EFFECT OF ANTENNA SPACING ON THE PERFORMANCE OF MULTIPLE INPUT MULTIPLE OUTPUT LTE DOWNLINK IN AN URBAN MICROCELL

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ABSTRACT

The paper presents design of a 2×2 multiple input multiple output (MIMO) LTE Downlink using OFDM with 16-QAM scheme, operated in a spatial Multiplexing (SM) mode. An urban Microcell Winner channel model is assumed to investigate the performance of the system. The focus of this paper is to understand the effect of antenna spacing of end transceivers on the performance of 2×2 MIMO LTE Downlink. The performance parameters like Capacity, Throughput and Bit error rate are determined for different antenna spacing at Base station (BS) as well as at mobile station(MS) for single user. Further the quantitative superiority of closed loop MIMO over Open Loop MIMO is established and discussed. The results depicted in the paper could be of vital importance for commercial deployment of MIMO based systems to fulfill requirements of contemporary wireless baseband technology.

KEYWORDS

Spatial Multiplexing, Spatial Diversity, Multiple Input- Multiple Output (MIMO), Space Time Coding, Rician factor.

1. INTRODUCTION

It is theoretically established fact that MIMO may be a potential technique supporting relatively high and robust data rates with increased spectral efficiency, and data throughput as compared to SISO system of identical bandwidth and transmitted power [1].Because of these attributes, it is being adopted for next generation wireless broadband systems [2]. MIMO transmission strategies can be broadly classified into diversity and spatial multiplexing. While diversity aims to lower the probability of error and thereby improve the reliability of the communication link, spatial multiplexing is used to increase the achievable data rates [3, 4] MIMO transmission strategies can also be classified as open-loop and closed-loop. In open-loop strategies, the transmitter does not have any knowledge of the channel and transmission follows a deterministic pattern that is independent of the channel. Open-loop transmission strategies include spatial multiplexing and diversity schemes like space time block codes, cyclic delay diversity etc. Closed loop schemes require knowledge of the channel at the transmitter to adapt the transmitted signal to the channel conditions, here the mobile station (MS) feeds back the CSI (channel state information) to Base Station (BS) for best utilization of MIMO Channel [5]. A detailed comparative study between closed loop and open loop MIMO schemes for OFDM based mobile broadband radio access for 3GPP UTR LTE is carried out to establish superiority of Closed loop MIMO over open loop MIMO [6] . 3GPP LTE is the evolution of the Third-generation of mobile communications, UMTS, to the Fourth generation technology, which is

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essentially a wireless broadband Internet system with voice and other services built on top. LTE is designed to increase data rates and cell edge bitrates, improve spectrum efficiency (unicast as well as broadcast) and allow spectrum flexibility (1.25, 2.5, 5, 10, 15 and 20 MHz) for flexible radio planning. [7]

In the literature, theoretical studies have been reported showing the effects of antenna spacing at the transmitter and the receiver sides, where the correlation coefficient of the incoming signals with respect to antenna spacing was investigated. The impact of antenna spacing on channel capacity has been measured intensively in a variety of scenarios and conditions [8, 9]. Recently, the influence of antenna spacing on the throughput of an OFDM transmission was studied in [10, 11] by using sounded channel coefficients in a simulation. By far very few literature is available reporting the effect of open loop and close loop MIMO along with antenna spacing [13-18].

The performance analysis is performed in the downlink of a 3GPP LTE OFDMA system. Multiple input multiple output (MIMO) technologies introduced in LTE such as spatial multiplexing, transmit diversity, and beam forming are key components for providing higher peak rate at a better system efficiency, which are essential for supporting future broadband data service over wireless link [11]. LTE uses OFDMA on the downlink, which is well suited to achieve high peak data rates in high-spectrum bandwidth.

To evaluate the performance of MIMO strategies in LTE, different antenna spacing combinations have been considered. We have investigated the performance of the MIMO base station Antenna Spacing with reference to capacity, throughput and BLER of the System. Both open-loop and closed-loop Single User MIMO systems are discussed with particular emphasis on the data rate maximization aspect of MIMO.

2. SYSTEM DESIGN AND PARAMETERS

System Description: Figure 1 shows a simplified system block diagram of a 2X2 MIMO System

