

$$\theta = \tan^{-1}\left(\frac{10\ mi}{100\ mi}\right) = 5.7^{\circ}$$

Here 10 mi is tropospheric layer

100 mi is the propagation distance

It indicates that no strong power should be transmitted upward by 5° or more in order to avoid long distance propagation.



Benifits of umberella pattern :

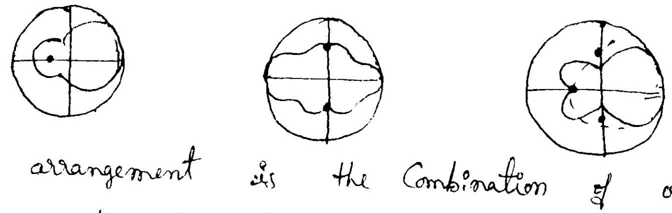
1) with a normal antenna pattern we can't raise the antenna height to cover weak spots but it is done by umberella antenna pattern for increasing the antenna height & decreasing the cochannel interference

2) The frequency reuse distance can be shortened.

Use of parasitic elements :

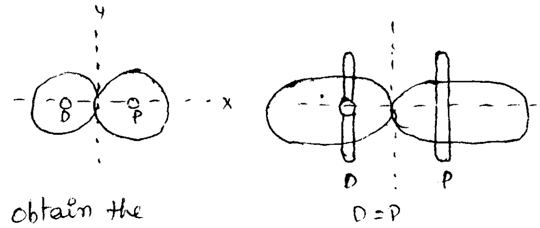
→ Interference at the cell site can be reduced by using parasitic elements, because they created a desired pattern in a certain direction. A driven antenna and a single parasite can be combined in several ways

1) Normal Spacing : A single parasite spaced approximately one quarter wavelength from the driven element. The two parasites spaced one half wavelength from the driven element.



The effective arrangement is the combination of one quarter & half wavelength parasite elements structure.

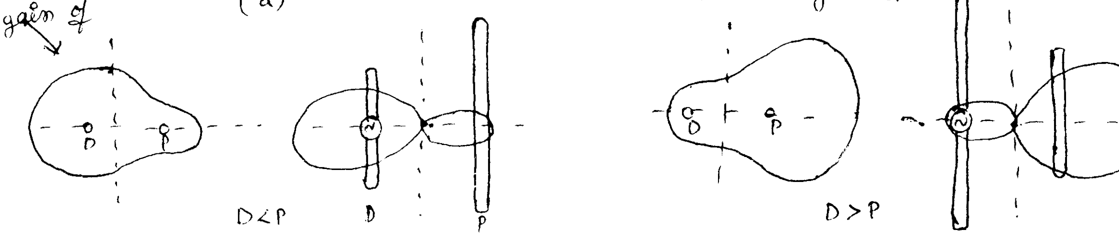
2) Relatively close spacing : In relatively close spacing two elements are placed close as 0.04λ



→ Here we can get the directive gain of 3 dB

Here we obtain the directive gain of 6 dB

Here we obtain the directive gain of 8 dB



Diversity Receiver: Diversity Scheme is applied at the receiving End of the antenna is an Effective technique for reducing the multipath fading. when the fading reduces, the reception level can be increased.

The diversity schemes can be classified as

a) Polarisation diversity
b) Field Component Energy density
c) Space diversity
d) Frequency diversity
e) Time diversity
f) Angle diversity

→ The performance obtained from any of the diversity Scheme is same and that is the Correlation Coefficient of the two received signals becomes zero.

→ The performance can also vary with different diversity Combiner techniques

a) The maximal ratio Combiner: is the best performance Combiner
b) The Equal gain Combiner: has 0.5 dB degradation as Compared with the maximal ratio Combiner.
c) The selective Combiner: has 2 dB degradation as Compared with the maximal ratio Combiner.

