SindhUniv. Res. Jour. (Sci. Ser.) Vol. 47(3): 585-590 (2015)

SINDH UNIVERSITY RESEARCH JOURNAL (SCIENCE SERIES)

Optimum Cell Sectorization for Capacity Enhancement

S. ABBASI[++], S. SHAH, F. KHUHAWAR*, R. SHAH, N. MEMON

Institute of Information and Communication Technology, University of Sindh, Jamshoro, Sindh, Pakistan

Received 11th April 2015 and Revised 5th September 2015

Abstract: Adoption of new technologies is expensive for existing systems; cell sectorization is traditional way to increase its capacity, where system capacity and sector order have linear tradeoff. Moving to higher order (3, 4, 6) to achieve higher capacity brings up the problem of beam boosting. Thus, introduces interference and negatively impacts on system throughput. This work is focused on the analysis of systems with different number sector antennas and suggests the best selection for the optimum performance. Proposed work illustrates and quantifies the specific benefits of the sector antennas in terms of coverage, system capacity, signal quality, and system cost.

Keywords: Cellular systems, Sectorization, Interference, Capacity and directional antenna.

1. INTRODUCTION

Cellular communication has been one of the fastest growing technology in the world. The rapid growth of wireless telecommunication establishes the need for capacity evolution methods for the cellular systems of today (Madfors *et al.*,1997). System capacity can be enhanced by adopting new sophisticated technologies, such as Code Division Multiple Access (CDMA) (Lee, 1991), Adaptive Antenna Arrays (Garg and Huntington, 1997), Smart Antenna (Winters, 1998), etc.

These techniques are capable of handling high interference, increasing system capacity in addition to increasing the cost to replace base station equipment (Wang and Leung, 2000). Proposed work is based on a traditional technique to enhance system capacity: cell sectorization; it is an economical solution to enhance system capacity of existing cellular networks without change of existing equipment. This reduces the additional cost for adoption of new technologies employed with smart antennas, adoptive beam antenna and steerable antennas. The work did not consider the analysis of these advance systems on the basis of proposing of economic solution for existing systems. The proposed work focused on analysis of sector antennas with 60, 90 and 120 degrees. The work also highlighted the problems associated with higher order sectorization. Suggest a system with maximum capacity and coverage with nominal interference level.

To support a large number of subscribers, service providers must utilize the limited spectrum in a more efficient manner by using frequency reuse technique, which introduces co-channel interference in cellular system (Akella *et al.*, 2008), while in cellular systems the channel capacity heavily depends upon the interference caused by the signal power of other users, By carefully controlling the transmission of signals to directions where they are really intended, directional antennas cut down the co-channel interference. This results in a higher carrier-to-co-channel interference ratio (Kim, *et al.*, 2003).

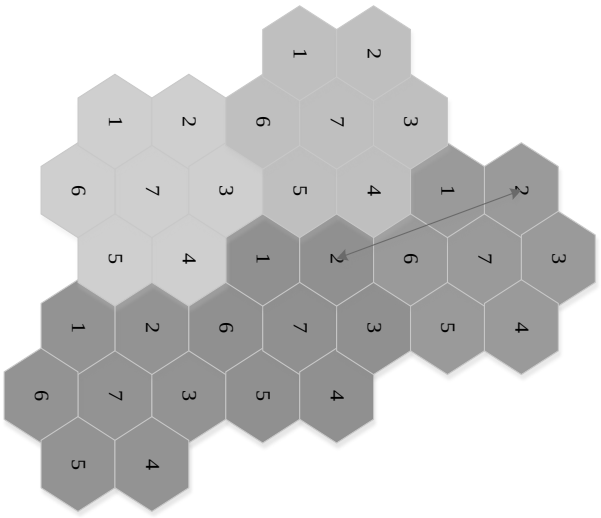


Fig. 1 : Frequency reuse with Co-channel Interference

Cell sectorization is used extensively to increase the capacity of cellular systems (Sabharwal, Avidor and Potter, 2000) and typically, a cell within a cellular network grows from minimal number of sector (omni-cell) to more sectors (3-sector or more) in response to the growth of tele-traffic demand.

[++]Corresponding Author Email: shazia.abbasi@usindh.edu.pk ; Tel.: +92-334-2631661
* Institute of Advanced Research Studies in Chemical Sciences, University of Sindh, Jamshoro, Sindh, Pakistan

Presently Cellular systems are working on three antennas with 120 degree or six antennas with 60 degree architectures.