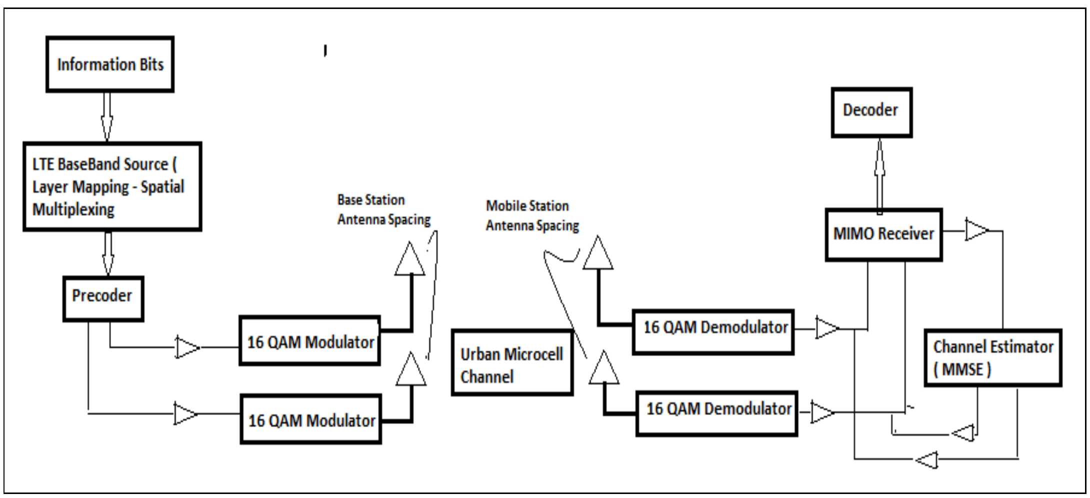

Figure 1. 2 × 2 MIMO System

Figure 2 depicts a typical urban microcell propagation scenario is modeled as high rise buildings and down town streets with base station antenna height of typical lamp post height, much lower than the surrounding buildings and structures. The mobile station height is assumed to be 1.5 meters. The resultant signal at the receiver is the vector sum of multiple rays reaching through multiple reflections of the building walls. The main street and perpendicular streets length are kept at 500 meter each and the speed of mobile is fixed at 20km/hr.

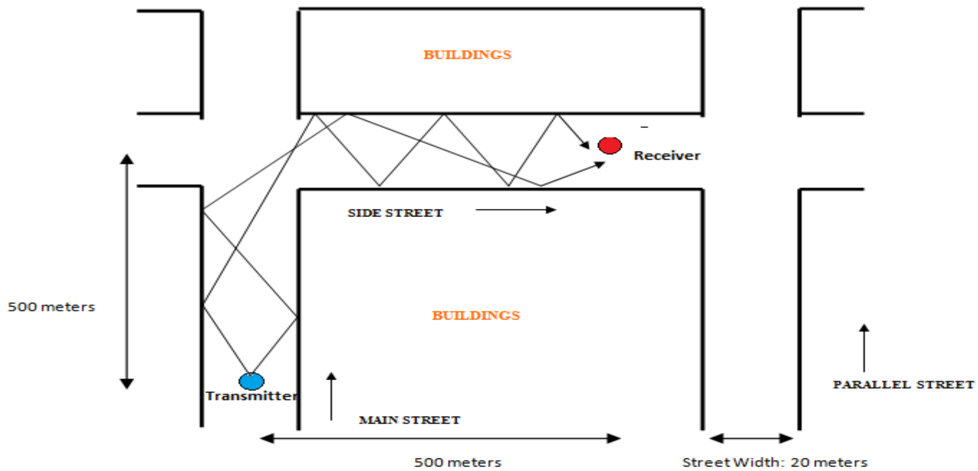

Figure 2. Geometry of Urban Microcell Scenario (NLOS)

The aim is to optimize antenna spacing for downlink in urban microcellular scenario. The system parameters are tabulated below in table 1.

Parameter	Specification
Mode	MIMO Open Loop Spatial Multiplexing MIMO Closed Loop Spatial Multiplexing
Main Street	500 meters
Perpendicular Street	500 meters
Transmitting Antenna	3- Sector
Receiving Antenna	Omni directional
Frequency	2.15 GHz
Modulation Scheme	16QAM (½ Code rate)
Detection scheme	MMSE
Vehicular Speed	20Km/hr
Channel Bandwidth	10 MHz
Transmitter height	10 meters
Receiver height	1.5 meters
Transmit Power	10 dBm

Table 1: System Parameters

3. OBSERVATION

(a) Capacity v/s SNR:

The Capacity curves are as shown in figure 3 & figure 4 respectively. The capacity analysis is undertaken to optimize antenna spacing at Base Station for downlink in urban microcell Scenario

