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Interference and Signal Quality Analysis of Cellular Wireless Network

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Abstract: The frequency reuse technique that is used to face the insufficiency of bandwidth available for cellular service operators to extend the network capacity. Although, cells use the same channels are physically separated by a reused distance, the problem of interference in the same channel that affect the system performance will be created. In this research, the simulation results are supported to study the impact of increasing carrier frequency for reduce cell radius size and frequency reuse factor on system quality. Where two tier co-channel interfering cells are effective. The up-link (reverse link) of cellular network and the dual-slope path loss propagation model are used for analysis network performance. The results are shown that for higher frequencies and smaller cell radius, the two tier of co-channel interference cell become effective comparison to frequencies of 1800 MHz. This leads to a reduce in the quality of the system as well as increasing in reuse factor led to increase in the quality of system but this undesired for capacity.

Key words: Break point distance, signal to interference ratio, radio propagation, carrier frequency, network performance, quality of the system

INTRODUCTION

Due to the limited radio spectrum available to wireless communication systems it is required to emerge wireless communication to perform a high stage of spectrum efficiency and accommodate a large number of subscribers (Driessen and Foschini, 1999). The cellular system is used to perform this case by take advantage of the power fall off with distance of propagation signal to reuse the same frequency channel in a sites are spatially separate (Molisch, 2005). Higher spectral efficiency can be achieved by operating the cellular on higher carrier frequencies and reducing the radius of cell to provide the required high speed data service (Yao and Sheikh, 1992; Jakes, 1994). Operating at higher frequency of the carrier means that cell the radius of cell in need to be reduced by transition into micro-cell or pico cell in order to avoid an increase in loss of the path. Moreover, reduction in cell size a problem of co-channel cell interfering cell is generate. At frequencies maximal than 1800 MHz, second tier interfering cell become more efficient. Therefore, co-channel interference is considered a limiting factors which limits a bit error rates obtainable to a user and the system capacity (Takada *et al*., 2002).

At higher frequencies, the line of sight among a transmitter and a receiver is mostly blocked especially in urban environments because of obstacles existing in propagation medium. Thus, the best way to propagate radio waves is to use the two slope path loss model (Oda *et al*., 2000).

MATERIALS AND METHODS

Formation of cluster and reuse distance: In order to increase the number of simultaneous calls in cellular mobile communication networks, a large zone is divided into a great number of small zones called cells and each small zone is served on one base station as shown in Fig. 1. The channels of a cell are reused to another cell after skipping several cells before the same frequency is

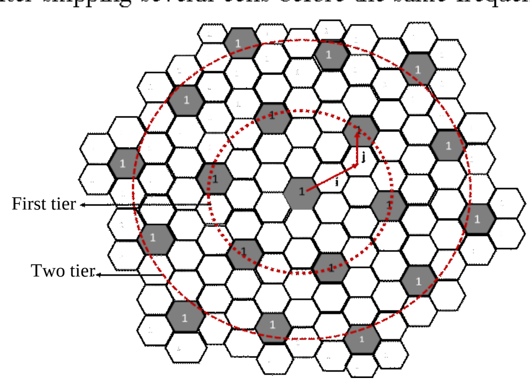

Fig. 1: Cellular wireless communication with co-channel interference, cluster size = 7

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reused. Thus, the limited frequency band is reused in distant cells to extend the network capacity. The idea beyond frequency reusing is to avoid the interference between mobile phones operating on the same channel (Abbasi *et al*., 2015). Co-channel cells are the cells which utilizing the same frequencies. So, the interference among these signals is called a co-channel interference. Then, to decrease a co-channel interference, the cells that use same frequency must be separated to provide the desirable isolation (Theodore, 2002). The distance between the cells utilizing the same carrier frequency channel is called as reuse Distance it is indicated (D). The reuse distance proportional with cell's Radius (R) and with No. of cell (N) in a cluster, D = (v3N) R. So, the reuse factor will be (D/R = v3N). Where The Number of cell (N) per cluster is presented as:

$$N = i^2 + ij + j^2 \tag{1}$$

Which i indicating as number of cells over the direction I from cell's center and (j) indicates as number of cells at 60° towards the direction of i assumed that there is a two-dimensional hexagonal micro-cellular network where the base stations omnidirectional antennas architecture are located at the center of cell and are distributed uniformly as illustrated in Fig. 1. The signals from all users in the co-cells of the first tier and the second tier are received by base stations of each cell, so, the interference is generated.

