PBERI Wing Plan – A Cell Layout Strategy

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Abstract— **The need of the hour in the field of cellular and mobile communication is to improve the ability of the cell to service more number of subscribers (traffic) at the given bandwidth with least interference and with minimum power levels. We have suggested a cell layout strategy called "PBERI Wing Plan" which serves the important factors of a cell. The expansion for PBERI is 'Power and Bandwidth Efficient with Reduced Interference' model for a cell layout strategy. The system consists of base stations with multi antennas with full frequency set access. So total area could be covered by transfer of control from one antenna to another of the same base station. This is achieved because each antenna in a base station has the ability to service the available frequency set allocated for the particular area, thereby providing a better coverage and the need for high power transmission is solved by multi antennas covering the area. This plan serves three important factors in a cell. First, the bandwidth is very much efficiently reused and the system is capable of providing frequency reuse ratio of 10.4 for a cluster size of 7. The co channel interference is greatly reduced and the carrier to interference ratio of 27 dB could be achieved for a cluster size of 7.**

I. INTRODUCTION

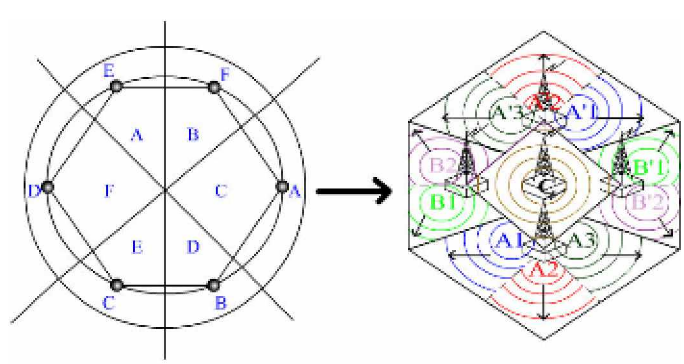
Although in theory as cells are split into smaller sizes, the interference received from the reuse cells in irregular propagation in dense urban areas, and non circular cell shapes leads to increase in interference being received from surrounding cells all using the same channel set. One way of reducing the power level of interference is to use directional antennas at the base stations, with each antenna illuminating the sector of the cell and with the separate channel set allocated to the each sector. There are two commonly used methods for sectorization, using three 120 degree sectors or six 60 degree sectors, both of which reduce the number of prime interference sources. The three sector case is generally used with seven cell repeat pattern giving an overall requirement for 21 channel sets. The improved channel rejection in the six sector case, however, particularly the rejection of secondary interferers, results in a four cell repeat pattern being possible, but needs an overall requirement of 24 channel sets.[2]

A disadvantage of sectorization is that the large number of channel sets required results in fewer channels per sector, and thus a reduction in trunking efficiency. This means that the total traffic which can be carried for a given grade of service reduced. An already available cell layout strategy known as the Stockholm ring can be employed as shown in the figure 1 [2]. The central site can have access to all the available channels which are sectored in 60 degree co sited sectors. This strategy is suitable only for the walled European Roman type of city such as Avignon in France, Chester in England and Solothurn in Switzerland. These drawbacks are eliminated in PBERI (suggested) model.

II. PBERI CELL ARCHITECTURE (SUGGESTED MODEL)

The PBERI model for a cell in a cellular mobile system is a "Power and Bandwidth Efficient with Reduced Interference model". In the system each cell consists of five base stations. This is similar to Stockholm's ring plan [2] where seven base stations are employed. But this system proves to be more efficient in both power control and frequency (Bandwidth) reuse. The cell which is hexagonal in shape is divided into five areas each consists of a base station .The architecture (splitting) of a cell is shown in the figure 1 which resembles four wings surrounding a central square region

In this architecture, the whole cell is divided into 5 regions as shown in the figure 1. So, the frequency available for the cell is also divided into 5 bands. The frequency band allocation to each region depends upon the traffic in the region.



Stockholm ring plan   PBERI wing plan

Each cell consists of a central square region (C) surrounded by four ring shaped regions (A, A', B, B'). The regions A and A' has three directional antennas A1, A2, A3 and A'1, A'2 and A'3 respectively as shown in the figure 1. The regions B and B' has two directional antennas B1, B2 and B'1 and B'2 respectively. The central square region C uses a single isotropic antenna.

The bandwidth allocation in each area could be preferably done in the following way for efficient bandwidth re use:

1) The areas A and A' use the same frequency set, but in reverse order of allocation as shown in the figure 1 for greatest distance of separation between them. Similarly area B and B' use the same frequency set.
2) The central area uses an isotropic antenna and it should be provided with more bandwidth and high traffic should be assigned to this region.
3) Another criteria for call establishment with the mobile unit is antenna selection i.e., the MTSO has to make a best choice of antenna through which mobile could be reached. This criterion is useful in power control. If the mobile unit in coverage of first antenna and when it moves to coverage of second antenna then no need to increase the power radiated but we can switch the call to the second antenna. Because each antenna in a region is capable of radiating all the frequency sets available for a particular area. This provides a good power control in addition to efficient frequency reuse.