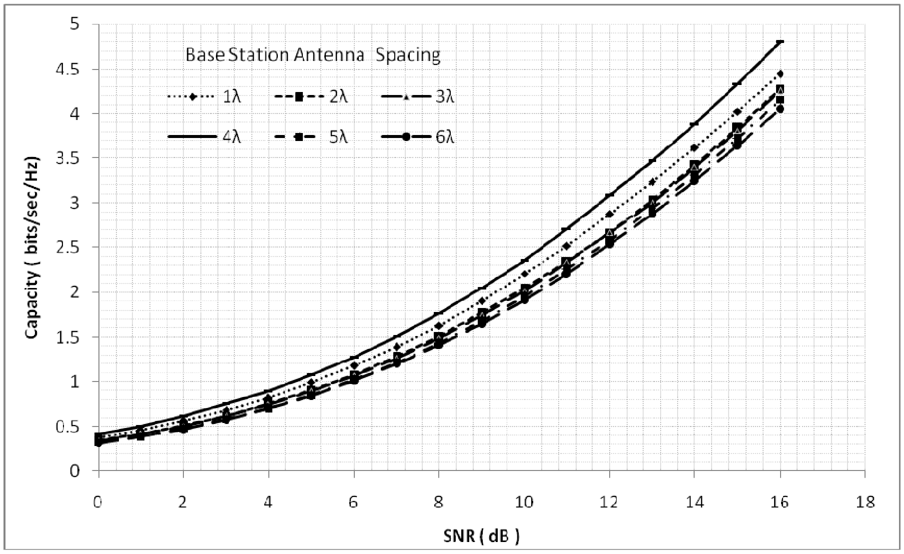

Figure 3. Capacity v/s SNR Plot for Open-Loop MIMO

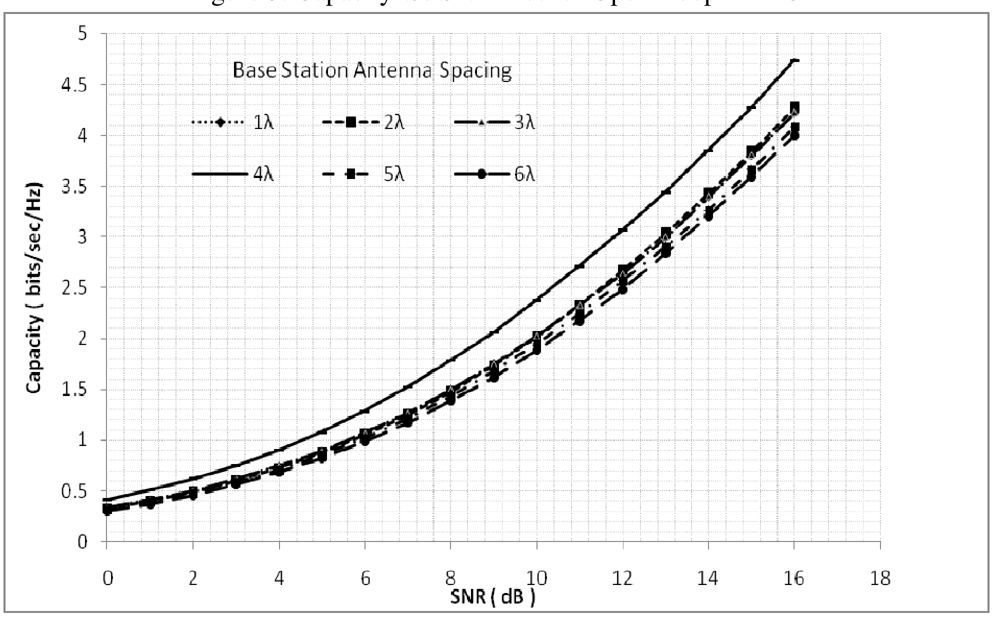

Figure 4. Capacity v/s SNR Plot for 2x2 Close-Loop MIMO

Referring to figure 3 and 4 the capacity increase in antenna spacing at Base station from λ to 6λ a small increase is observed , being maximum for an antenna spacing of 4λ at all ranges of SNR. However for relatively lower SNR (<=5 dB) the capacity gain with varying antenna spacing is not found to be significant.. For moderate SNR (<=10dB and >=5) dB, the spacing effect is more pronounced in terms of capacity curves, it indicates increase in capacity almost linear to increase in SNR for fixed antenna spacing.

The CDF of capacity curves for open loop and closed loop MIMO are shown in figures 5 and 6 respectively.

