Interference

Introduction to Co-channel Interference:-

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

→ 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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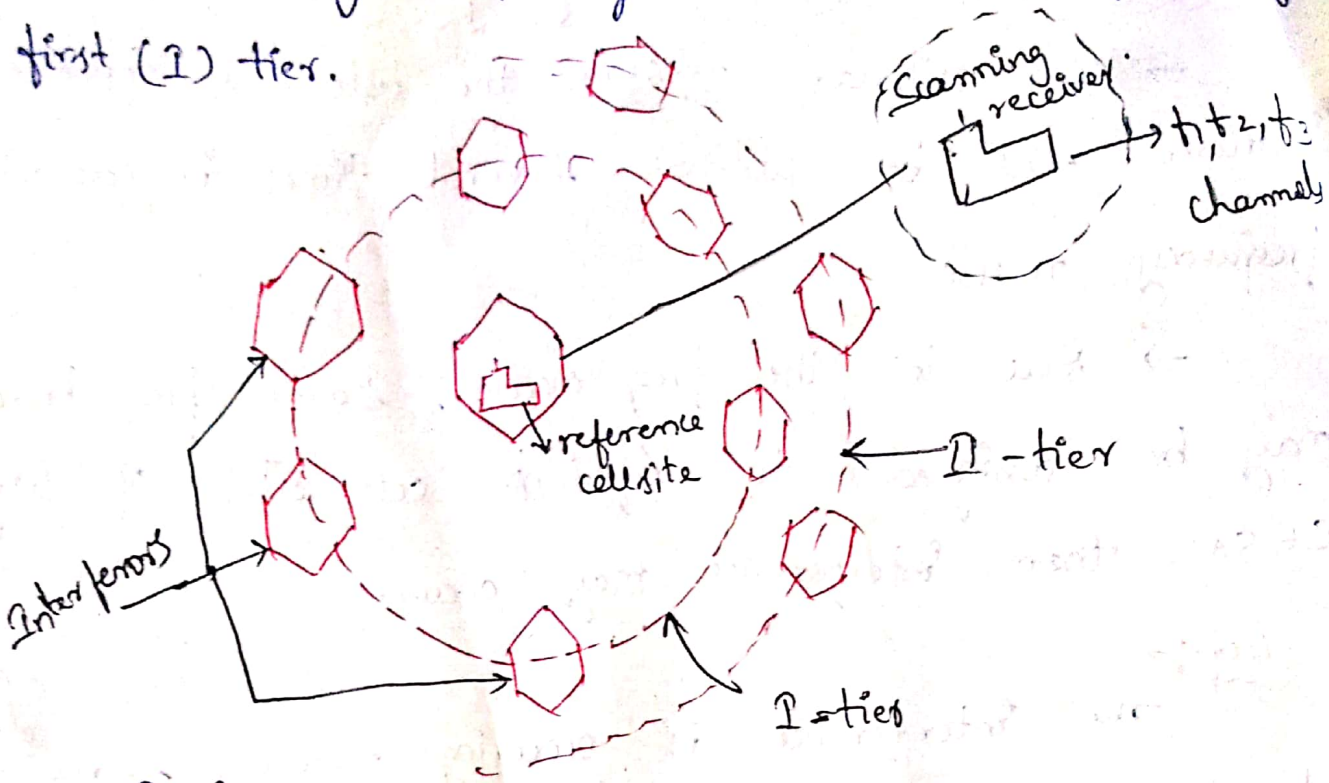
Test-1 Finding cochannel interference areas from mobile receiver

→ Assuming $k=7$ System with 6 interferenors 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 $\geq$ 18 dB then there is no interference and no coverage issues system is properly designed.
(greater than)

→ 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 ~~then~~ and $C/I \cong C/N$ 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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→ 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 are estimated.