III. HIGHLIGHTING FEATURES

This architecture has the following highlighting features

1) The four corners of the central square area are chosen for placing the four base stations for the other four wing shaped areas. This type of base station placement reduces the co channel interference in the frequency reuse areas. In the figure 1 the area A & A' use the same frequency set. Similarly areas B & B' uses the same frequency set. The co channel interference between the area A-A' and B-B' is very much reduced and it is negligible due to following reasons

a) The placement of base stations at the corners of the central square area rather than at its sides provides a diagonal distance (greatest distance between two points in a square) of separation between the base stations where the frequency is re used.

b) The use of directional antennas at the four corners surrounding the centre isotropic antenna provides the reduction of interference.

IV. ANGLE OF SEPARATION

The important consideration in this architecture is the angle of separation between the three directional antennas 1, 2, 3 in a base station.

A cellular model for this system was synthesized and experimentation showed that the angle between the central antenna '1' and the side antennas should be 52.5 degree to cover the whole area. The placement of three antennas has to be made with care if it is not placed at exactly it will cause NULL areas. NULL area is an area in a cell where the base station could not establish connection with the mobile unit. The figure 2 shows the effect of antenna angle on the NULL area.

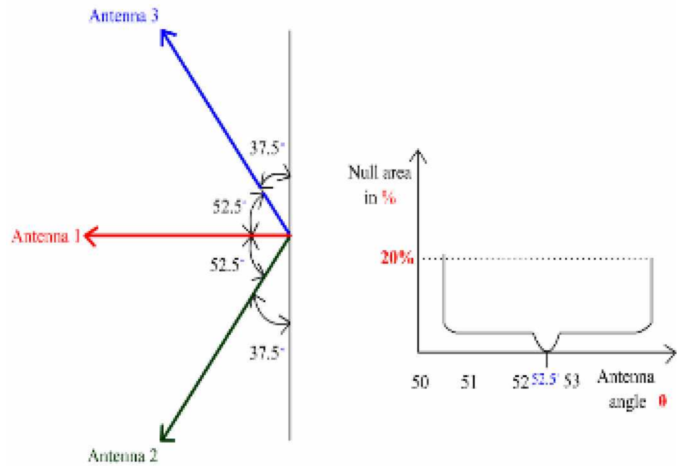


Figure. 2. Angle of separation

The size of the NULL area increase more that 20% of the total area then the mobile unit at certain points in the cell becomes un reachable for the base station .

V. REDUCTION OF CO CHANNEL INTERFERENCE

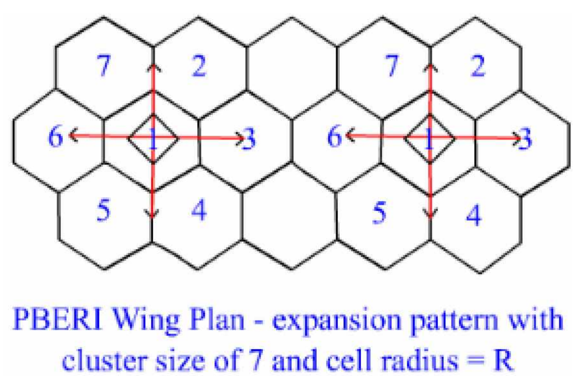


Figure. 3. PBERI Wing plan – expansion pattern.

The figure 3 shows the actual cellular system with PBERI architecture being employed in each cell. The co channel interference in the areas shown by upward arrow marks are absolutely nil in horizontally parallel co cells. Similarly the co channel interference in the areas shown by horizontal arrow marks are absolutely nil in the vertically parallel co cells. The horizontally arrow marked in each cell cause interference in horizontal parallel co cells. Similarly the upward arrow marked areas in each cell cause interference in vertically parallel co cells .But this co channel interference is very negligible because of two valid reasons

1) The distance with that the radiated power from an antenna has to travel to reach a co cell is 5 times the cell radius (5R).
2) The inverse fourth power propagation law states that the received power at any point is inversely proportional to fourth power of distance of separation between the transmitter and receiver.[3]

$$\mathrm{Re} \quad \frac{k}{(Dis\tan ce)^4}$$

In this case distance = 5R.

Therefore $\mathrm{Re}\,ceivedpowe = \frac{k}{(5R)^4} = \frac{k}{625 * R^4}$

This value is very much negligible to cause co channel interference. So this model provides absolutely nil co channel interference.