→ At the Cell site: the Correlation Coefficent $\rho \leq 0.7$ should be used for two branch space diversity, with this Coefficient the separation of two antennas at the Cell site meets the requirement of $\frac{h}{d} = 11$

where h is the antenna height
d is the antenna separation

→ At the Mobile unit: the Correlation Coefficient is Equal to zero for best diversity antenna, with a separation of $d = 0.5\lambda$

* Types of Non Cochannel Interference :

1) Measuring of Receiver Sensitivity :

→ For Measuring the Voice quality we have to know the parameters like

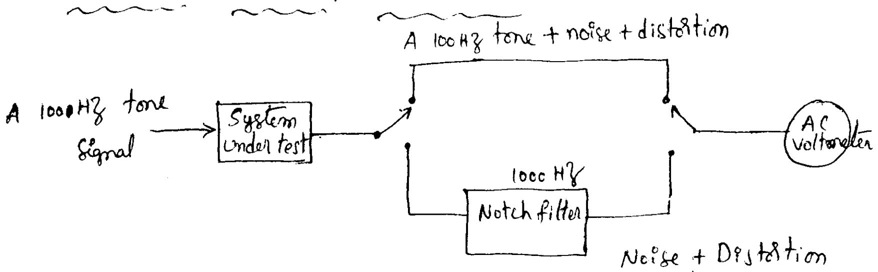
a) Carrier to Interference Ratio (C/I)
b) Carrier to Noise Ratio (C/N)
c) Signal to Noise Ratio (S/N)
d) Signal to noise and Distortion ratio (SINAD)

→ In a mobile radio Environment, because of the multipath fadings and Variable mobile Speeds are the major factors for measuring the Voice quality

→ The methods that help to Correct the imbalance are

a) Let the received Carrier level be high to increase Signal level
b) Let the receiver Sensitivity be high to lower the noise level
c) Maintain a low distortion level in the receiver to increase SINAD
d) Use a diversity receiver to reduce the fading
e) Use a good System design in a mobile radio Environment and a good adjacent channel rejection to reduce the interference

2) Measurement of SINAD :



a) The SINAD of baseband o/p signal is defined as the ratio of the total output power to the power of noise pulse distortion

$$SINAD = \frac{\text{Total o/p Power}}{\text{noise distortion}} \Rightarrow \frac{\text{Signal + noise + Distortion}}{\text{noise + Distortion}}$$

In Cellular radio Equipment, an input of −116 dBm is Equalent to a SINAD of 12 dB.

b) A high Signal level Can be measured by

$$SINAD = \frac{\text{Signal + Noise}}{\text{noise}} \Rightarrow \frac{\text{Signal}}{\text{Noise}}$$

c) Receiver sensitivity can be measured by modulating with a 1KHz tone at 3KHz peak modulation deviation

1KHz Tone → 3KHz Peak deviation → Fm Rx'er under test → SINAD meter

→ The signal generated attenuator should be adjusted untill the SINAD meter shows 12 dB. then the microvolt o/p is read from the attenuator dial, which reveals the "12 dB" of SINAD sensitivity of the receiver.

→ If the receiver noise is higher, the minimum i/p signal level should also be higher in order to maintain the 12 dB SINAD.

d) Noise voltage can be measured from a C-Message weighting filter on any kind of telephone circuit.
The frequency response of C-message weighting filter is based on human voice. The noise measured at the o/p of filter is the noise with holding in the speech frequency spectrum

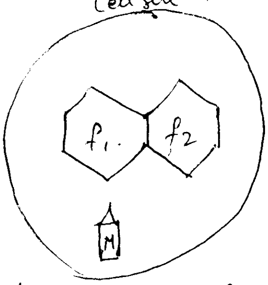
e) The SINAD meter also can be used as distortion meter if the noise is very low in comparison to the distortion.

Types of Non Cochannel Interferences :
1) Adjacent channel interference
2) Next channel interference
3) Neighbouring channel interference
4) Near End - Far End interference

→ Adjacent channel Interference : Adjacent channel interference can be eliminated by the frequency assignment