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

Real time Co-channel interference measurement at mobile transceiver :-

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

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

→ 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

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

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

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

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

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

→ For the computation of r, 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)

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

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

→ 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 $\boxed{q = D/R}$

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

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

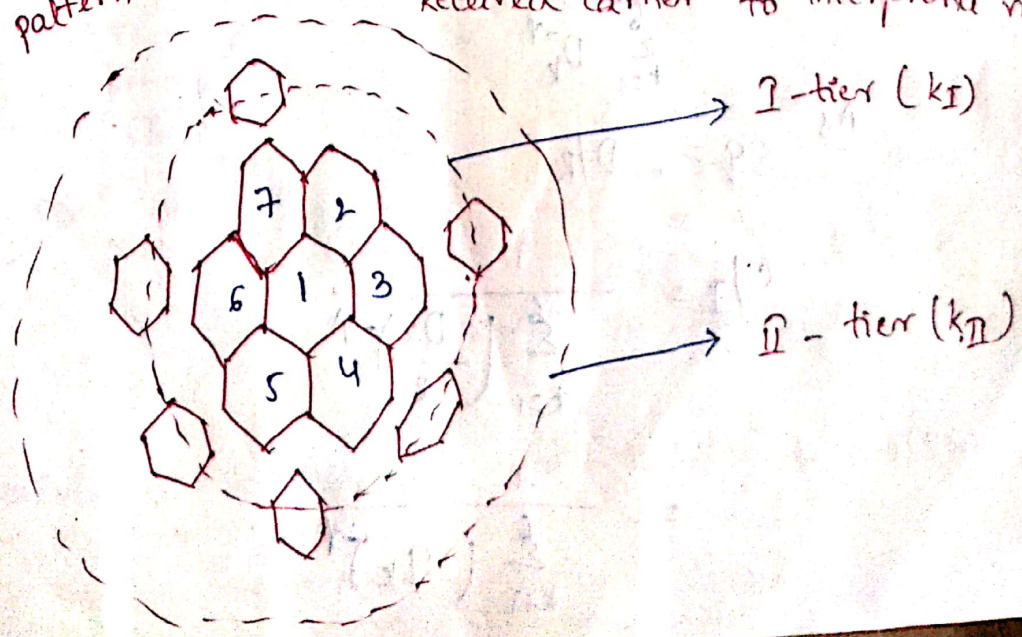
→ Reuse distance is a function of K_I & C/I

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

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

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

k=7 pattern



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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

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

→ we know that the carrier power is given by

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

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

where γ - propagation path loss slope

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

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

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

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

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

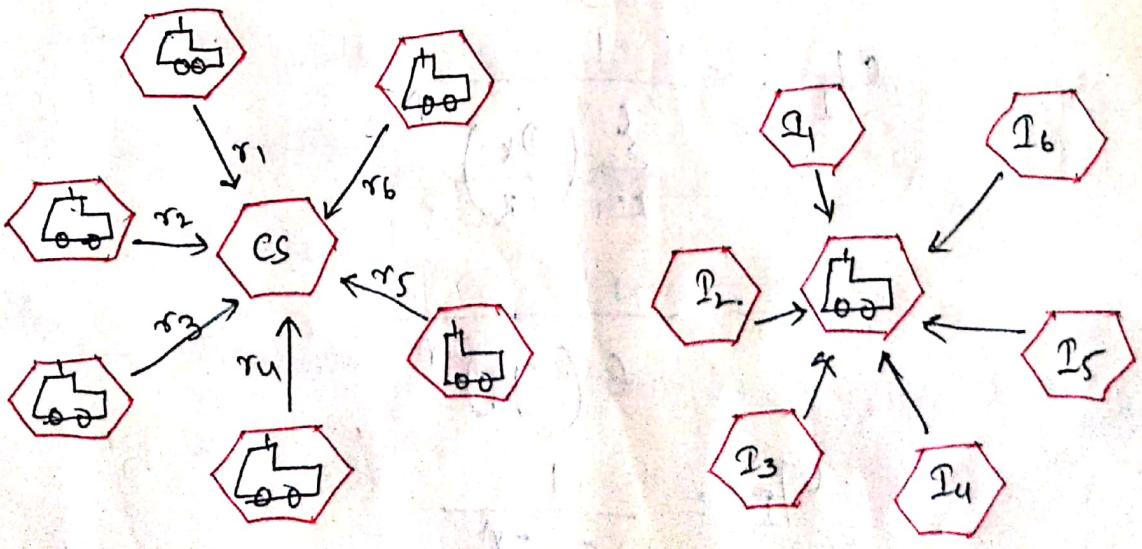
Desired C/I from a Normal case in a Omni directional Antenna system :-