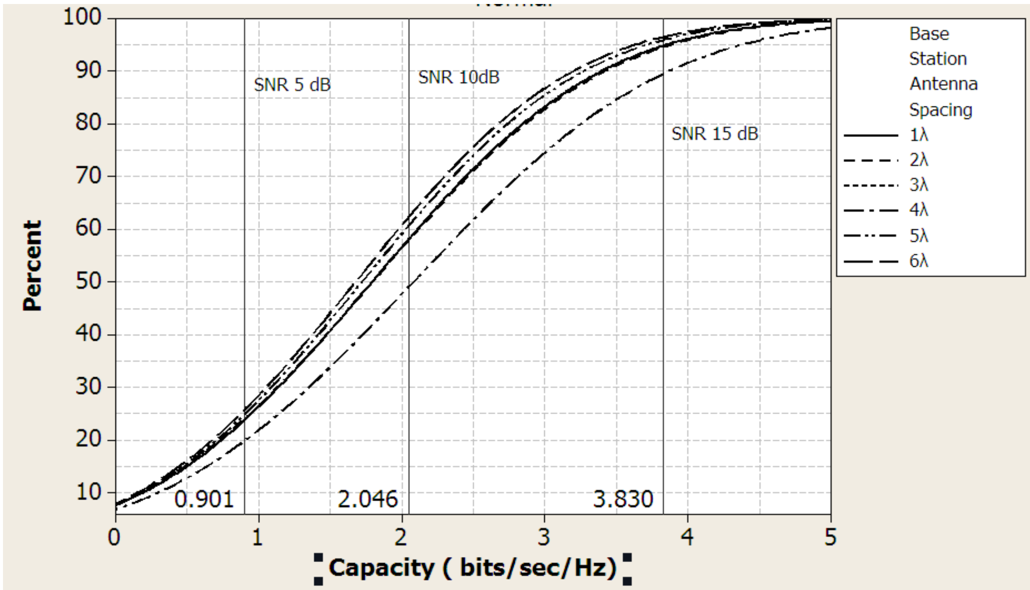

Figure 5. CDF Plot for capacity of Open-Loop MIMO

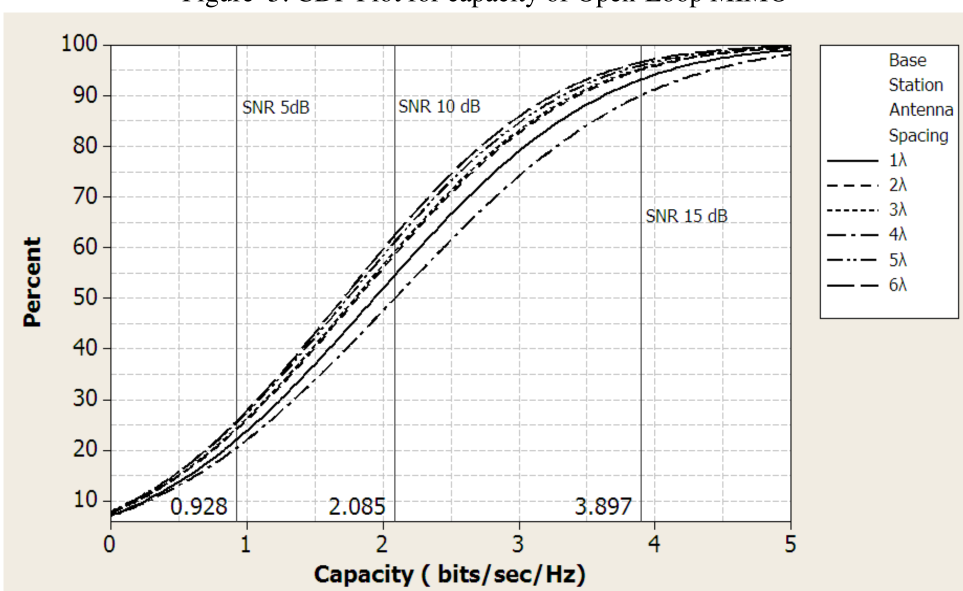

Figure 6. CDF Plot for capacity of Close -Loop MIMO

It can be observed that for relatively lower SNR (<=5dB) close loop MIMO provides a marginal improvement of about 3% (0.027 bits/sec/Hz) over open loop MIMO with SNR gain of around 2dB.

The improvement for moderate SNR range (>5 & <10) is of around 1.9 % (.049 bits/sec/Hz) and higher SNR values (>10 dB) is 1.7% (0.057 bits/sec/Hz) .

(b) Throughput v/s SNR:

The throughput curves are as shown in figure 7 and 8 for Open and Close Loop MIMO respectively. The analysis is undertaken to optimize antenna spacing at Base Station for downlink in urban microcell Scenario.