Distribution of users: A uniform density of mobile units in desired and interferer cells overall system is assumed. All mobile units are supposed to be located in the cell that is free from the reactive field effects of base station antenna (far field zone). The Probability Distribution Function (PDF) of any mobile unit position over the cell related to its serving base station that is assumed to be located at the cell center is given as:

$$\rho(r,\theta) = \frac{r - r_{ff}}{\pi(R_c - r_{ff})^2} \tag{2}$$

$$r_{ff} \le r \le R_c, 0 \le \theta \le 2\pi$$

$$\rho(r,\theta) = 0; \forall r > R_c$$

Where:

- r = The mobile unit location within the cell
- r_{ff} = The minimum far-field distance of base station antenna that is given by

$$r_{ff} = \frac{2L^2}{\lambda}$$

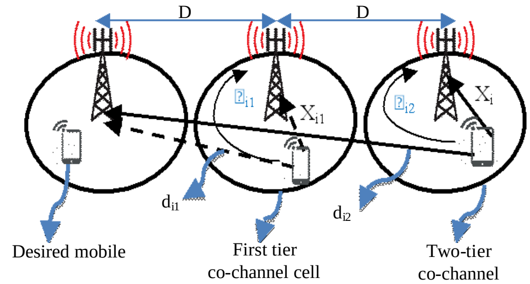

Fig. 2: Geometry of cellular system

Where:

- L = The largest linear dimension of the base station antenna
- λ = The carrier wavelength

Analysis of propagation and interference modeling: For interference generation a first tiers also second tiers of co-channel cell are considered. The home cell phone is existed in a home cell and the interfering phones are found in first and second tier as displayed in Fig. 2. To facilitate the analysis, these assumption were done in the model of co-channel interference. In a given tier, the number of co-channel interfering cells is offered as (Anang *et al*., 2011):

$$N_n = N_1 \times n \tag{3}$$

where, (n = 1, 2, 3, 4, ...,) N_1 is defined as number of interfering cells in a first tier, also (n) is defined the nth number of tier and it is always an integer. The uplink interference of the BS power station is the unlinked total interfering signals from the mobile user served by the home base station and the mobile users served through other BS stations (Singh *et al*., 2010). Similarly, the required user defines the Signal to Interference Ratio (SIR) is known as the rate of averaged signal power received to the sum of interfering power. Thus, the SIR of desired user can be given as:

$$SIR = \frac{P_d}{P_I} = \frac{P_d}{\sum_{i1=1}^{N_{I1}} P_{i1} + \sum_{i2=1}^{N_{I2}} P_{i2}} \tag{4}$$

Where:

- P_d [w] = The desired received power of MS
- P_I = The sum of individual interfering power in tiers 1 also 2
- N_{I1} and N_{I2} = The number of co-channel interfering cell in a first tier and second tier

From Fig. 2, assume that the base stations at the center of cell. The distance between any two co-channel cell centers in tier 1 is Denoted (D) and the distance between any two co-channel cells in the second tier is denoted (2D), Let the mobile user (i1) be located at any one of the first tier interfering cells surrounding the reference and let the mobile user (i2) be located at any one of second tier interfering cells surrounding the reference cell. Assume randomly located of users respective to their BS's when the user (i1) connects its serving base station, the interference power received by the desired base station at reference cell in up-link (P_{i1}) is determined by utilizing the two-slope model as:

$$P_{i1} = \frac{C}{(d_{i1})^{\alpha}(1+d_{i1}/g)^{n}}P_t \quad (5)$$

Where:

- P_t = The power transmitted by the mobile user
- i1, d_{i1} = The distance from the user
- i1 = Reference base station
- C = The constant that depends on operating frequency, antenna heights and gains of the base station and mobile station and
- α = Exponent propagation of path loss (α>2)
- n = The extra exponent of path loss (ranges from 2-6),
- g = The breakpoint distance

Where:

$$g = \left(\frac{4h_b h_m}{\lambda c}\right)$$

Where:

- λc = The carrier wavelength
- h_b = BS antenna height
- h_m = MS antenna height