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 of 3 components C, I, N

C → Carrier, I → Interference, N → Noise

→ In interference environment, Noise is negligible

→ C/I ratio is estimated from the received power

→ It is given by,

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

→ 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 $q = D/R$

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

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

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

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

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The desired C/I to be maintained is

$$C/I = 18\ dB$$

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

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

After simplification

$$q = 4.41$$

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

For the standard equation,

$$C/I = 18\ dB \qquad n = 4$$

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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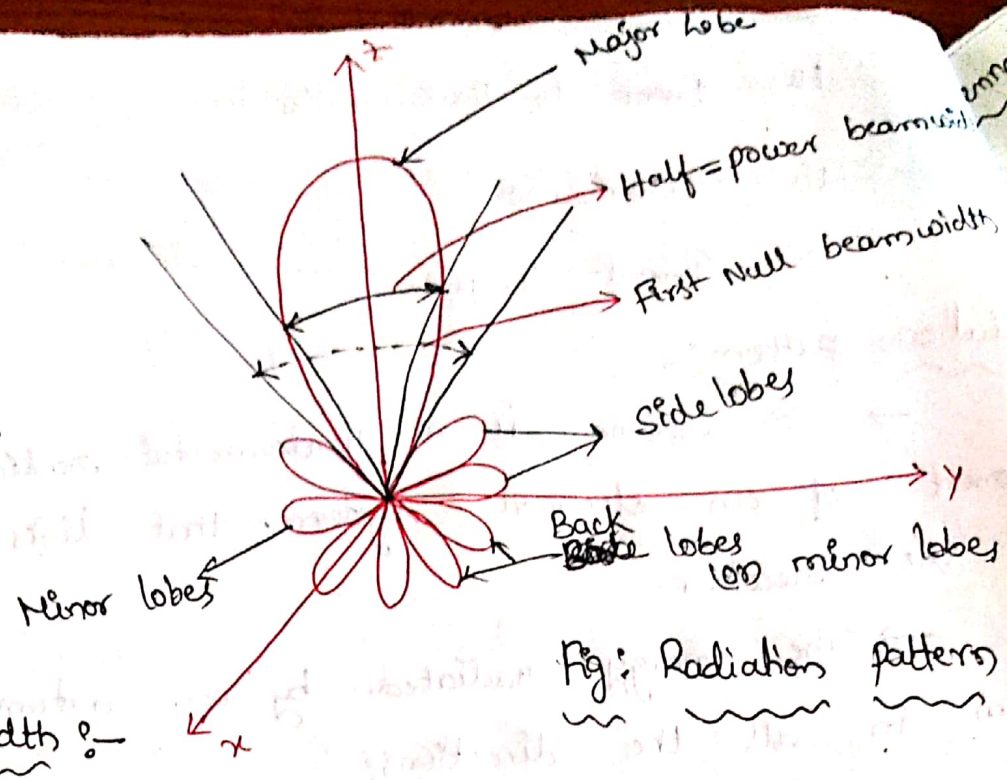

Fig: Radiation pattern

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".

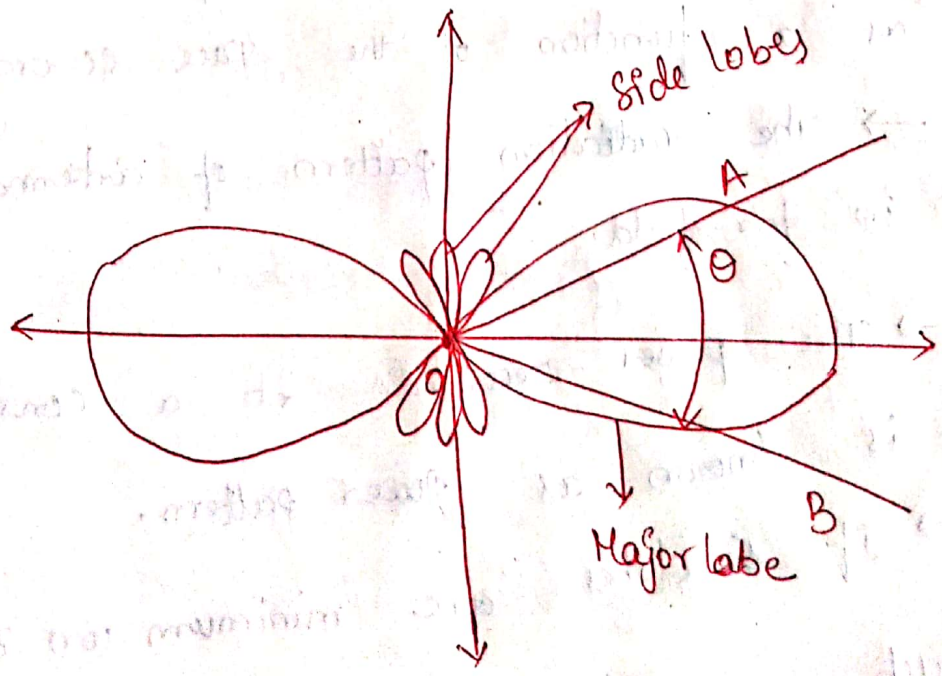

Fig: Beam width

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Antenna Gain :-

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

$$\boxed{W = E \cdot H}$$

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.