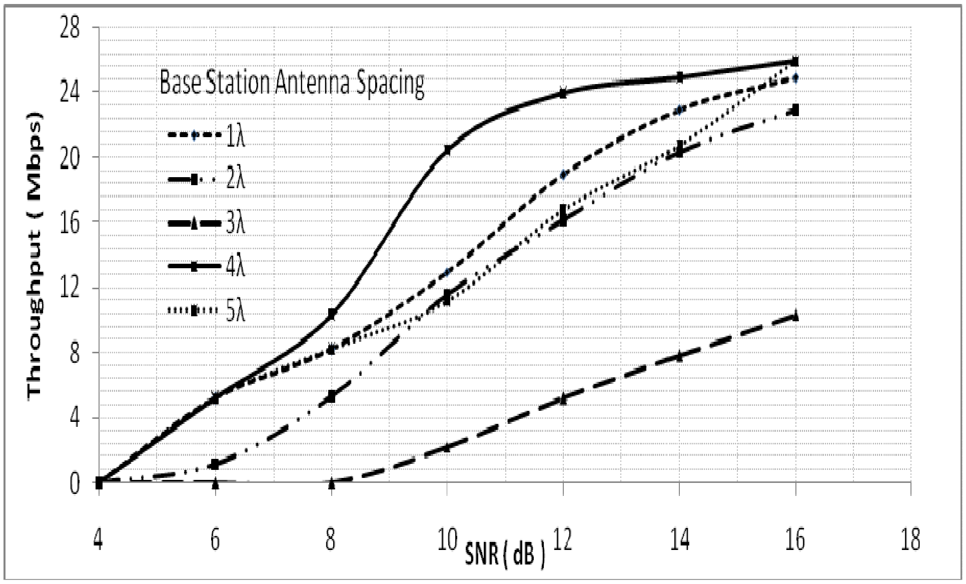

Figure 7. Throughput v/s SNR Plot for Open-Loop MIMO

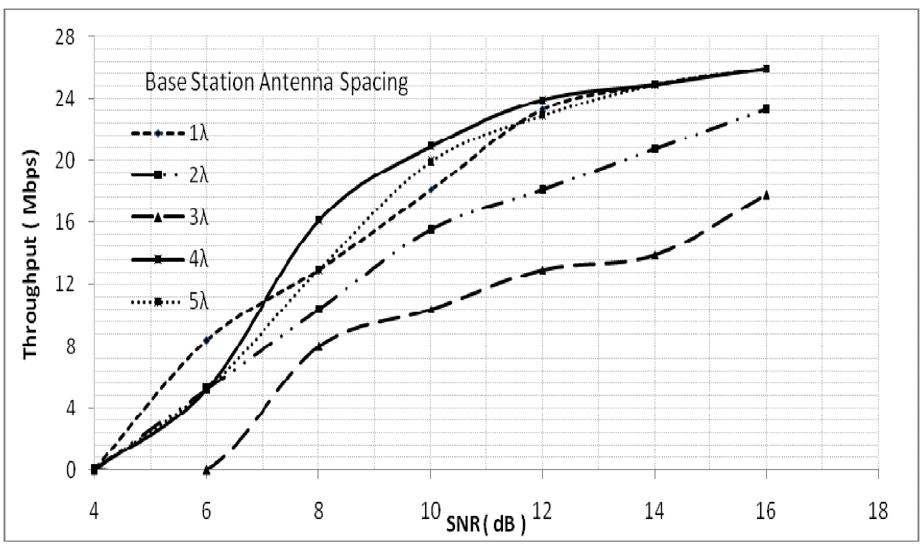

Figure 8. Throughput v/s SNR Plot for close-Loop MIMO

For relatively lower SNR (<=5dB) the antenna spacing 4λ and 1 λ reveals identical throughput of 2Mbps , however for other antenna spacing it is insignificant. The antenna spacing effect is pronounced at SNR >=8 dB . Antenna Spacing of 4λ gives maximum throughput and 3λ gives minimum throughput. One critical observation is that, throughput deteriorates with increase in base station antenna spacing till 3λ, however it starts improving beyond 3λ for all ranges of SNR. As the channel conditions improves (>=8 dB) Increase in spacing from 1λ to 6λ has distinct effect on throughput, the largest being from 3λ to 4λ. For Open Loop MIMO 4λ achieves roughly 2dB theoretical gain over 1λ and 3dB gain over 2λ whereas , in close loop 1.2 dB gain is achieved over 1 λ and 2 dB gain over 2 λ is obtained at a reference throughput of 15 Mbps.

The CDF of throughput curves for open loop and closed loop MIMO are shown in figures 9 and 10 respectively.

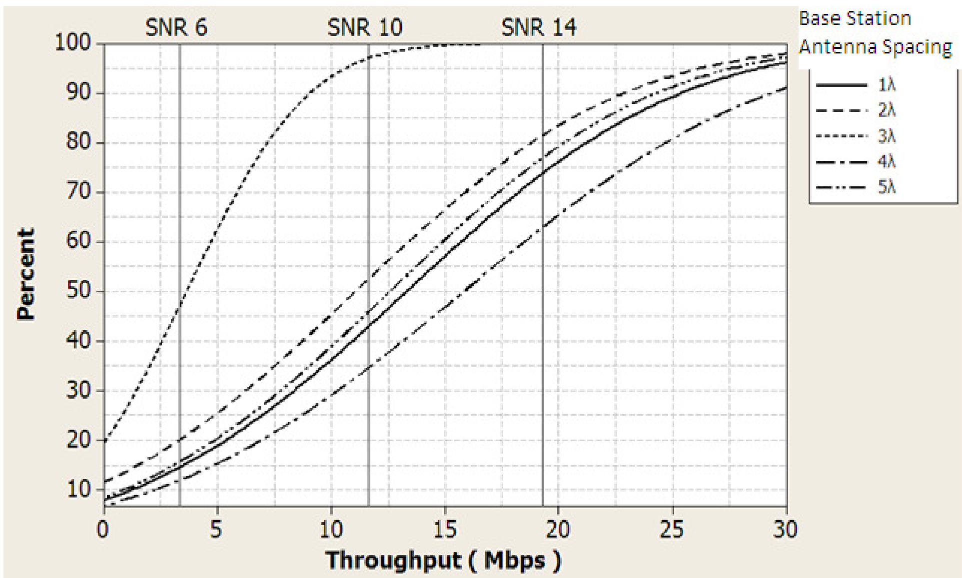

Figure 9. CDF Plot for Open-Loop MIMO

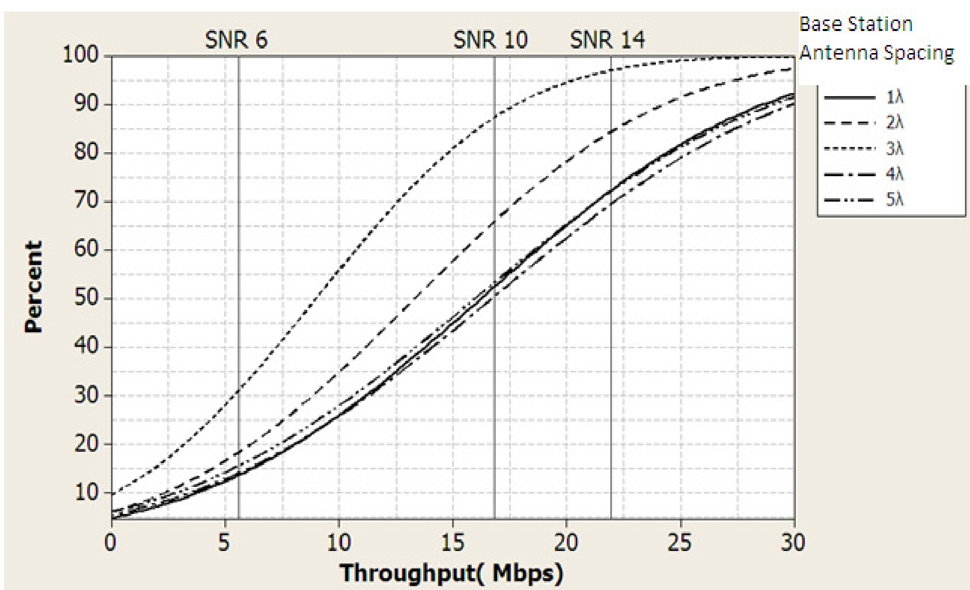

Figure 10. CDF Plot for Close -Loop MIMO

It is observed that performance degrades in open loop MIMO compared to close loop MIMO for all SNR range. The throughput effect becomes more significant for higher (> 10 dB) and moderate SNR (5 to 10 dB) values . For moderate SNR values improvement from open loop to close loop is around 21% (11.66 Mbps v/s 15.86 Mbps) whereas for High SNR range it reaches to 45% (18.66 Mbps v/s 22.96 Mbps) for all antenna spacing.

(c) BLER V/S SNR:

The BLER v/s SNR curves are as shown in figure 11 and 12. The analysis is undertaken to optimize antenna spacing at Base Station for downlink in urban microcell Scenario.