Cell site 1

$f_1 \rightarrow$ 800 - 850 mHz
$f_2 \rightarrow$ 851 - 890 mHz

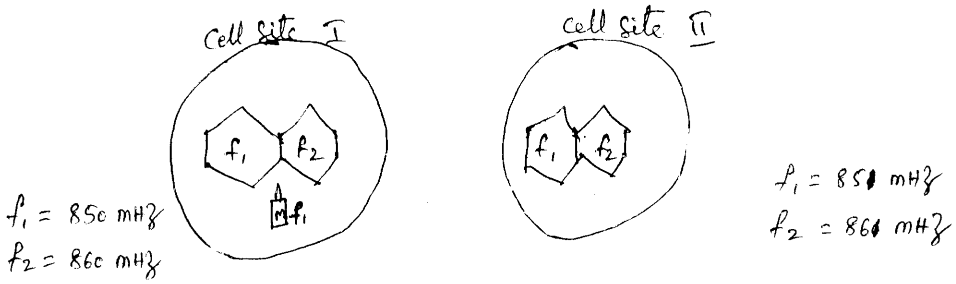


$f_1 \rightarrow$ 850 mHz
$f_2 \rightarrow$ 851 mHz

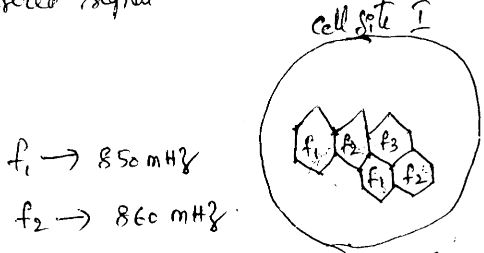
when the mobile wants respond for 'f_1' of 850 mHz. But because of interference & moving nature of mobile, it will operate for 'f_2' of 851 mHz is called adjacent channel interference.

Next channel Interference :

→ Next channel interference affecting a particular mobile unit cannot be caused by transmitters in the common cell site, but must originate at several other cell sites if the system is not designed properly



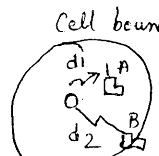
Neighbouring channel Interference : The channels which are several channels away from the next channel will cause interference with the desired signal.



when the mobile operates for f_1, then if it will operate for f_2 of next channels will cause interference with the desired signal. i.e a fixed set of serving channels is assigned to each cell site.

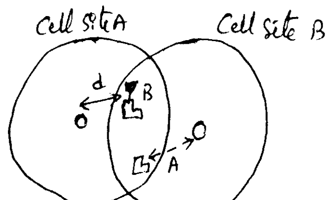
Near End - Far End Interference :

In one cell : The mobiles in a given cell are usually moving some mob units are close to the cell site & some or not. The close in mobile uni. has a strong signal which cause adjacent channel interference. At the situation, near end - far end interference can occur only at the reception point in the cell site



→ If a separation of 5 B (five channel Bandwidths) is needed for two adjacent channels in a cell inorder to avoid the near end - Far end interference

In cells of two systems :



→ In thes situation adjacent channel interference can occur at both the cell site & mobile unit

→ The solid arrow indicates the interference ma occur at cell site A & dotted arrow indica that interference may occur at mobile unit

→ Thus the frequency channels of both cells of two systems must be coordinated in the neighbourhood of the two system frequency bands.

1) a) Explain how cochannel interference is measured in real time mobile radio environment

b) Prove that K=7 cell pattern does not provide a sufficient frequency reuse distance even when an ideal condition of flat terrain is assu

2) a) Distinguish b/w Co channel interference & Non co channel interference

b) Discuss various techniques to measure the co-channel interferences

3) a) Explain the Diversity receiver ?

b) Explain the effects of cell site antenna heights

4) a) Compare the cochannel interference performance of a directional antenna system at K=7 & K=4

b) what is tilting antenna ? How can these antenna patterns reduce the cochannel interference

5) a) Define the cochannel interference reductions using the directional antenna system ?

b) Describe the different types of non cochannel interference in the cellular system. How are they dealt ?

6) a) Define cochannel interference. How is it measured at mobile unit

b) Describe the effect of antenna parameters on the cell interfe

7) a) Discuss the effect of Near End - far End interference of mobile uni

→ Method (3) is a good approch Especially when the number of frequency reuse cells is fixed.

The use of directional antennas in Each cell can have two purposes

1) Further reduction of cochannel interference if the interference cannot be eliminated by fixed separation of co channel cells

2) Increasing the channel capacity when the traffic increases