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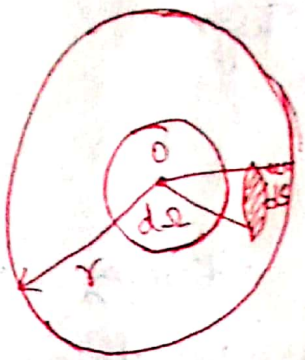
→ Let the ds is elemental surface area, r is the radius & dΩ be the solid angle, then

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



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'.

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

→ 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."

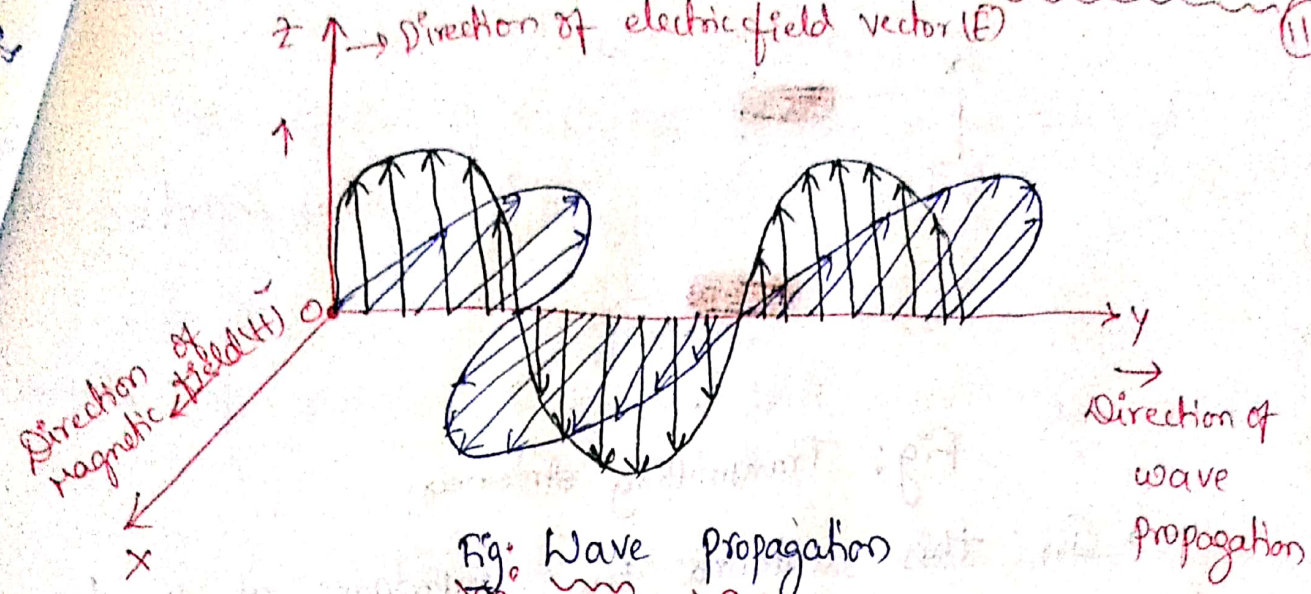

Fig: Wave propagation

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.

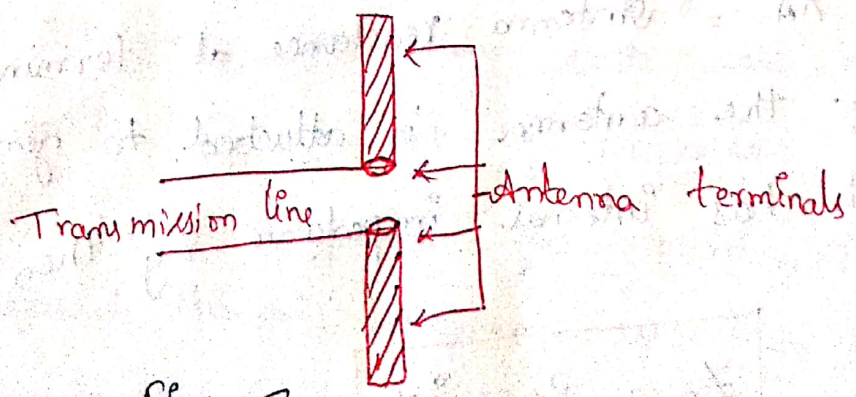

Fig: Transmission line with antenna as load.