The accurate value of C and P_t are not required in this analysis. Thus assumed C = 1, P_t = 1.The interference power from user i2 in the second tier while received at reference cell P_{i2} as:

$$P_{I2} = \frac{C}{(d_{i2})^{\alpha}(1+d_{i2}/g)^{n}}P_t \quad (6)$$

where, d_{i2} is the distance from the user i_2 to reference base station. Assuming that the all users transmitting power is the same in the cell due to random location of the users therefore SIR is a random based on the user's random mode and over lapping amounts of interference from tiers. Wanting power control the average interference arrangement identify to the state where all the N_{I1} and N_{I2} co-channel interferes are at a center of their respectively BS's, at a distance d_{i1} = D, d_{i2} = 2D from the desired mobile station's as given in Fig. 2. Assuming all users transmitting power is same and substituting 5 and 6 into 4 yields. Where D is produce of R_u and R, R_u is the normalized reuse distance and R is the radius of cell:

$$\begin{aligned} SIR &= \frac{P_d}{P_I} = \frac{P_d}{\sum_{i1=1}^{N_{I1}} P_{i1} + \sum_{i2=1}^{N_{I2}} P_{i2}} \\ &= \frac{r^{-\alpha}\left(1+\frac{r}{g}\right)^{-n}}{\sum_{i1=1}^{N_{I1}} d_{i1}^{-\alpha}\left(1+\frac{r_{i1}}{g}\right)^{-n} + \sum_{i2=1}^{N_{I2}} d_{ia}P_{i2}^{-\alpha}\left(1+\frac{ri2}{g}\right)^{-n}} \\ &= \frac{r^{-\alpha}\left(1+\frac{r}{g}\right)^{-n}}{\sum_{i1=1}^{N_{I1}} (D)^{-\alpha}\left(1+\frac{D}{g}\right)^{-n} + \sum_{i2=1}^{N_{I2}} (2D)^{-\alpha}\left(1+\frac{2D}{g}\right)^{-n}} \\ &= \left(\frac{2D}{r}\right)^{\alpha}\cdot\left(\frac{g}{g+r}\right)^{n}\cdot\left(\frac{N_{I2}}{2^{\alpha}N_{I1}N_{I2}\left(\frac{g}{g+D}\right)^{n} + \left(\frac{g}{g+2D}\right)^{n}}\right) \end{aligned} \quad (7)$$

Simulations: MATLAB Simulations were simulated to assess the ratio of signal to interference. The basic parameters are used in this simulation shown in the Table 1. In simulations, users are randomly placed and distributed uniformly as described in study. The relative position of cell phone users in the cells randomly varies, giving a normal distribution of potential functions. The polar coordinates (x_{i1},θ_{i1}) and (x_{i2},θ_{i2}) of the N_{I1} and N_{I2} at first and second tier are assumed uniformly distributed approbating to Eq. 1. The distance d_{i1} for each co-channel interfering cell from the first t ier to the desired base station is determined by:

$$d_{i1} = \sqrt{(D)^2 + (x_{i1}) - 2Dx_{i1}\cos(\theta_{i1})} \quad (8)$$

The distance d_2 from interfering cell second tier to the desired base station in desired cell for this simulation is determined by:

$$d_{i2} = \sqrt{(2D)^2 + (x_{i2})^2 - 4Dx_{i2}\cos(\theta_{i2})} \quad (9)$$

Table 1: System Parameters

Parameters	Value/Types
Radius of cell (R)	100-1000 m
Propagation exponent (α)	2
Extrapropagation exponent (n)	4
Base station height (h_b)	15 m, variable
Mobile station height (h_m)	1.5 m
Frequency reuse factor (Ru)	4/variable
Carrier frequencies (fc)	1.8, 2.1,3.35 and 8.45 GHz

The two-slope path loss model in Eq. 2 is used to determine the average signal to interference ratio power. then, the SIR is calculated as:

$$\text{SIR} = \frac{1}{r^{\alpha}(g+r)^{n}\left(\sum_{i1}^{N_{i1}}\frac{1}{(d_{i1})^{\alpha}(g+r_{i1})}+\sum_{i2=1}^{N_{i2}}\frac{1}{(d_{i2})^{\alpha}(g+r_{i2})^{n}}\right)} \quad (10)$$

Repeat the above procedure 1000 after the position of desired user is selected.