Six sector cells have some problems as its relative narrow beam shout to other cells and produce interference, it require more base station equipment and number of handoff would be increase with more sector (Ata, *et al.,* 2001), to overcome these problems. Six cell sector systems are replaced with replace with 3 sector cells. Systems with complete 360 degrees coverage produce some interference at the edges of bandwidths as they overlap in the propagation pattern of 3 cell sector and 6 cell sectors.

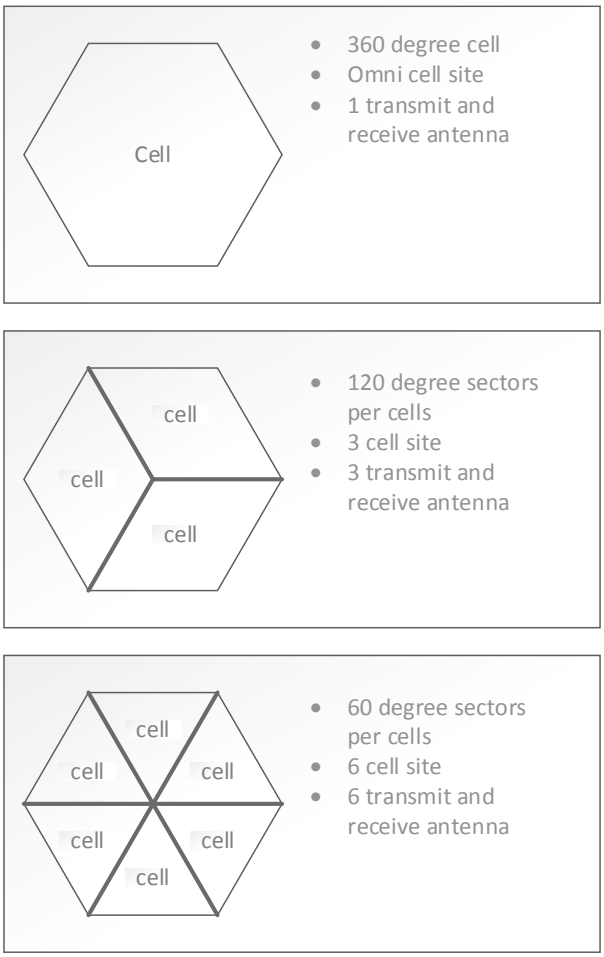


Fig. 2: Current Cell Sector Configurations

To minimize these all problems, we propose an economical solution for existing cellular networks with cell sectorization pattern of $4(60^{\circ})$ sector configuration, having 4 antenna with 60 degree beamwidth.

We show that the system capacity can be increase with 4 sector and 60 degree beamwidth. Furthermore, the configuration can also reduce area of interference signals. This results in maximum coverage with better quality and increase capacity of the system.

The rest of the paper is organized as Section 2 describes related work, Section 3 discusses proposed approach; the results and discussion is reported in Section 4 and finally conclusions are driven in Section 5.