→ 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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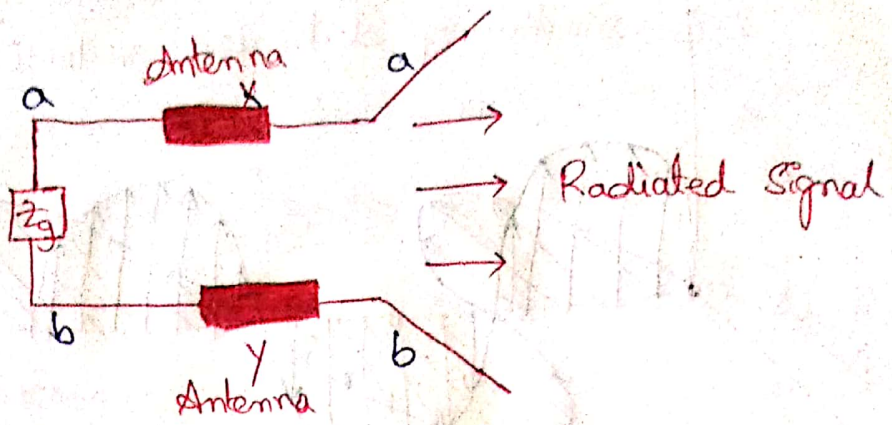

Fig: Transmitting Antenna.

→ 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,

$$\boxed{Z_A = R_A + jX_A}$$

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

$$\boxed{Z_g = R_g + jX_g}$$

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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 ($\cong$ 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 tilted antenna pattern.

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(viii) Thus, the notch in the mechanically tilted antenna 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 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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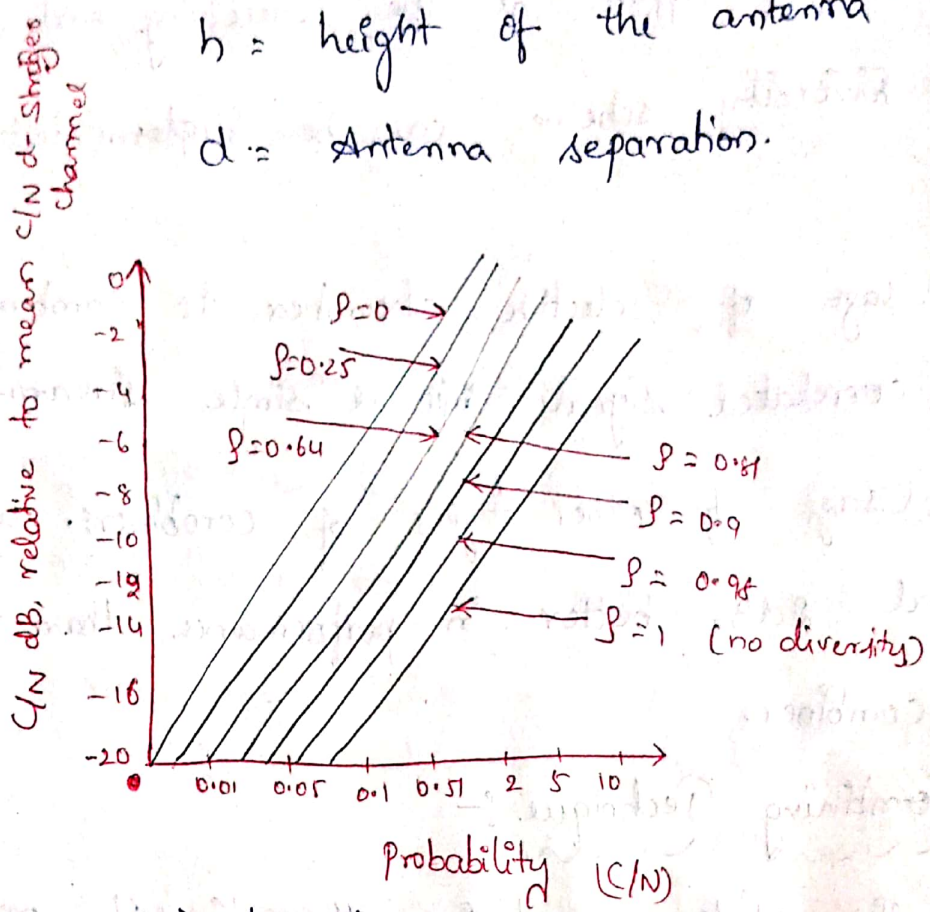
$$\boxed{\frac{h}{d} = 11}$$

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 $\rho = 0$ and $\rho = 1$ are compared.

