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Effect of Channel Condition on the Performance of LTE in various Transmission Mode

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Abstract: - *Long Term* Evaluation (LTE) is an emerging 4G wireless technology. Multiple-Input Multiple-Output (MIMO) systems are a primary enabler of the high data rate to be achieved by LTE . According to LTE Release 9 there are 7 MIMO configurations from mode 2 to 8. An LTE base station is expected to select and switch among these transmission modes based on channel quality feedback like Channel Quality Indicator (CQI) . In this paper we have investigated the effect of different channel conditions at different SNR levels on the performance achieved through transmission mode 1 to 4. The simulation output shows that the mode 3 and 4 which are open loop and close loop spatial multiplexing respectively using 4 transmitting antenna outperforms all other mode in terms of high throughput at very reasonable BLER.

Keywords: - *LTE, Transmit Diversity, Open Loop Spatial Multiplexing, Close Loop Spatial Multiplexing, Throughput*

I. INTRODUCTION

In This Paper we have investigated the effect of channels as CQI on the performance of LTE Release 9 through LTE link level simulator developed by the Institute of Communications and Radio Frequency Engineering, Vienna University of Technology[1]. This paper is made for the developing countries, who are migrating towards 4G LTE Technology, so that they can use this as a helping manual.That's why transmission mode 1-4 are simulated in high multipath fading environment and the superiority of the open loop and close loop spatial multiplexing were demonstrated.

The paper is organized in following section. In section two we have presented the brief over view of LTE transmission modes. In Release 8 , Long Term Evaluation(LTE) [2] was standardized by 3GPP as the successor of the Universal Mobile Telecommunication System (UMTS). The targets for downlink and uplink peak data rate requirements were set to 100Mbits/sec and 50Mbits/sec, respectively when operating in a 20MHz spectrum allocation [3].

First performance evaluations show that the throughput of the LTE physical layer and MIMO enhanced WCDMA [4] is approximately the same [5-9] . However, LTE has several other benefits of which the most important are explained in the following.

The LTE downlink transmission scheme is based on Orthogonal Frequency Division Multiple Access (OFDMA) which converts the wide-band frequency selective channel into a set of many flat fading sub-channels. The flat fading sub-channels have the advantage that even in the case of MIMO transmission – optimum receivers can be implemented with reasonable complexity , in contrast to WCDMA systems .OFDMA additionally allows for frequency domain scheduling , typically trying to assign only "good" sub-channels to the individual users . This offers large throughput gains in the downlink due to multi-user diversity [10,11].

II. TRANSMISSION MODE DOWNLINK IN LTE

In the downlink, LTE uses technologies such as MIMO, transmit diversity or SISO, Beamforming etc are used to achieve high data rates. In the Release 9 specification [12], up to four antennas are defined in the base station and up to four antennas in the UE[13].

Table 1: Transmission Modes in LTE Release 9		
Transmission Mode (TM)	**Description**	**Comment**
1	Single transmit antenna	Single antenna port; port0
2	Transmit diversity	2/4 antennas
3	Open loop spatial multiplexing with cyclic delay diversity(CDD)	2/4 antennas
4	Close loop spatial multiplexing	2/4 antennas
5	Multi-user MIMO	2/4 antennas
6	Close loop spatial multiplexing using a single transmission layer	1 layer (rank 1), 2/4 antennas
7	Beamforming	Single antenna port; port 5
8	Dule-layer beamforming	Dule-layer transmission, antenna ports 7 or 8

Here we discussed about Transmission Mode 1,2,3,4.
Transmission Mode 1 is Single transmit antenna[13].

Transmission Mode 2 is Transmit diversity which sends the same information via various antennas, whereby each antenna stream uses different coding and different frequency resources. This improves the signal-to-noise ratio and makes transmission more robust. For two antennas, a frequency-based version of the Alamouti codes (space frequency block code, SFBC) is used, while for four antennas, a combination of SFBC and frequency switched transmit diversity (FSTD) is used [13] .

Transmission Mode 3 is Open loop spatial multiplexing with CDDwhich supports spatial multiplexing of two to four layers that are multiplexed to two to four antennas, respectively, in order to achieve higher data rates. It requires less UE feedback regarding the channel situation (no precoding matrix indicator is included), and is used when channel information is missing or when the channel rapidly changes, e.g. for UEs moving with high velocity[13].