VI. POWER CONTROL IN PBERI MODEL

The MTSO controls the transmitted power levels at both the cell sites and the mobile units. The MTSO control over the power level is more efficient in this model because the working power level of each base station is considerably low compared to other models.

The advantages of having the MTSO control the power levels are as follows

1) Control of the mobile transmitted power level:

When the mobile unit is approaching the cell site, the mobile unit power level should be reduced for the following reasons.

a) Reducing the chance of generating inter modulation products from a saturated receiving amplifier.

b) Lowering the power level is equivalent to reducing the chance of interfering with other co channel cell sites.

c) Reducing the near-end-far-end interference ratio.

2) Control of the cell site transmitted power level:

When the signal received from the mobile unit at the cell site is very strong the MTSO should reduce the transmitted power level of the radio at the cell site and at the same time lower the transmitted power level at the mobile unit. Advantages are as follows:

a) For a particular radio channel the cell site decreases significantly, the co channel re use distance increases and the channel interference are inversely proportional to co channel reuse distance.

b) The adjacent channel interference in the system is also reduced. However in most cellular systems it is not possible to reduce only one or a few channel power levels at the cell site because of the design limitation of the combiner. The channel isolation in the combiner is 18db. If the transmitted power level of one channel is lower, the channel is having high power levels will interfere with this low power channel. In this model an unequal power combiner is designed for the system operator so that the power level of each channel can be controlled at the cell sites.

3) The power transmitted, small cell is always reduced, and so is that from a mobile unit. The MTSO can facilitate adjustment of the transmitted power level of the mobile unit as soon as they enter the boundary.

VII. BASE STATION ANTENNA

The base station antennas should direct signals to the wanted coverage area as effectively as possible. In the case of the cellular systems, it is also beneficial that the distribution of the power is restricted accurately in order to minimize the frequency reuse distance in the system.

VIII. TRADIITONAL NON ADAPTIVE BASE STATION ANTENNA

The gain of the base station antennas towards the coverage area should be as high as possible. On the other hand the coverage area should be large, so the directivity can not be increased much in the horizontal plane. This is the case in traditional non adaptive antennas. Thus, the gain is increased by decreasing the beamwidthin the vertical plane, which results typically in the gain values of 5 to 17 dB. The horizontal plane beamwidth varies typically between (50-360) degree. Directive antennas are used in the sectorised base station sites usually having 2 to 3 sectors. In a typical 3-sector configuration the beamwidth of a single antenna is usually 65 degree instead of the obvious 120 degree to optimize the coverage and the interference in the network. The vertical beamwidth varies typically between 10^{o} and 70^{o}. The beam of the BS antennas may be tilted (typically less than 15^{o})down to reduce the interference level in neighboring cells. Sometimes the beam is shaped so that the vertical plane side lobes above the main beam are minimized. In addition to the radiation characteristics and beamwidth, important aspects of BS antennas are weight, wind load, size and appearance. Common types are dipoles, corner reflectors, patch arrays and horns. By adjusting the angle of the corner reflector between 60 and 270 degree, Horizontal half power beam widths of 60 to 180 degree can be obtained.

IX. BASESTATION ANTENNA USED IN THE PBERI MODEL

Adaptive base station antennas: In terrestrial mobile communications, the user distribution and propagation channel for user changes continuously. The basic task of the adaptive BS antenna is to improve the signal to interference and noise ratio (SINR) of single connections and maximize the coupling between the base station and the wanted user while minimizing the coupling between the other users. This may be accomplished equally well both in the uplink and the downlink direction. This requirement creates an obvious optimization problem as the complex multipath propagation channel can usually be fully detected at the BS and thus information required for adaptation is available only for the uplink. The respective information for downlink must be either estimated, which ia difficult for FDD systems where the duplex separation is often larger than correlation bandwidth of the propagation channel, or feedback control should be used, which increases the required signaling capacity. Therefore, the downlink direction is critical for the system gain obtained through the use of adaptive BS antennas. The benefits obtained by the adaptive BS antennas can be classified as:

1) Increased capacity due to increase of SINR.
2) Increased coverage or range due to higher apparent gain of the BS antenna.
3) Reduced output power especially at the MS, where the battery life time is critical.

Beamforming:
The adaptive BS antenna used in the suggested model is to use an **adaptive beamforming** technique. Adaptive beamforming implemented at RF or baseband can be used to form pattern maxima to wanted directions and null to unwanted directions as shown in the figure 4 [7]. However, due to the limited number of antenna elements in practical adaptive BS antennas, only a few maxima and nulls can be realized simultaneously. Further broader multiple-null minima may be required, because the path between BS and MS is spread in angular domain due to local scattering around the mobile unit.