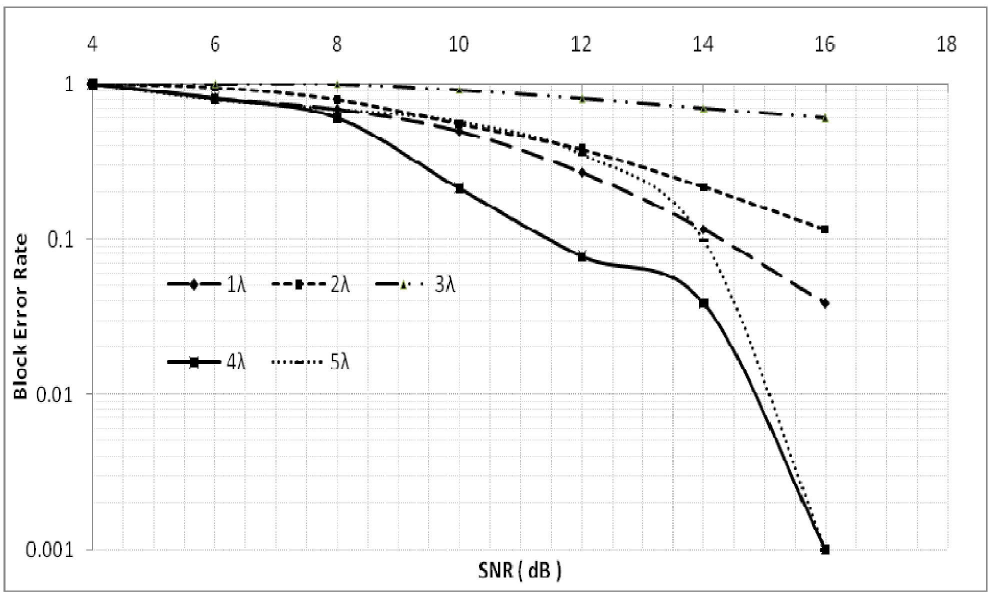

Figure 11. BLER v/s SNR Plot for Open-Loop MIMO

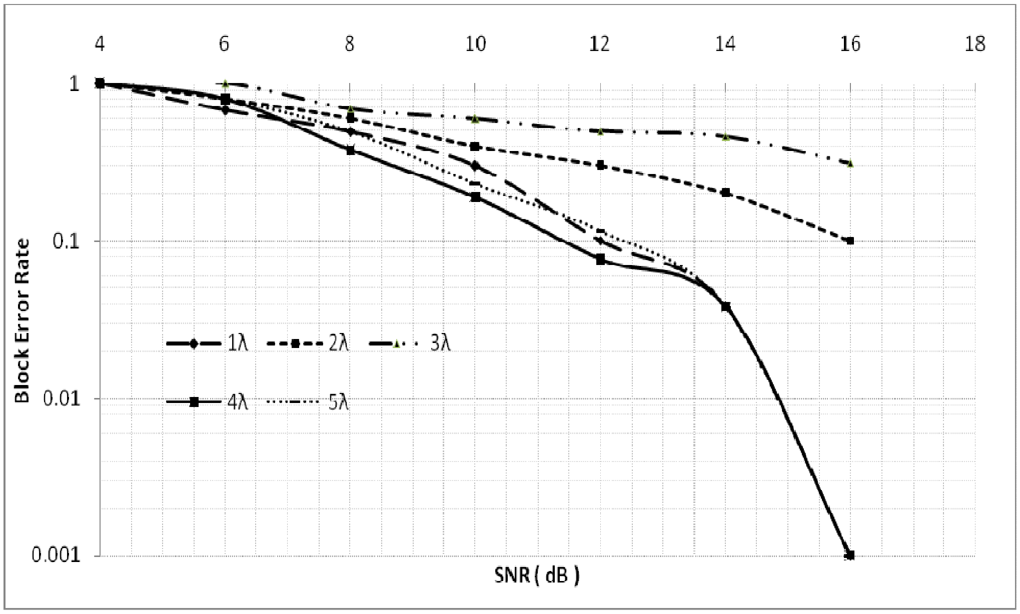

Figure 12. BLER v/s SNR Plot for Close-Loop MIMO

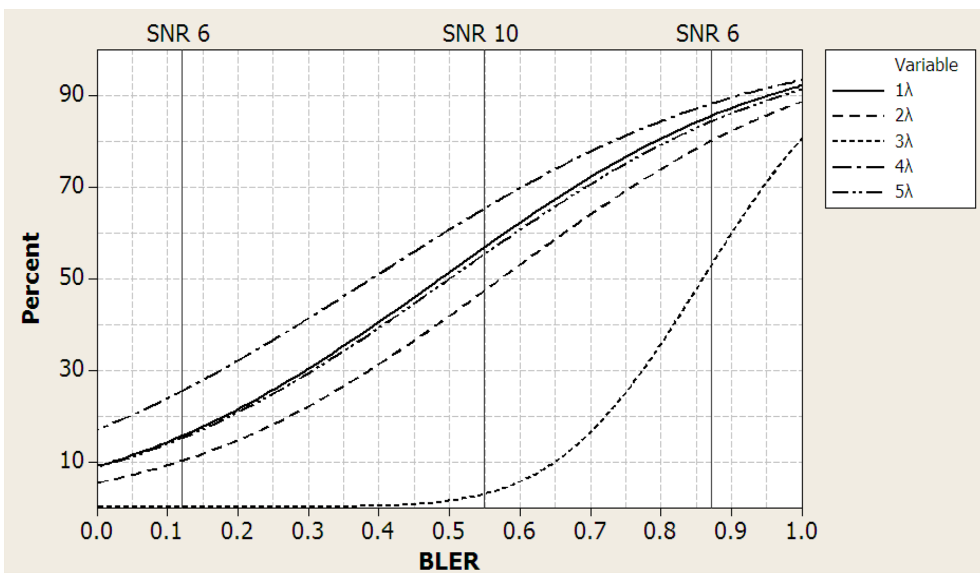

Figure 13. CDF Plot for Open-Loop MIMO

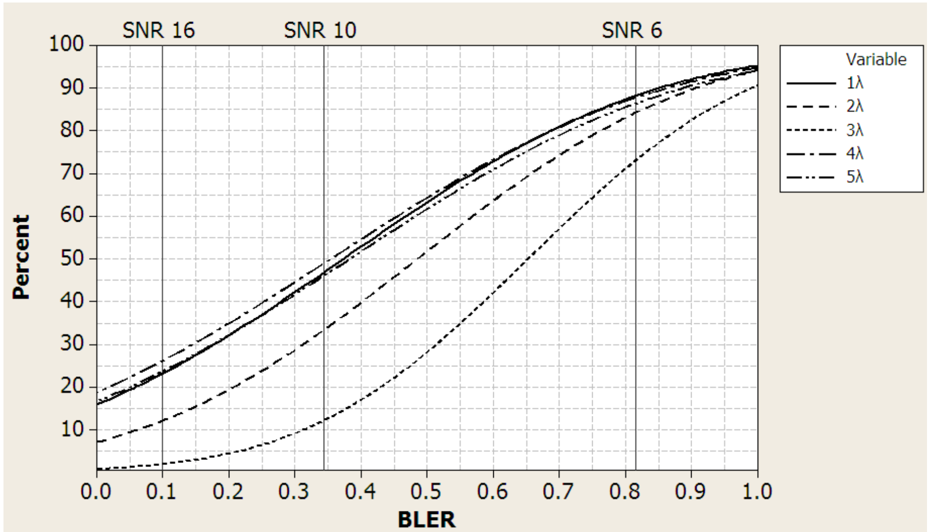

Figure 14. CDF Plot for Open-Loop MIMO

It is observed from figure 11 to 14 that BLER for all condition decreases with increase in SNR. The roll off becomes steeper as SNR ranges beyond 12 dB. For Open loop MIMO small antenna spacing (< 2 λ) suffers 3dB penalty in performance compared to 4 λ at a reference BLER of 10%, corresponding to BER of 10-2. Remarkably in close loop MIMO the effect of antenna spacing is not significant for a reference of 10% BLER , as only 0.5dB gain is achieved with larger spacing

4. RESULTS & DISCUSSIONS

The effect of BS antenna Spacing on the system performance for open loop and closed loop MIMO is carried out in order to optimize the Base Station Antenna spacing for microcellular Propagation Scenario. The channel model used in the simulation is the Spatial Channel Model Extension (SCME) Urban Micro scenario which is specified in 3GPP [12]. In urban micro-cell scenarios the height of both the antenna at the BS and at the MS is assumed to be well below the tops of surrounding buildings. The streets in the coverage area are classified as 'Main Street', where there is LOS from all locations to the BS, and that intersect the Main Street are referred to as Perpendicular streets. The BS height is set to 10 meter and MS height is set to 1.5 meter with urban microcell length of 500 meters. A three -sector BS antenna and Omni directional MS antenna with 0.5λ is used with MIMO set to Spatial Multiplexing (SM) mode, 16-QAM mapping, ½ Code rate with subcarrier spacing of 15 KHz. The MS speed is kept constant at 20 Km/hr. The detection is performed with Minimum Mean Square Estimator (MMSE) and a reference Transmit power is 10 dBm.