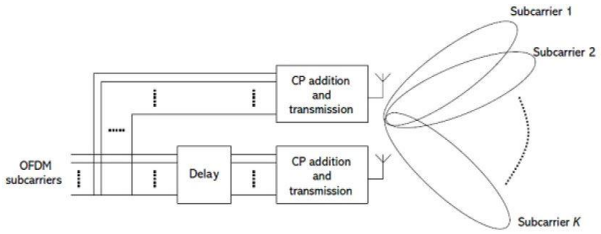

figure 1: TM 3, Spatial multiplexing with CDD

Transmission Mode 4 is Closed loop spatial multiplexing with up to four layers that are multiplexed to up to four antennas, respectively, in order to achieve higher data rates. To permit channel estimation at the receiver, the base station transmits cell-specific reference signals (RS), distributed over various resource elements (RE) and over various timeslots[13].

Table 2 : Codebook indices for spatial multiplexing with two antennas [12]

Spatial multiplexing LTE		
Codebook index	Number of layers υ	
	1	2
0	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\1\end{bmatrix}$	$\frac{1}{\sqrt{2}}\begin{bmatrix}1 & 0\\0 & 1\end{bmatrix}$
1	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-1\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 1\\1 & -1\end{bmatrix}$
2	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\j\end{bmatrix}$	$\frac{1}{2}\begin{bmatrix}1 & 1\\j & -j\end{bmatrix}$
3	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-j\end{bmatrix}$	-

III. SIMULATION RESULT

In LTE we have seen the variation in Throughput & BER with the change of Transmission mode & CQI. Ideally it seems like the picture below :

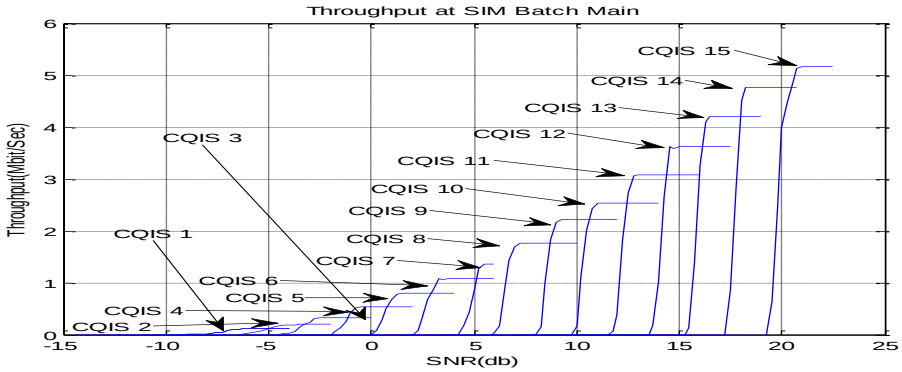

figure 2:Ideal variation in throughput with the change of CQI

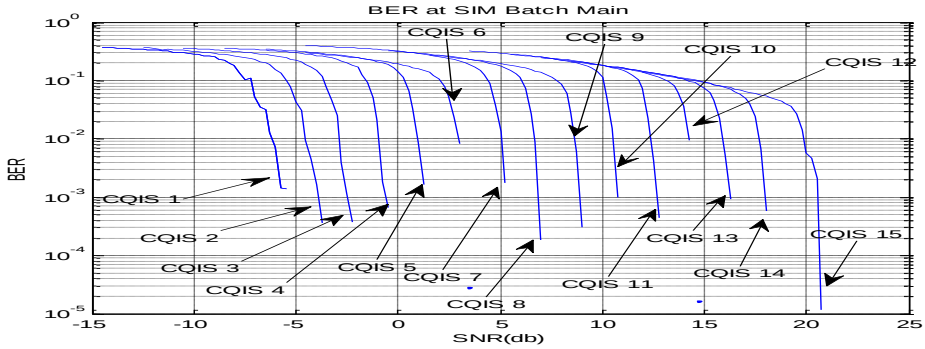

figure 3:Ideal variation in SNR with the change of CQI

Here SUMIMO (Single User Multiple Input Multiple Output),MUMIMO(Multiple User Multiple Input Multiple Output),SUSISO(Single User Single Input Single Output) are used as parameters.