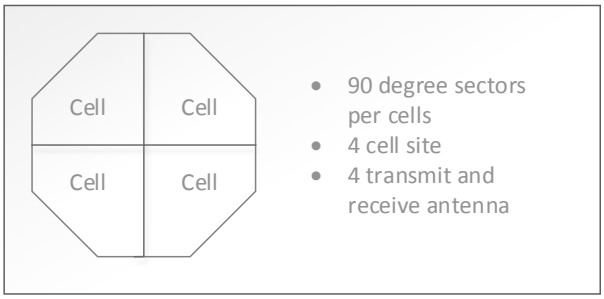


Fig. 3: Proposed Cell Sector Configuration

2. RELATED WORK

All the time Cellular networks are looking for techniques to improve the network capacity within the limited frequency spectrum. The most effective method is to increase the number of sectors per base station (Zetterberg, 2004), (Gilhousen *et al.,* 1991). Sectorization effect on the efficiency of the spectrum is studied in (Chan, 1992), work identified that spectrum efficiency could be enhance with decrease in cluster number for sectorization. On other side, the sectoral capacity of a CDMA system has been studied in (Wong and Prabhu, 1997). Authors proved that beside the standard sector size, the selection of optimum selection of sectors enhances the sectoral capacity. The selection is in the consideration of available resources. The work of (Niemela and Lempiäinen , 2003) focused to analyze the effects azimuth angle on capacity of WCDMA network. They show that increase in sector size while reducing beamwidth, enhances the system capacity. In Substitute the work of (Marsch, *et al.,* 2012), study different deployment ideas for cellular networks in the consideration of progressive spectral efficiency with feasible cost estimations. It is discovered that sectors holding rings based inward-pointing is best strategy deployment. The work of (Foo, 2014) focused to analyze the beam coupling factor (BCF) for higher sectorization, and proved that at minimum level of BCF network capacity could be enhanced with increase in sector numbers. The paper (Sheu, *et al.,* 2014), investigates the cell sectorization and power management for MIMO systems. It is shown that both the signal strength and interference quantity greatly depend on the layout of cell sectorization. It is found the diamond-shaped frequency reuse (DSFR) is better than the triangle-shaped frequency reuse (TSFR) in the

consideration on minimizing the interference of MIMO transmission.

Co-channel interference is addressed in (Kumar, *et al.,* 2012), and proposed a Reuse distance (D) in relation of co- channel interference ratio (CCIR), the work focused to directional antennas. While (Huang *et al.,* 2010) focused to increase throughput while considering interference reduction in multiple sectors. Work of (Kapoor, *et al.,* 2014) focused on comparison of smart antennas and sector antennas with reference to enhancement of system capacity and claimed smart antennas offer more enhanced system capacity at the additional deployment cost.

3. METHODOLOGY

In this work, the system model is analyzed on the following assumptions, The cellular system employs different reuse factor (N) particularly (2,3,4,7, and 12) with different orders of sector antennas, 360 degree (Omni-directional), 120 degrees, 90 degrees and 60 degrees sector antennas.

Sector antennas are located in the center of the base station. The system is analyzed to calculate the Directional Gain, Signal-to-Interference Ratio and System Capacity versus Frequency Reuse Factor for different sector sizes. All the results are analyzed using MATLAB.

3.1 Parameters

The parameters used in the study are the following;

System Frequency is standard GSM frequency 900 MHz with standard System Impedance of 50 Ohm (Coaxial and Feeder Cables), Path Loss Exponent $\eta = 4$ due to deployment of the system in urban area (in which Base Transceiver Station (BTS) are installed closer to each other due to dense population of the users), so the Transmitter Power is minimum 10 dBm. Receiver Sensitivity and transmitter antenna gain is set on default values as 84 dBm and 3 dBi respectively.

Gain of receiving antenna using the beamwidth method using azimuth and elevation angles is calculated using the following equation;

$$Gain\ (db) = 10 \log_{10} \frac{31000}{Az^{\circ} \times El^{\circ}}$$

Interference is vital issue in cellular systems employing frequency reuse, this is calculated using different frequency patterns using the following equation;

$$\frac{S}{I} = \log_{10} \sqrt{\frac{(3N)\eta}{i}}$$

Capacity of cellular systems is calculated by;

$$C = E \times Bt$$

Where,

$$E = \frac{1}{Bch \times Nc \times Ac}$$

Area of cell (Ac) is calculated using the following equation.

$$Ac = \frac{\sqrt[3]{3}}{2R^2}$$

4. RESULTS

(Table-1) and **(Fig.4** are related to Antenna Gain verses Sector Size, suggesting that the Gain increases with the decrease in Sector Size. Sector size is selected as 60, 90 and 120 degrees which are most common selection of sector sizes for cell systems according to the limitations of hexagonal geometry of cell antennas, rest angles are not considered as those are not supported by hexagonal geometry, while it is further compared with Omni directional antenna having beam width of 360 degrees to prove the focused concept of sectorization. Here the elevation angle is kept to 5 degree while azimuth angles vary as Sector Size.

Table 1 : Gain of sector size of 360, 120, 90 and 60 degrees

Sector Size (Degrees)	Azimuth (Horizontal) 3 dB Beamwidth (Degrees)	Elevation (Vertical) 3 dB Beamwidth (Degrees)	Directivity/Ideal Gain $\boldsymbol{Gain\ (dB) = 10 \log_{10} \frac{31000}{Az^{\circ} \times El^{\circ}}}$
360	**360**	**5**	**12.36089189**
120	**120**	**5**	**17.13210443**
90	**90**	**5**	**18.3814918**
60	**60**	**5**	**20.14240439**