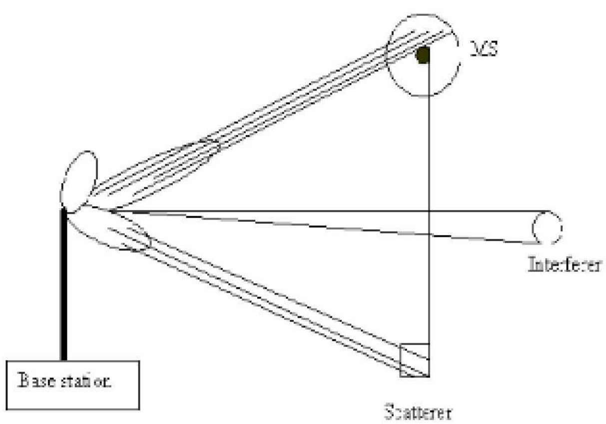


fig. 4. beamforming with maxima toward wanted signal paths and a broad minima toward an interferer.

X. MOBILE STATION ANTENNA

The antenna for a mobile phone should enable connection to the BS in all locations and orientations for the mobile unit. For small cellular, hand-helds, the incoming field consists of several multipath signals so the antenna receives several signals with random directions of arrivals and polarizations. Therefore it is difficult to set any clear requirements for the antenna. In most environments vertical polarization dominates making a vertical polarized omni directional antenna, like a vertical dipole, preferable. But the head of the user may block some of the signal. The most critical performance goals especially for the antennas of small portable phones are adequate bandwidth and high efficiency, which are difficult to achieve simultaneously for small antennas. As small antennas for cellular systems are usually self resonant, their performance can be evaluated using the unloaded quality factor, from which the bandwidth with certain matching criterion at the edge of the band can be calculated in the following way,

$BW=(S-1)/Q_u$^0.5.

Where,
BW=relative impedance bandwidth, dimensionless.
S=VSWR at the edge of the frequency band, dimensionless.
Q_u=unloaded quality factor of the antenna, dimensionless.

This equation holds for the situation where the matching of the antenna is perfect at the center frequency, i.e. with the critical coupling of the resonant antenna to feed circuitry. The typical matching criteria are return loss of 10dB giving S=1.9 and BW=2/3* Q_u. About 10% wider bandwidth can be obtained with slight over coupling.

XI. CONCLUSION

All the highlighting features of the suggested cell layout strategy are explained above. This cell layout strategy improves the frequency reuse ratio, increases the carrier to interference ratio, and provides a good power control. The table 1 shows a comparative performance level of the UK TACS system at present and how it would be if PBERI is employed. The table clearly indicates that the PBERI model can be employed in a cell to enhance the capacity of the cell. [4].

Cluster size N	Reuse Ratio (TACS)	Reuse Ratio (PBERI)	Carrier to interferenc e ratio C/I(TACS)	Carrier to interference ratio C/I(PBERI)
3	3	4.2	11	18
4	3.5	5	14	23
7	4.6	6.2	18	27
9	5.2	7.3	21	30
12	6	8.1	23	32
21	7.9	11	28	37

Table. 1. Comparative performance of TACS and PBERI.

The reuse of the frequency also improves the maximum number of channels per cell (b). In this system we can achieve a maximum of b=136 channels for a cluster size of 3. The value of b=66 for a cluster size of 7 in PBERI which is only 39 for a TACS system

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XII. REFERENCES

[1] Macario R.C.V, 'CELLULAR RADIO' Second edition, McGraw Hill, 1990.
[2] Lee C.Y, 'Mobile Cellular Telecommunication System' Second edition, McGraw Hill, 1989.
[3] Lee C.Y, 'Mobile Communication engineering' 1998.
[4] Lee C.Y, 'Mobile Communication Design Fundamentals', John Wiley, 1993.
[5] Parsons and Gardinar, 'Mobile Communication systems', Hallstead Press, 1988.
[6] A.B. Carlson, 'Communication System', McGraw Hill.
[7] 'Mobile Communication' Second edition Jochen Schiller.
[8] Lu, W.(2002) 4th generation mobile initiatives and technology, IEEE communication magazine.
[9] J.Proffitt, 'Portable Cell Site', 36 th IEEE vehicular technology conference, Dallas, Texas, May 1986.
[10] Anderson, J.B.Rappaport 'Propagation Measurement and Models for Wireless Communication Channels', IEEE communication magazine 1995.
[11] GSM association (2002) http://www.gsmworld.com/.
[12] 3G Americas (2002) http://www.3gamericas.com/.
[13] Wireless World Research http://www.wireless-world-research.org/.