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MIGITATION OF INTER CELL INTERFERENCE AND FADING IN LTE SYSTEMS

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ABSTRACT

In this study we investigate the compensation of outage area utmost. It introduces the self optimization of the neighbors of the outage cells with antenna tilts for the generation of the most suitable configuration settings for the network with base stations/eNodeBs positional information. All the neighbors of the outage cell increase their coverage area and thus contribute to cell outage compensation. Every neighbor cell calculates the edge points of its antenna reach by propagation path loss model in order to minimize the inter-cell interference. Antenna parameter selection and optimization has an important role to achieve maximum capacity and coverage performance in LTE and beyond (LTE-A). For this reason, the LTE framework is adopted for simulations and Cell coverage extension, cell capacity enhancement and Inter-Cell Interference (ICI) mitigation provided by optimized antenna parameter investigations on the basis of specifications (TR25.814 and TR36.814). The simulation results provide strong evidence that our scheme delivers substantial gains in terms of coverage compared to existing solutions without sacrificing the SINR.

Keywords: Long Term Evolution, OFDMA, Transmission Time Interval, Channel Quality Indicator, Intercell Interference, Region of Interest, User Equipment

1. INTRODUCTION

LTE access network forms the standard technology ensured to achieve the future requirement of advanced universal telecommunication. With simplified network architecture LTE supports more users per cell and emphasis Self Organized Network (SON). The principle of introducing SON is self-configuring, self optimizing network capacity coverage and service quality. LTE provides better user experience by improving fairness in throughput and higher data rates with a flexible design. Innovation of eNodeB provides higher capacity in cell edge throughput and to reduce the interference existing between the cells.

Orthogonal Frequency Division Multiple Access (OFDMA) is a modulation technique used in LTE to support wide range spectrum and provide high data rates, low latency with respect to previous networks. The use of subcarrier structure enables simpler implementation of Multi Input Multi Output (MIMO) for increasing the system capacity effectively for the demand of significant growth in mobile data traffic.

Selection of antenna parameters with respect to the path loss, macroscopic, shadow fading and channel quality indicator plays a key role in the optimizing the coverage capacity and mitigating the fading that occurs.

2. SYSTEM MODEL

In LTE downlink transmission, the binary source generator generates the signal randomly. The number of the generated binary symbols depends on the modulation scheme, i.e., the number of bits per symbol and the number of subcarriers (Ikuno *et al*., 2010). These binary input data stream is converted into two parallel data streams by using serial to parallel converter. Parallel data stream is modulated with different subcarriers and

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modulation is required to achieve bandwidth efficiency and high data rates in LTE. After the physical resource mapping, zero padding is done because the sampling rate is much higher than the transmission bandwidth of the system. The zero padded signals are applied to Inverse Fast Fourier Transform (IFFT) block for the sake of modulation, where the serial input data stream is divided into a number of parallel streams. To maintain orthogonality, minimum frequency separation is required between these subcarriers. IFFT is used to generate symbols and also reduces the complexity of the transmitter. OFDMA system has the ability to completely remove ICCI between two symbols. Cyclic prefix are inserted before the transmission of the modulated signal to remove the ICCI. The receiver section basically performs the reverse operation of the transmit ter. Physical-layer identity (SAL, 2013) of the cell detection is made through using IFFT and FFT respectively (**Fig. 1**):

$$\begin{aligned} & N_{ID}^{cell} = 3\,N_{ID}^{(1)} + N_{ID}^{(2)} \\ & N_{ID}^{(1)} = 1,\ldots,167 \quad \text{and} \\ & N_{ID}^{(2)} = 0,1,2 \end{aligned} \tag{1}$$