But practically, the variation doesn't happen in this way. The throughput & BER varies differently for each types of transmission mode. Every transmission mode follows a definite rate to vary the parameter (Throughput & BER). We can observe the variation rate through the table below:

Table 3 : Variation Rate of Transmission Mode with the change of CQI

CQI	Transmission Mode (Transmission mode,nTx,nRx)	Peak throughput (Mbit/Sec)
1	1	0.1
	221	0.1
	242	0.1
	342	0.2
	442	0.2

2	1	0.25
	221	0.25
	242	0.2
	342	0.35
	442	0.35
3	1	0.35
	221	0.35
	242	0.35
	342	0.75
	442	0.75
4	1	0.55
	221	0.5
	242	0.5
	342	1
	442	1
5	1	0.8
	221	0.75
	242	0.7
	342	1.4
	442	1.5
6	1	1.1
	221	1.01
	242	1
	342	2
	442	2
7	1	1.4
	221	1.3
	242	1.4
	342	2.4
	442	2.4
8	1	1.8
	221	1.8
	242	1.6
	342	3.2
	442	3.2
9	1	2.2
	221	2.1
	242	2
	342	4
	442	4
10	1	2.6
	221	2.4
	242	2.3
	342	4.6
	442	4.6
11	1	3.1
	221	2.9
	242	2.8
	342	5.6
	442	5.6
12	1	3.6
	221	3.4
	242	3.3
	342	6.5
	442	6.5
13	1	4
	221	4
	242	3.8
	342	7.6
	442	7.6
14	1	4.8
	221	4.5

	242	3.5
	342	8.9
	442	8.9
15	1	4.1
	221	4.8
	242	2.4
	342	8.8
	442	8.8

The variation rate & characteristics' can also be determined graphically at a fixed value of SNR.

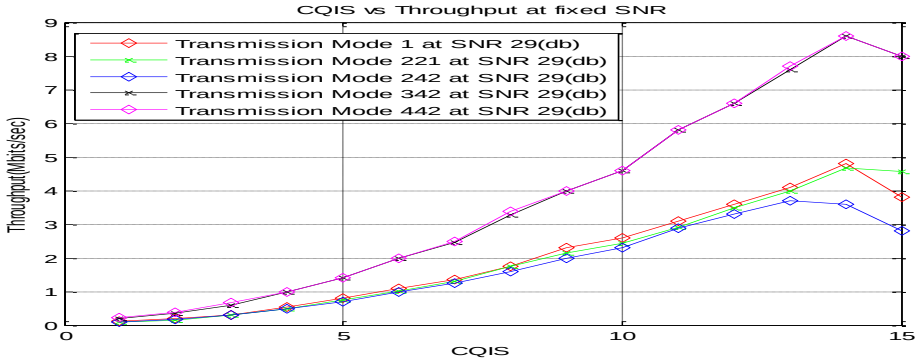

figure 4: Variation Rate of Transmission Mode

IV. SIMULATION COMPARISON

From the graph we have seen that, Transmission Mode 3 & 4 have highest throughput rate.At the same time we have observed that each transmission mode has a peak value for a fixed CQIS.After that it tends to decrease . we can compare all the four transmission modes (1,2,3,4) by taking graphs showing all transmission mode for some CQI.