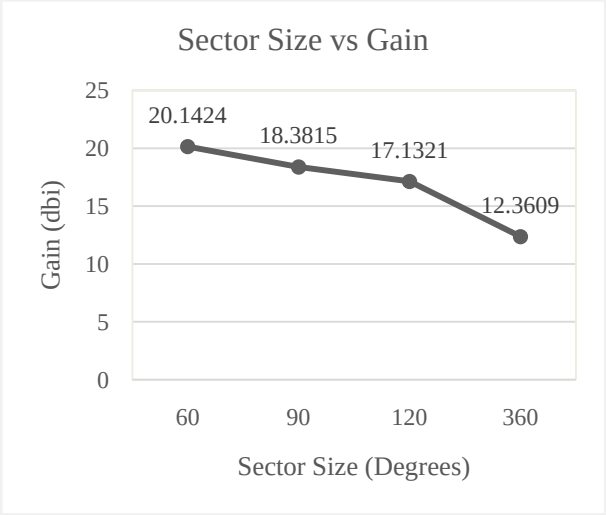


Fig.1 : Gain versus Sector Size

Table 2 : Signal-to-Interference versus Sector Size

Beamwidth 360 degree		
N	$\frac{S}{I}=\sqrt{\frac{(3N)\eta}{i}}$	$\log\left(\frac{S}{I}\right)$
2	6	0.77815125
3	13.5	1.130333768
4	24	1.380211242
7	73.5	1.866287339
12	216	2.334453751
Beamwidth 120 degree		
N	$\frac{S}{I}=\sqrt{\frac{(3N)\eta}{i}}$	$\log\left(\frac{S}{I}\right)$
2	12	1.079181246
3	27	1.431363764
4	48	1.681241237
7	147	2.167317335
12	432	2.635483747
Beamwidth 90 degree		
N	$\frac{S}{I}=\sqrt{\frac{(3N)\eta}{i}}$	$\log\left(\frac{S}{I}\right)$
2	24	1.380211242
3	54	1.73239376
4	96	1.982271233
7	294	2.46834733
12	864	2.936513742
Beamwidth 60 degree		
N	$\frac{S}{I}=\sqrt{\frac{(3N)\eta}{i}}$	$\log\left(\frac{S}{I}\right)$
2	36	1.556302501
3	81	1.908485019
4	144	2.158362492
7	441	2.644438589
12	1296	3.112605002