The neighboring cell identification is made with relation indicated in Equation 1. The PSS and SSS provide the UE with its physical layer identity within the cell (TSG-RAN, 2009). It supports 504 possible physical layer cell identities and is divided into three groups. Each has 168 cell layer identities for the formation of cell ID. These signals provide time and frequency synchronization within the cell (Zyren, 2007). The performance analysis is estimated with respect to Measurements of the Signal to Interference plus Noise Ratio (SINR) of each Transmission Time Interval and the path loss of the antenna where the measuring of the Signal to Interference plus Noise Ratio (SINR) of each Transmission Time Interval (TTI) are fed back to the serving eNodeB via a Channel Quality Indicator (CQI) in order to adjust the Adaptive Modulation and Coding (AMC) parameters for future TTIs appropriately (Kim *et al*., 2010). The serving eNodeB presumes the downlink channel matches the CQI reported by the UE. The performance of this link adaptation is dependent on a non varying SINR within the validity period of a CQI. Consequently, unpredictable SINR variations caused by, e.g., inter-cell interference may result in unpredictable performance losses. Henceforth, Inter-Cell Interference Coordination (ICIC) techniques are indispensable in LTE-compliant mobile communication systems and various strategies were introduced in the past (Carvalho and Vieira, 2011; Wrulich and Rupp, 2009). Castaneda *et al*. (2007) the authors investigated possible performance gains as utilized in LTE closed loop spatial multiplexing transmission mode. Most of these techniques aim at a reduction of the inter-cell interference instead of a full suppression by utilizing sophisticated scheduling methods for cell-edge users or by negotiation of physical resources between adjacent cells. Consequently, the remaining inter-cell interference is still unpredictable and its influence on the SINR can be described by statistical means only. Currently no fundamental statistical analyses of inter-cell interference exist in literature. Finally, in this contribution the inter-cell interference and the resulting SINR is done in LTE closed loop spatial multiplexing mode. Analytical results are verified by numerical simulations.

3. SIMULATION AND RESULTS

OFDMA is employed in the downlink, where orthogonality between different subcarriers allows ignoring interference between users within one cell (Claussen and Nguyen, 2010). LTE considers a frequency reuse factor of one between adjacent cells and, therefore users may suffer from inter-cell interference caused by neighboring cells located at the edge of a cell. Moreover, the adjustment of the downlink transmission as per the channel conditions observed at the User Equipment (UE) is employed through MIMO techniques.

3.1. Block Length Error Rate

The BLER and throughput for 15 different Modulation Coding Scheme (MCS) corresponds to 15 Channel Quality Indicator value at the receiver was obtained with Additive White Gaussian Noise (AWGN) and simulations were performed. In LTE, adaptive modulation and coding has ensured a BLER value smaller than 10 %. The SINR-to-CQI mapping required to achieve this goal is thus obtained by plotting the 10% BLER values of the curves over SNR as shown in **Fig. 2**. An effective SINR was obtained from mapping the set of sub-carrier-SINRs assigned to the UE.

The effective SINR is obtained by non-linear averaging of several Resource Block SINRs given by Equation (2):

$$\gamma_{eff} = -\beta \ln\left(\frac{1}{N}\sum_{i=1}^{N} e^{\frac{-SINR_i}{\beta}}\right) \tag{2}$$