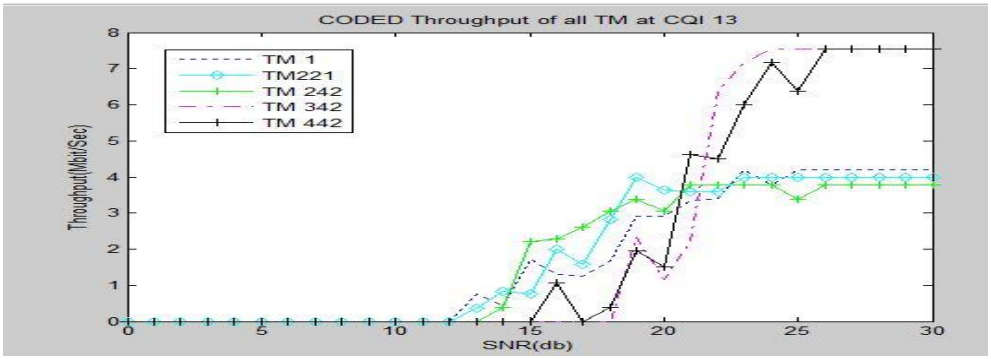

figure 5 : Coded Throughput for all Transmission Mode at CQI 13

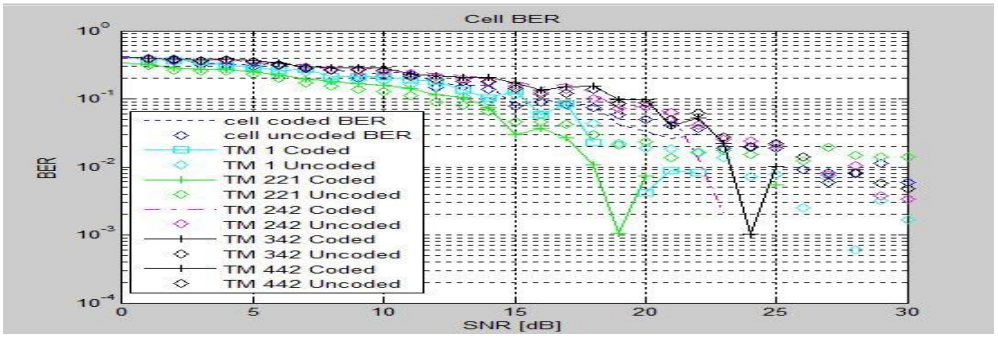

figure 6: SNR for all Transmission Mode at CQI 13

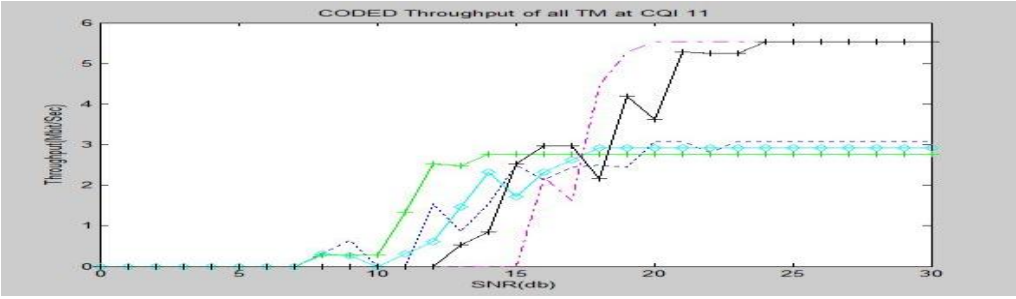

figure 7 : Coded Throughput for all Transmission Mode at CQI 11

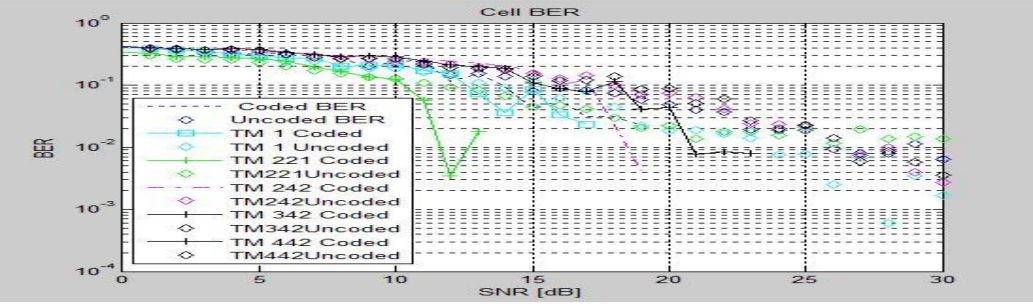

figure 8: Snr for all Transmission Mode at CQI 11

From the comparison we can easily say that transmission mode 3 & 4 (Open loop & close loop spatial multiplexing) has large throughput than transmission mode 2 (transmit diversity).

V. CONCLUSION

For transmit diversity[14], Space Time Block Codes (STBC) are used to provide improvement against the channel deteriorating effects. Alamouti STBC are considered to be the simplest space time block codes. It is well known that Alamouti codes [15] can achieve full diversity and full code rate simultaneously. For this reason it is used in noisy channel.

Spatial Multiplexing[16] provides extra gain as compared to TxD Independent data streams are transmitted from the NT transmit antennas in spatial multiplexing. Two classes of spatial multiplexing, open and closed loop spatial multiplexing Figures 3 and 4, are discussed. OLSM transmits the independent data streams without deploying any feedback algorithm. In CLSM essential amount of CSI is used as feedback which enables us to achieve high throughput. That's why in noiseless channel Spatial Multiplexing (Transmission Mode 3 & 4) is used for getting high throughput.

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