RESULTS AND DISCUSSION

The model is simulated to show the effect of radius of cell of different carrier frequency, frequency reuse factor and height of base station on the performance of micro-cellular system working at different frequencies where two tier of co-channel interference are considered. Figure 3 show comparison the SIR for the singleand two tier of co-channel interference models for fc = 1800 MHz as a function of radius of cell for omni directional antenna, this curves show that when fc = 1800 MHz and cell Radius (R) = 0.1 km then the decrease in signal to interference ratio between two model was 4.31% at (R = 0.3 km) the decrease was 2.85 % .and at (R = 0.5 km) the decrease in signal to interference ratio among two tier model was 0.97%.

The curves in Fig. 4 show that for fc = 2100 MHz at radius of cell (R = 0.1 km), the decrease in the signal to interference among the two interference tier model was 11.59%. When (R = 0.3 km) then a decreasing was 3.81%. In the case of (R = 0.5 km) the decrease in signal to interference ratio between two model was 1.2 %.

In Fig. 5, the curves show that for f_c = 3.35 GHz the decrease in signal to interference become more and emerging second tier more clearness. The decrease in SIR between the two interference model was13.2% at 0.1 km, 4.12% at radius of cell = 0.3 km and 2.01% at (R = 0.5 km).

For Fig. 6, at f_c = 8.45 GHz, then the decreasing in SIR between the two interfering cell models was 15.66% at (R = 0.1 km), 6.15% at (R = 0.3 km) and 3.68% at (R = 0.5 km).

Figure 7-10 shows the effect of the reuse distance pattern and the radius of the cell on the performance of micro-cellular wireless. The figures confirm that the average signal to interference ratio is increased when the reuse factor increase. The figure show the decreasing at SIR with increasing carrier frequency. This explain the fact of depending SIR on the cell size also on carrier frequency.

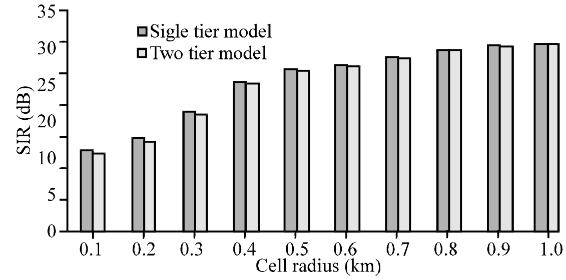

Fig. 3: Average uplink signal to interference ratio versus cellradius at carrier frequency1800 MHz

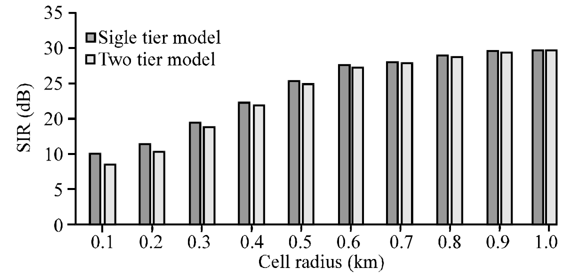

Fig. 4: Average uplink signal to interference ratio versus cell radius at carrier frequency fc = 2100 MHz

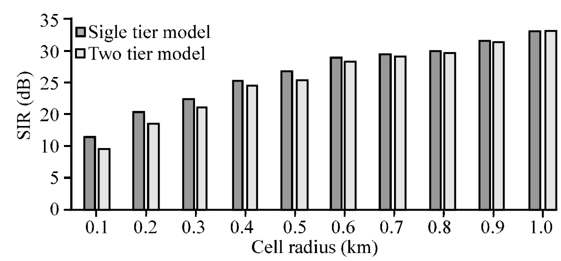

Fig. 5 : Average up-link signal to interference Ratio versus cell radius at carrier frequency fc = 3.35 GHz

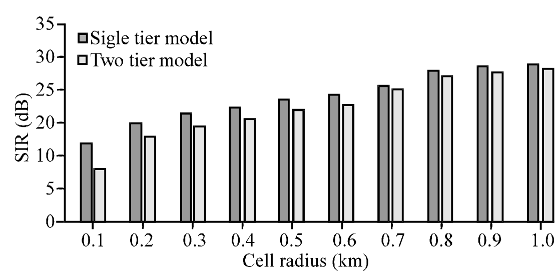

Fig. 6: Average uplink signal to interference Ratio versus cell radius at carrier frequency fc = 8.45 GHz