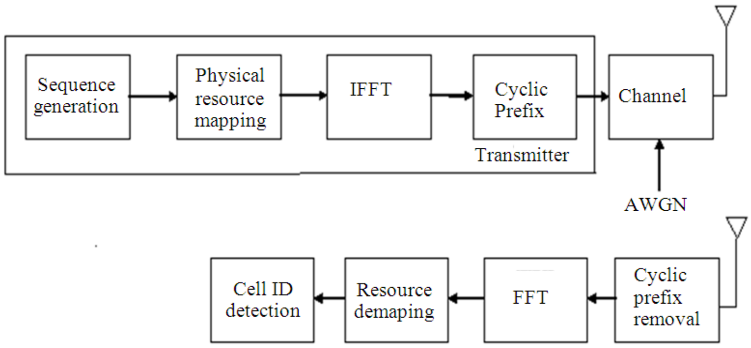

Fig. 1. Block diagram of signal transmission and reception

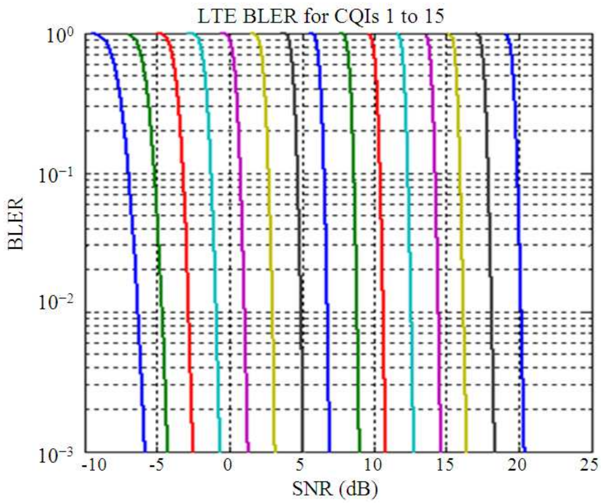

Fig. 2. BLER for different CQI Vs SNR

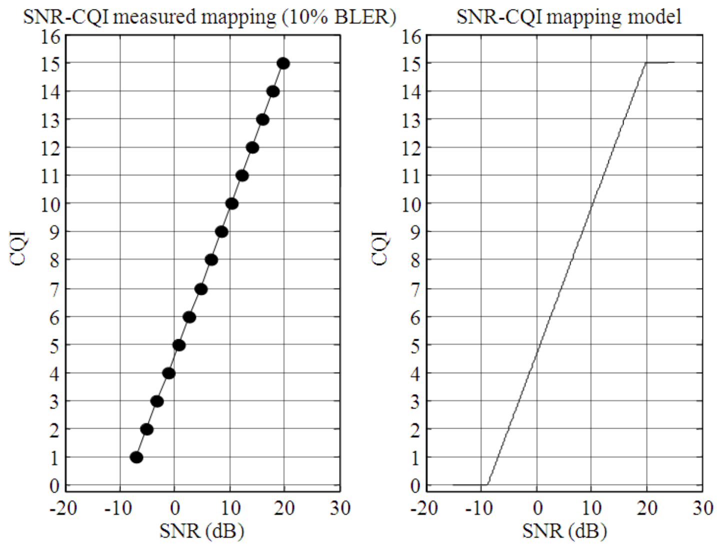

Fig. 3. CQI mapping with BLER of 10% points from BLER curve

Where N is the total number of sub-carriers to be averaged and β is calibrated by means of simulations to fit the function to AWGN BLER results. The obtained CQIs are floored to obtain the integer CQI values that are back to the eNodeB as shown in **Fig. 3**.

3.2. Transmission Time Interval

Transmission Time Interval (TTI) is commonly used parameter in legacy cellular systems. As LTE specification adopts this parameter, it has been reduced to 1ms in LTE standards. TTI defines the minimum time required to exchange Medium Access Control Protocol Data Units (MAC PDUs) with physical layer. This approach improves flexibility of network resources (Lee *et al*., 2007). In this study, we investigated the performance of e-node and UE positions LTE with varying number of users per TTI. Their corresponding positions have been traced in **Fig. 4 and 5**. For each TTI the UE is moved, when UE goes outside the ROI then UE are re-allocated randomly in the ROI. Every eNodeB receives a feedback after each feedback delay. The locations indicate the boundary bounce and the area of coverage and capacity where the interference may occur.

3.3. Region of Interest

The simulation is performed by defining a Region of Interest (ROI) in which the eNodeBs and UEs are positioned and the simulation length in TTIs. To this effect, the model has been split into three parts for obtaining the SINR are macroscopic pathloss, shadow fading and small-scale fading. The macroscopic pathloss models the pathloss and the antenna gain. Shadow fading is caused by obstacles in the propagation path between the eNodeB and the UE. It interprets the irregularities of the geographical characteristics of the terrain obtained from the macroscopic pathloss. Shadowing effects occurs over a large area to capture the dynamics affecting macro-cell diversity. Small-scale fading changes significantly even for small amounts of movement and this approach cannot adequately model the effects of shadow fading. The shadow fading effects occur over a large area (Foschini and Gans, 1998).