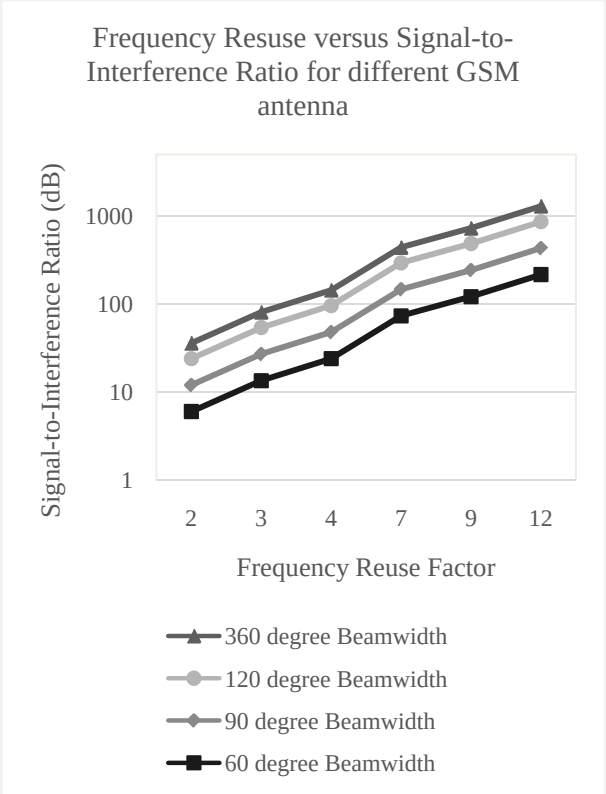


Fig.2 : Signal-to-Interference versus Sector Size

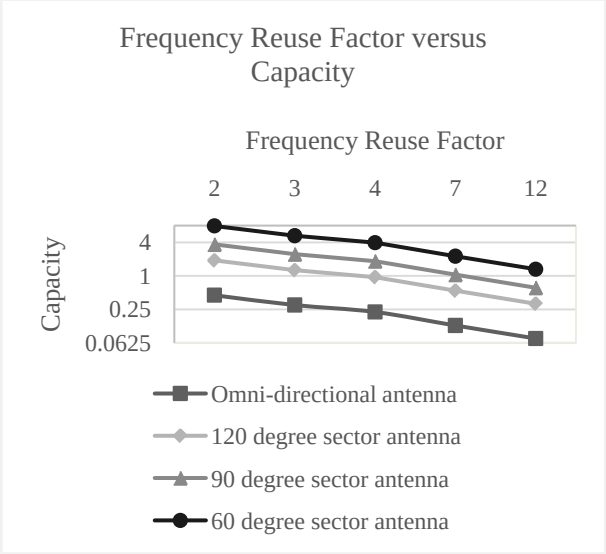


Fig.3 : System Capacity versus Sector Size

(Table-2) and **(Fig. 5)** are linked to Signal-to-Interference and Sector Size. The results shows that 60 degree sector order creates more Signal-to-Interference Ratio as compared to other Sector orders. Thus, the number of handoffs increase in a system and eventually maximum number of handoff decrease the efficiency of the system.

Table 3: System Capacity versus Sector Size

360 degree			
N	$Ac = \frac{\sqrt[3]{3}}{2R^2}$	$E = \frac{1}{Bch \times Nc \times Ac}$	$C = E \times Bt$
2	0.3576018	6.991016112	23.76945478
3	0.3576018	4.660677408	15.84630319
4	0.3576018	3.495508056	11.88472739
7	0.3576018	1.997433175	6.791272794
12	0.3576018	1.165169352	3.961575797
120 degree			
N	$Ac = \frac{\sqrt[3]{3}}{2R^2}$	$E = \frac{1}{Bch \times Nc \times Ac}$	$C = E \times Bt$
2	1.1478978	2.177894132	7.404840048
3	1.1478978	1.451929421	4.936560032
4	1.1478978	1.088947066	3.702420024
7	1.1478978	0.622255466	2.115668585
12	1.1478978	0.362982355	1.234140008
90 degree			
N	$Ac = \frac{\sqrt[3]{3}}{2R^2}$	$E = \frac{1}{Bch \times Nc \times Ac}$	$C = E \times Bt$
2	1.4227065	1.757214114	5.974527987
3	1.4227065	1.171476076	3.983018658
4	1.4227065	0.878607057	2.987263993
7	1.4227065	0.502061175	1.707007996
12	1.4227065	0.292869019	0.995754664
60 degree			
N	$Ac = \frac{\sqrt[3]{3}}{2R^2}$	$E = \frac{1}{Bch \times Nc \times Ac}$	$C = E \times Bt$
2	3.3587123	0.744332861	2.530731728
3	3.3587123	0.496221907	1.687154485
4	3.3587123	0.372166431	1.265365864
7	3.3587123	0.212666532	0.723066208
12	3.3587123	0.124055477	0.421788621

(Table 3) and **(Fig.6)** are associated to System Capacity and Sector Size. The results shows that 60 degree sector order yields maximum capacity as compared to other sector orders. Thus, the System Capacity decreases with the increase in the order of degree of sector antenna.

5. CONCLUSION

All sector order of GSM system are simulated and compared with respect to Gain, Signal-to-Interference ratio and System Capacity. The results shows that 60 degree sector order is better choice to increase the system capacity, however it creates more Signal-to-Interference Ratio due to the higher number of antennas in particular area. Moreover, it also increases the number of handoffs that create extra fatigue on the system. The 90 sector order gives a good compensation as compared to other sector orders, as it decreases the extra fatigue of handoff from the system and offers good Signal-to-Interference ratio and increased System Capacity.

REFERENCES:

Akella, M. R., R. Batta, M. Sudit, P. Rogerson, and A. Blatt, (2008) 'Cellular Network Configuration with Co-Channel and Adjacent-Channel Interference Constraints', *Computers and Operations Research*, vol. 35, no. 12, 3738-3757, Available: ISBN: 0305-0548.

Ata, O. W., H. Seki, and A. Paulraj, (2001) 'Capacity Enhancement in Quad-Sector Cell Architecture with Interleaved Channel and Polarization Assignments', IEEE International Conference on Communications, ICC 2001., 2317-2321.

Chan, G. K. (1992) 'Effects of Sectorization on the Spectrum Efficiency of Cellular Radio Systems', *IEEE Transactions on Vehicular Technology*, vol. 41, no. 3, . 217-225, Available: ISBN: 0018-9545.