Capacity: The Capacity curves for Open-loop and Closed-loop MIMO depicting the effect of variation in BS antenna spacing are determined and the corresponding CDF curve is plotted as shown in figure 6 and 7. The effect of BS antenna spacing from 0.5λ through 4λ, at relatively lower SNR (<=5 dB) indicates a marginal increase in capacity with maximum values observed for 4λ spacing for both open and close loop MIMO. However, at moderate SNR (5-10dB) and also at relatively higher SNR (>10 dB), the effect of antenna spacing is more pronounced leading to spectral efficiency gain of nearly 25% with 4λ spacing.

It is observed that at lower SNR (<5 dB), close loop MIMO provides a noticeable improvement of about 3% (0.027 bits/sec/Hz) over open loop MIMO leading to SNR gain of around 2dB. The capacity improvement at moderate SNR range is around 1.9 % (0.049 bits/sec/Hz) and at higher SNR values (>10 dB) is 1.7% (0.057 bits/sec/Hz).

Throughput: The CDF of throughput curves for open loop and closed loop MIMO are shown in figures 9 and 10. It is observed that performance degrades in open loop MIMO compared to close loop MIMO for all SNR range. For moderate SNR (10 dB) the throughput is 14 Mbps for 2λ spacing, 17 Mbps for 1λ spacing, and 21 Mbps for 4λ spacing. The improvement in throughput from open loop to close loop is around 21% (11.66 Mbps v/s 15.86 Mbps). As the channel condition improves (>10 dB) , increase in spacing from 0.5λ to 4λ has distinct effect on throughput, 4λ achieves roughly 3dB SNR gain in open loop, and 1.2 dB SNR gain in close loop over 2λ with maximum throughput on the order of 20 Mbps.