The **Fig. 6 and 7** states the UE traversing the ROI experiences a slowly changing pathloss due to shadow fading. The region closer to the eNodeB (Red Region) is the high SINR region and as we move away from the center towards the edges, the interference from the neighboring cell increases and thus the SINR value decreases.

3.4. Macroscopic Pathloss

The macro BS antenna radiation pattern to be used for each sector in 3-sector cell sites is plotted in **Fig. 8** below Equation (3):

$$A(\theta) = -\min\left[12\left(\frac{\theta}{\theta_{3dB}}\right)^2, A_m\right] \text{where} -180 < \theta < 180 \qquad (3)$$

θ is the 3dB beam width which corresponds to 65 degrees and Am = 20dB is the maximum attenuation. It is observed from the **Fig. 8** that wider horizontal beam patterns and larger downtilt angles provide better coverage and capacity performance as inter-cell interference is dominant (Ikuno *et al*., 2009).

The macroscopic pathloss between an eNodeB sector and UE is used to jointly model the propagation pathloss due to the distance and the antenna gain. The time-invariant and position-dependent macro-scale parameters are the pathloss, antenna gain and shadow fading. **Figure 8** indicates the gain Vs the antenna tilt angle, where the antenna gain is maximum at 0.

The losses caused by macroscopic pathloss and shadow fading are position-dependent and time-invariant, whereas small-scale fading is time-dependent.

To emphasize the difference shadow fading is set to 0 dB. The **Fig. 9** reflects the fact that antenna gain pattern keeps its original shape well in the case of electrical downtilt, whereas the shape of the antenna gain pattern may admit remarkable change when the mechanical downtilt is applied. On the other hand, since electrical tilt range is limited in practice due to changing side-lobe level, the impact of the hybrid approach which includes both mechanical and electrical downtilts with different proportions is investigated to find an optimal solution in terms of network performance (PLAE-UTRA, 2006).

As seen from the **Fig. 10**, in both 3GPP cases with macro and shadow fading and only macro fading, reduced power per PRB and additional interference from the adjacent vertical sector makes SINR worse. Antenna downtilt provides optimal performance for the detailed capacity and throughput evaluations.

The maximum achievable capacity gains for the cells in the 3-sector setup are compared. Although there is a remarkable decrease in SINR in both simulation scenarios, since the same resources can be used in both sectors, overall performance improves.