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

→ 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 Interference:-

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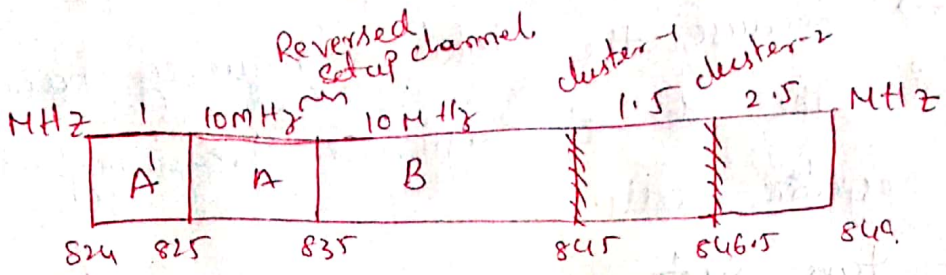
→ The frequency channels of both cells of the two systems must be co-ordinated in the neighbourhood of the two system frequency bands.

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

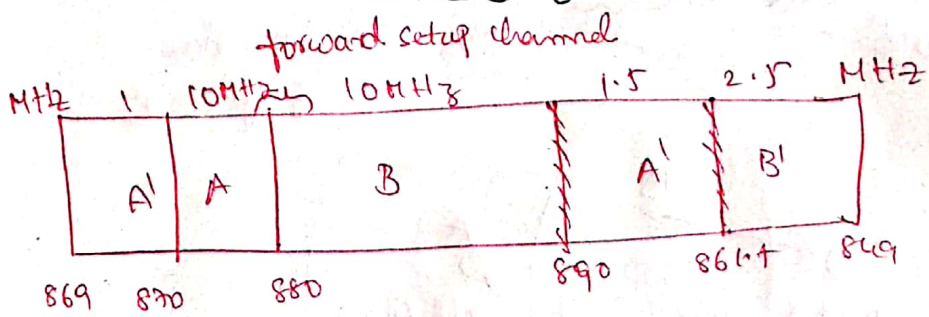
a) Interference caused on the setup channels.

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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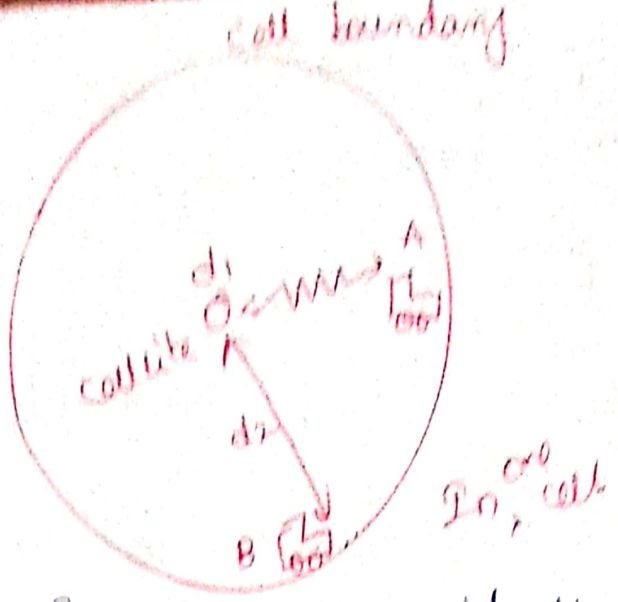
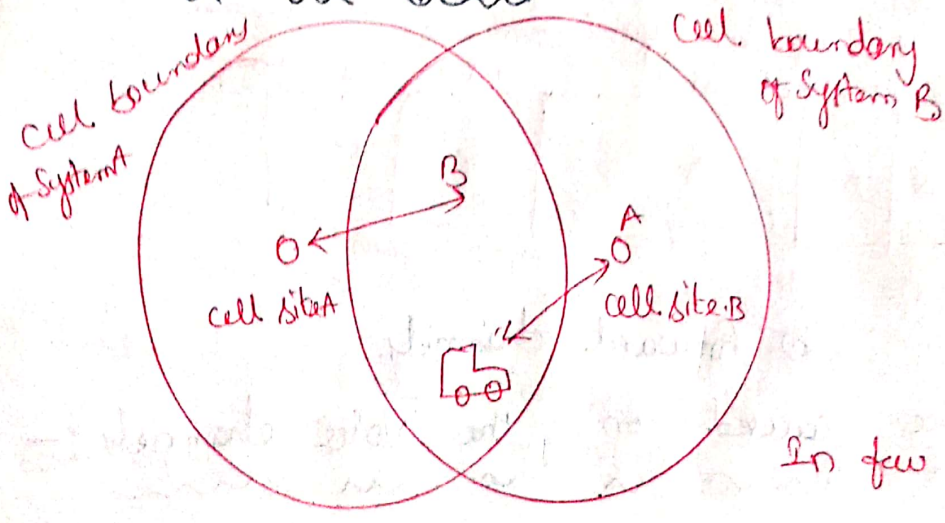