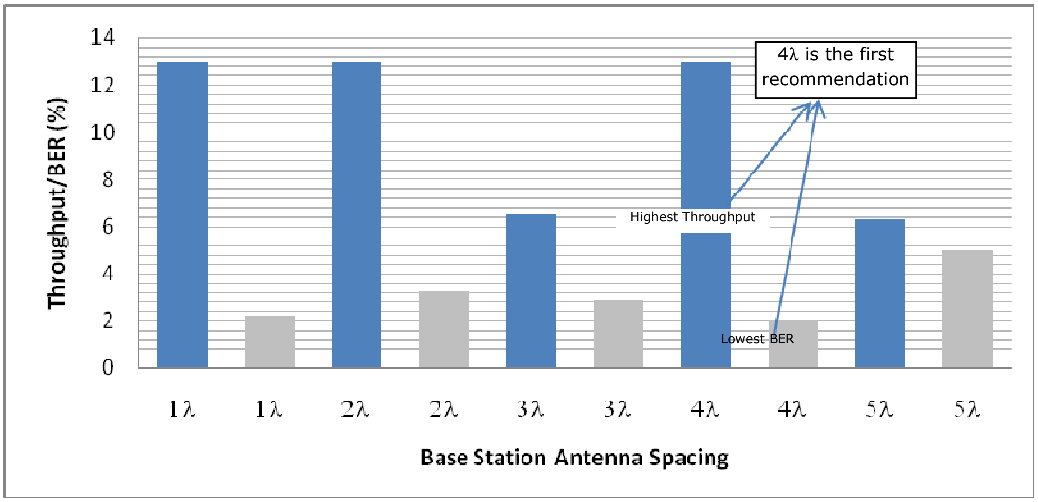

Figure 15: Throughput and BER plots with BS antenna spacing for 2×2 MIMO (at 2 SNR).

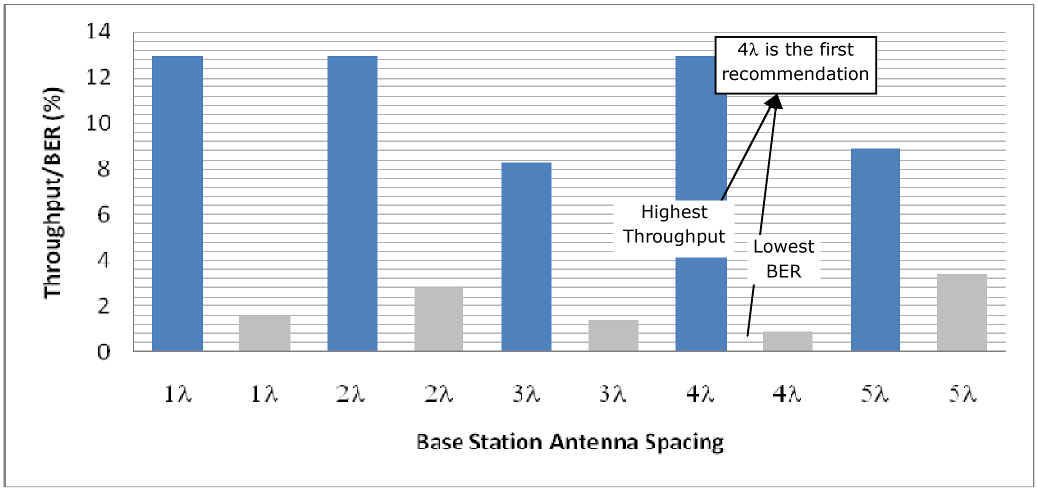

Figure 16: Throughput and BER plots with BS antenna spacing for 2×2 MIMO (at 8 SNR)

Bit Error Rate: The CDF of BER curves for Open-loop and Closed-loop MIMO depicting the effect of variation in BS antenna spacing are as shown in figure 13 and 14. It is obvious that BER in general, decreases with increase in SNR. The roll off becomes steeper as SNR ranges beyond 12 dB. In open loop system at a reference BER of 10%, base station spacing less than 2λ suffers 4dB penalty compared to 4λ. Remarkably, in close loop MIMO the effect of antenna spacing is not significant for a reference of 10% BER, as only 1 dB gain is achieved with larger spacing.

5. CONCLUSION

The performance improvement of 2X2 MIMO LTE downlink with increase in base station antenna spacing is quantitatively reported and discussed. The performance improvement is attributed to existence of highly uncorrelated MIMO channels for relatively large antenna spacing. The base station antenna spacing is found to be a key factor in influencing the overall performance of the system. It is observed that capacity is more or less dependent on SNR conditions, however throughput and BER are found to be sensitive towards antenna spacing variations. It is observed that at low SNR (<5 dB), antenna spacing of 1λ is preferred on account of throughput compared to 2λ/4λ. BER for both close loop and open loop does not have any significant effect over antenna spacing. With increase in SNR (10 dB), close loop MIMO significantly improves BER, Moreover, 4λ spacing shows a distinct effect on throughput with a rise of almost 50-60% compared to other spacing. At SNR beyond 12dB, large antenna spacing gives almost equal values of throughput in open loop and close loop. However BER is significantly reduced from average value of 10% to 1% for 4λ in open loop MIMO.

6. ACKNOWLEDGEMENT

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