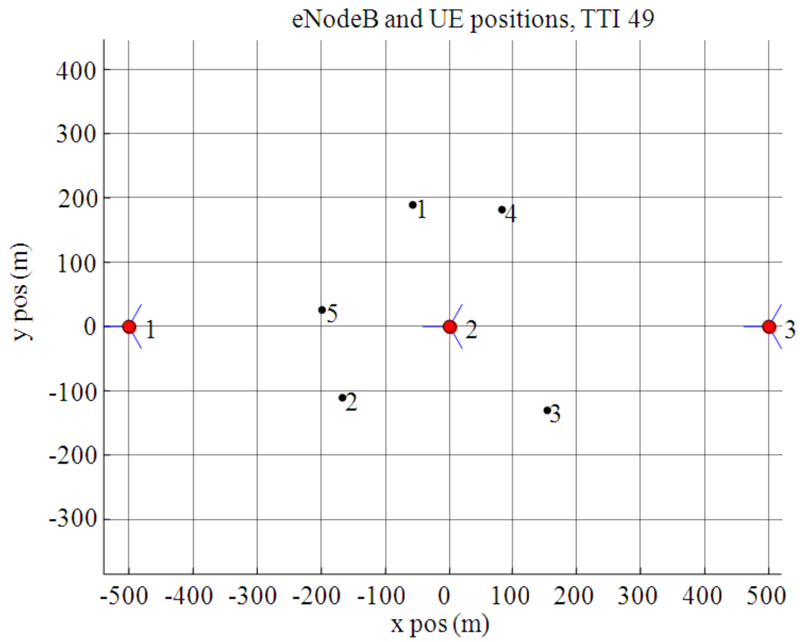

Fig. 4. Positions of eNodeB and UE at TTI 49

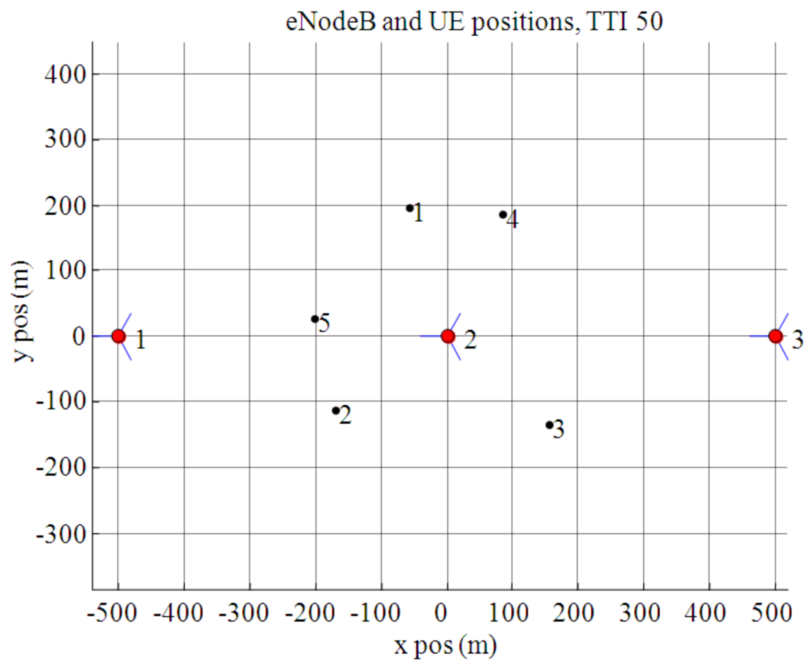

Fig. 5. Position of eNodeB and UE for TTI 50

Even though the vertical sectorization maximizes the overall cell capacity, the impact of vertical sectorization on the user throughput depends on the load of each vertical sector. Moreover, the load imbalance between adjacent vertical sectors becomes more severe when the inter-site distance is larger.