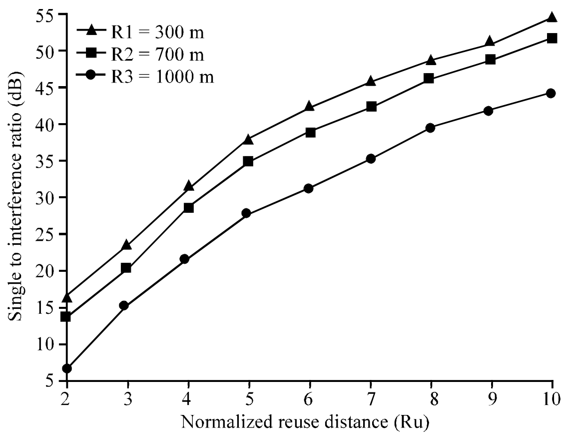

Fig. 7: Average uplink SIR Versus Ru, fc = 1800 MHz

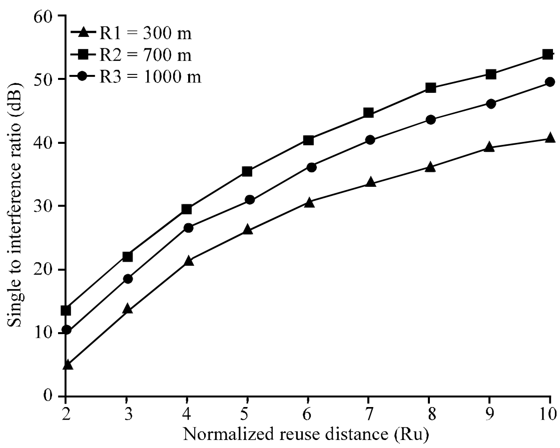

Fig. 8: Average uplink SIR versus Ru, fc = 2100 MHz

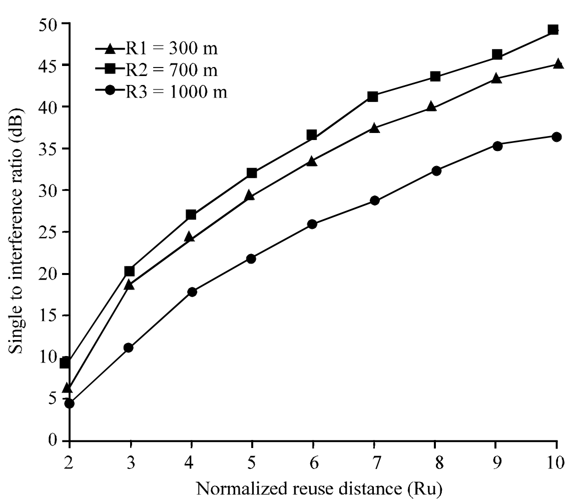

Fig. 9: Average uplink SIR versus Ru, fc = 3.35 GHz

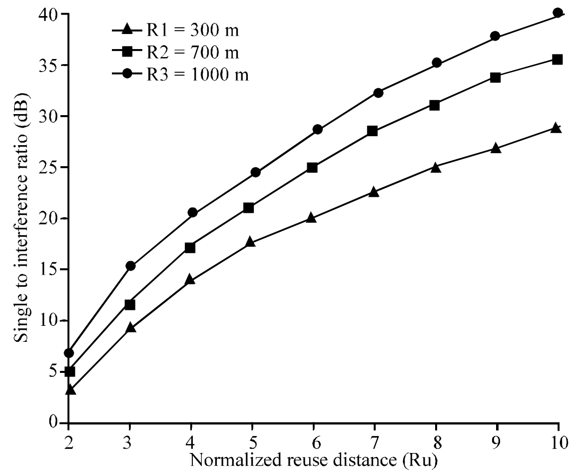

Fig. 10: Average uplink SIR versus Ru, fc = 8.45 GHz

CONCLUSION

In this study, the impact of cell radius and reuse distance are analyzed on the implementation of multiple access wireless system operating at higher carrier frequencies greater than 1800 MHz where two tier of interferers is effective. The analysis of performance was used the two-slope propagation path loss model and the SIR is characterizing as a function of a radius of the cell and cluster size. The implementing offered that as carrier frequency increases; Cell size reduces, multiple tiers of the co-channel interfering cells become effective which impulses a reduction in the reverse link quality of a cellular wireless system when increasing in cluster size this improves SIR but this lead to decrease in capacity due to decrease number of channel per cell. The results also showed that the for precise planning and cellular network design operating at higher carrier frequencies, other tier co-channel interfering cells needed to include in the regulation model.

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