Foo, S. (2014) 'On Higher-Order-Sectorization Cellular Arrays', IEEE Antennas and Propagation Society International Symposium (APSURSI), 111-112.

Garg, V. K. and L. Huntington, (1997) 'Application of Adaptive Array Antenna to a TDMA cellular/PCS System', *IEEE Communications Magazine*, vol. 35, no. 10, 148-152, Available: ISBN: 0163-6804.

Gilhousen, K. S., I. M. Jacobs, R. Padovani, A. J. Viterbi, (1991) 'On the Capacity of a Cellular CDMA System', *IEEE Transactions on Vehicular Technology*, vol. 40, no. 2, 303-312, Available: ISBN: 0018-9545.

Huang, H., O. Alrabadi, J. Daly, D. Samardzija, C. Tran, R. Valenzuela, and S. Walker, (2010) 'Increasing Throughput in Cellular Networks with Higher-Order Sectorization', Signals, Systems and Computers (ASILOMAR), 2010 Conference Record of the Forty Fourth Asilomar Conference on, 630-635.

Kapoor, N., Y. Kumar, and M. Sharma, (2014) 'Advancement in GSM and Wi-Fi technology using Smart Antenna', *International Journal of Research (IJR)*, vol. 1, no. 10, 973-977.

Kim, J., Y. J. Choi, and S. Bahk, (2003) 'Interference-Based Capacity Analysis in CDMA Cellular Systems', IEEE Wireless Communications and Networking, WCNC 1412-1417.

Kumar, S., R. Pal, and M. Azad, (2012) 'Simulation of Co-channel Interference Ratio (CCIR) for Directional Antenna in Mobile Computing', *International Journal of Computer Applications*, vol. 45, no. 3, 46-50.

Lee, W.C.Y. (1991) 'Overview of Cellular CDMA', *IEEE Transactions on Vehicular Technology*, vol. 40, no. 2, 291-302, Available: ISBN: 0018-9545.

Madfors, M., K. Wallstedt, S. Magnusson, H. Olofsson, P.O. Backman, and S. Engstrom, (1997) 'High Capacity with Limited Spectrum in Cellular Systems', *IEEE Communications Magazine*, vol. 35, no. 8, 38-45, Available: ISBN: 0163-6804.

Marsch, P., J. Moilanen, and T. Chapman, (2012) 'Alternative Concepts of Antenna Deployment and Cell Layout in Mobile Communications', IEEE International Conference on Communications (ICC), 4473-4478.

Niemela, J. and J. Lempiäinen, (2003) 'Impact of the Base Station Antenna Beamwidth on Capacity in WCDMA Cellular Networks', The 57th IEEE Semiannual Vehicular Technology Conference, VTC Spring., 80-84.

Sabharwal, A., D. Avidor, and L. Potter, (2000) 'Sector Beam Synthesis for Cellular Systems using Phased Antenna Arrays', *IEEE Transactions on Vehicular Technology*, vol. 49, no. 5, 1784-1792.

Sheu, J. S., S.H. Lyu. and S. J. Lyu, (2014) 'Cell Sectorization and Power Management for Inter-cell Interference Coordination in OFDMA-based Network MIMO Systems', IEEE Wireless Communications and Networking Conference (WCNC), 1638-1642.

Telecomabc (n.d) *Telecomabc.nl*, Available: http://www.telecomabc.nl/c/plaatjes/cel-cluster.gif.

Wang, L. C. and K.K. Leung, (2000) 'A High-Capacity Wireless Network by Quad-Sectore Cell and Interleaved Channel Assignment', *IEEE Journal on Selected Areas in Communications*, vol. 18, no. 3, 472-480, Available: ISBN: 0733-8716.

Winters, J. H. (1998) 'Smart Antennas for Wireless Systems', *IEEE Personal Communications*, vol. 5, no. 1, 23-27, Available: ISBN: 1070-9916.

Wong, T. W. and V. K. Prabhu, (1997) 'Optimum Sectorization for CDMA 1900 Base Stations', IEEE 47th Vehicular Technology Conference, 1177-1181.

Zetterberg, P. (2004) 'Performance of Three, Six, Nine and Twelve Sector Sites in CDMA - Based on Measurements', IEEE 8th International Symposium on Spread Spectrum Techniques and Applications, 394-399.