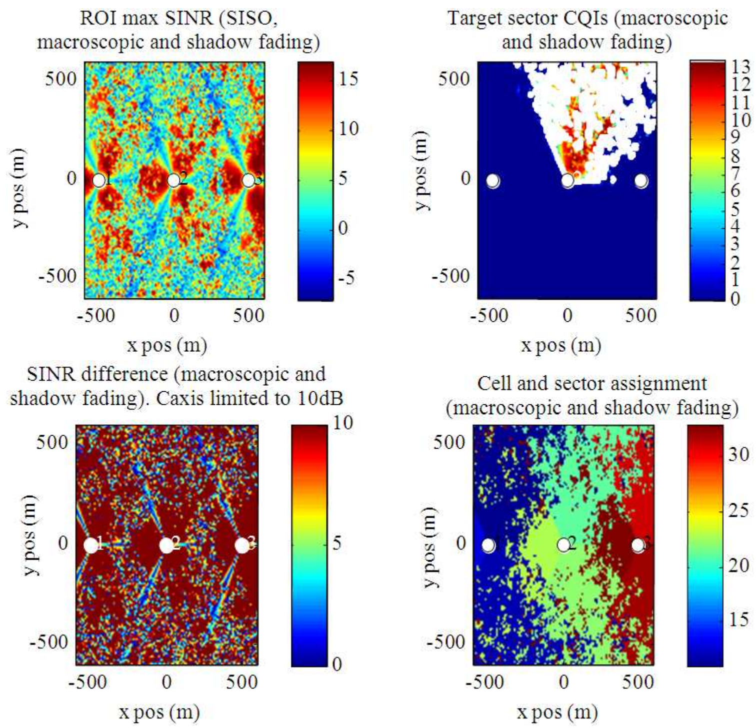

Fig. 6. ROI for different fading

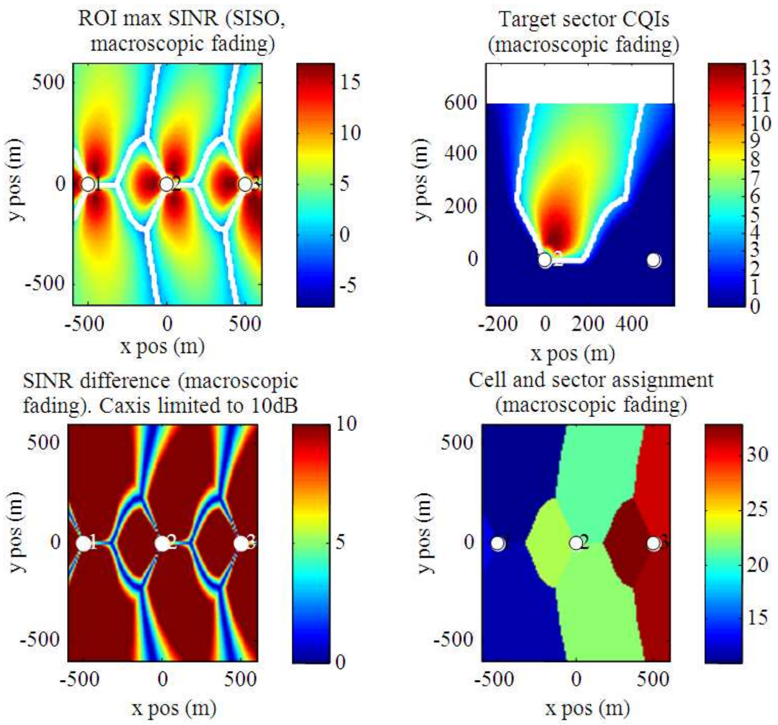

Fig. 7. SINR Vs ROI

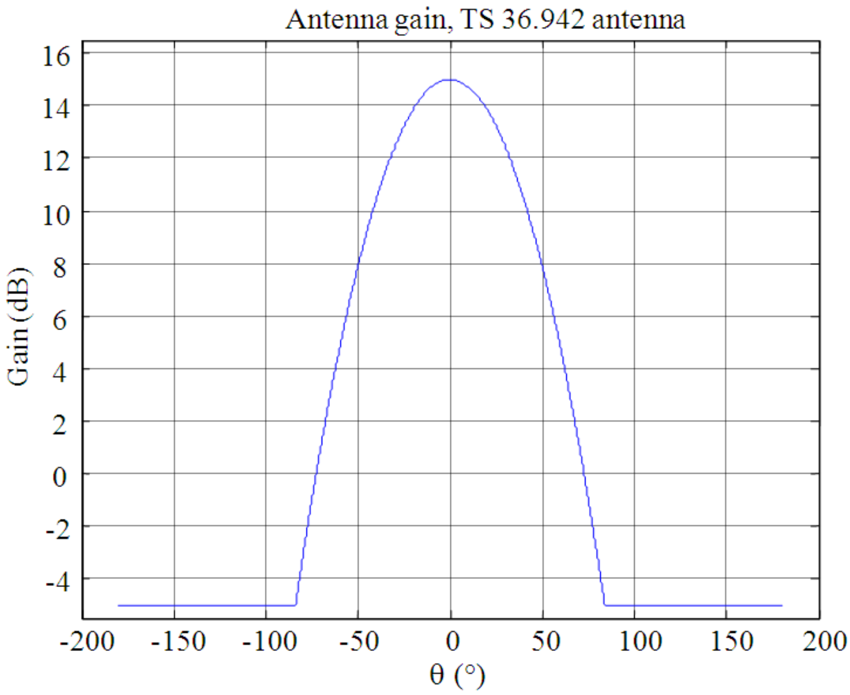

Fig. 8. Gain Vs Antenna tilt angle

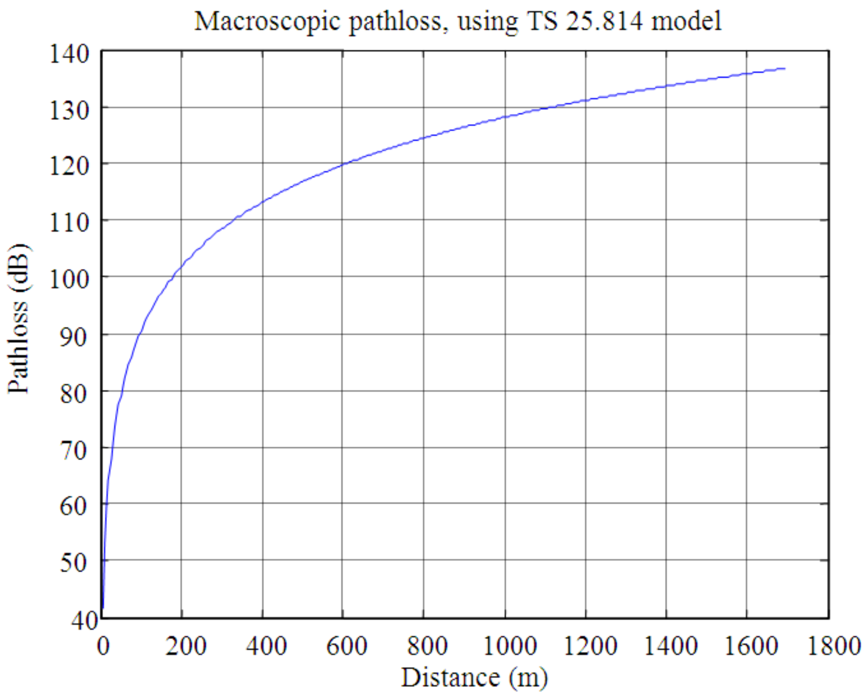

Fig. 9. Urban Pathloss Vs Distance

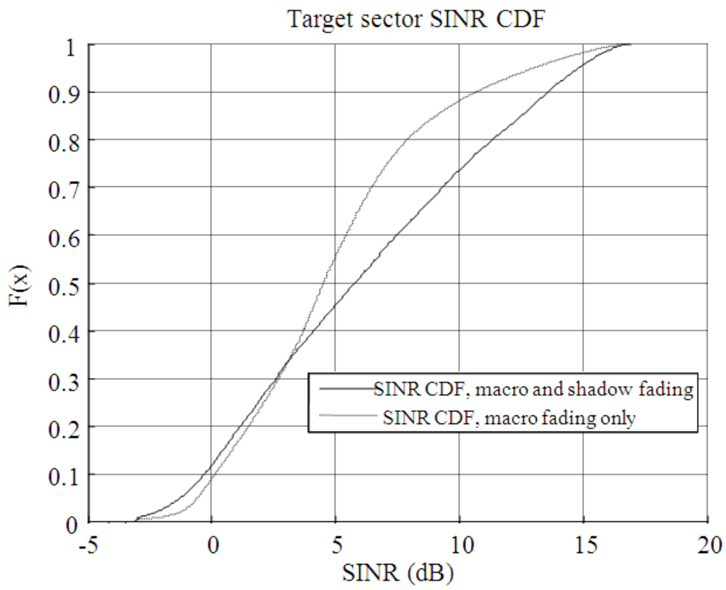

Fig. 10. SINR Vs fading effect

4. CONCLUSION

SINR optimization via electrical and mechanical tilting with pathloss was simulated. We use only two sub-carrier SINRs by which the amount of memory reduction was made and an effective SINR was obtained. The CQI reporting provides the eNodeB with a figure of merit of the state of the channel of the UE. Area Coverage and capacity in LTE networks was optimized using adaptive antenna systems. In simulation results, it is observed that the antenna tilt parameter has the major impact on the network performance especially in the interference limited conditions. Simulation results showed that electrical downtilt performs much better in interference-limited dense networks, whereas the performance slightly differs from each other in noise-limited sparse networks. It was also noticed that coverage and capacity criteria may lead to different optimal tilt angles in dense urban networks.

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