→ In order to avoid the near-end for interference, the separation of five channels bandwidth is needed for few adjacent channels in a cell.

→ 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 :-

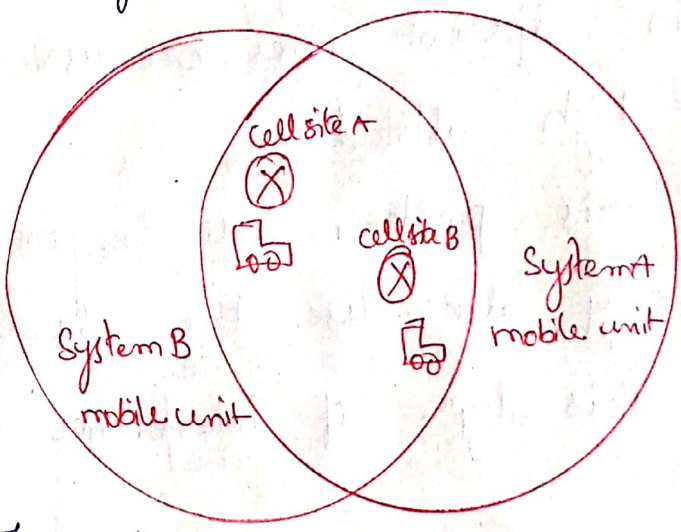
In this case, we need to consider the following two cases

(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 ~~sgl~~ city.

→ The interference products will produce the cross talk by leating 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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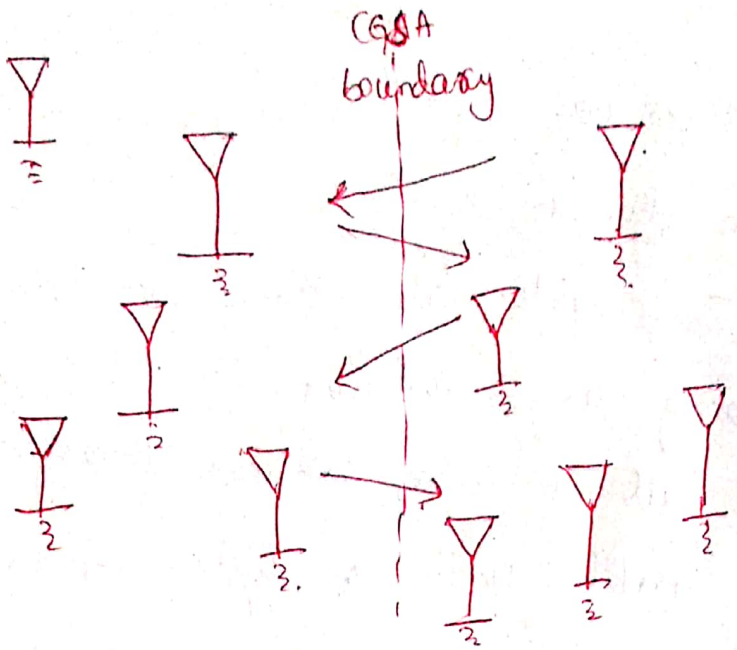
usage of two systems operating at same fre band and in two adjacent cites.



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

→ 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 two 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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(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 overwater 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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