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Agenda Item: **15.2**
Source: **Fujitsu**
Title: **Performance Evaluation of Coherent SU and MU CoMP for LTE-A**
Document for: **Discussion**

1. Introduction

In LTE-A technique report (TR) [1], downlink coordinated multi-point (CoMP) transmission can be accomplished by dynamic coordination among multiple geographically separated transmission points, including

- Coordinated scheduling and/or beamforming
  - ✓ data to a single UE is instantaneously transmitted from one of the transmission points
  - ✓ scheduling decisions are coordinated to control e.g. the interference generated in a set of coordinated cells.
- Joint processing/transmission
  - ✓ data to a single UE is simultaneously transmitted from multiple transmission points, e.g. to (coherently or non-coherently) improve the received signal quality and/or cancel actively interference for other UEs

System performance for down-link CoMP has been investigated with coherent transmission in [2][3], where both sector throughput and cell coverage can be improved under some ideal simulation assumptions such as zero backhaul delay and perfect reception timing. However, the detailed exposition of where the gain comes from is not clearly demonstrated and the relevant performance evaluation in terms of geometry gain and SINR gain in 3D antenna configuration seems a vacuum. To fill up this blank, in Seoul meeting, we investigated the CoMP performance by compared between CoMP (single user) and non-CoMP, finding that a trade-off between sector throughput and cell coverage always occurs [4].

In this contribution, furthermore, we focus on the performance evaluation of coherent CoMP with single user (SU) and multi-user (MU) by means of a system level simulation with 3D antenna pattern. To this end, we evaluate the system performance for coherent CoMP transmission which is precisely defined as SU and MU CoMP transmission scenarios in our contribution [5]. The main intention of this CoMP work is to clarify the performance between SU and MU CoMP. Our system level simulation shows that the coherent MU CoMP does not perform any gain as opposed coherent SU CoMP.

2. Coherent CoMP Transmissions

As discussed in [5], CoMP joint processing/transmission could be categorized into coherent SU CoMP and coherent MU CoMP transmissions. The purpose of utilizing coherent SU CoMP transmission is to improve the cell coverage, and in contrast, the purpose of utilizing coherent MU CoMP transmission is to improve the sector throughput.

The coherent SU transmission [5] is evaluated in this contribution, which is illustrated in Figure 1, where both serving and coordinated cells simultaneously serve a single UE0 and deliver the same data with a universal code book. In this case, the UE0 served by serving and coordinated cells is capable of estimating both channels of $\Gamma_0(k,l)$ and $\Gamma_1(k,l)$. According to $\Gamma_0(k,l)$ and $\Gamma_1(k,l)$, a code book $U_{0,1}$ is universally determined, and the data s is transmitted from both serving and coordinated cells. In the UE receiver, the UE0 receives the precoded desired data which is only contaminated by AWGN noise.

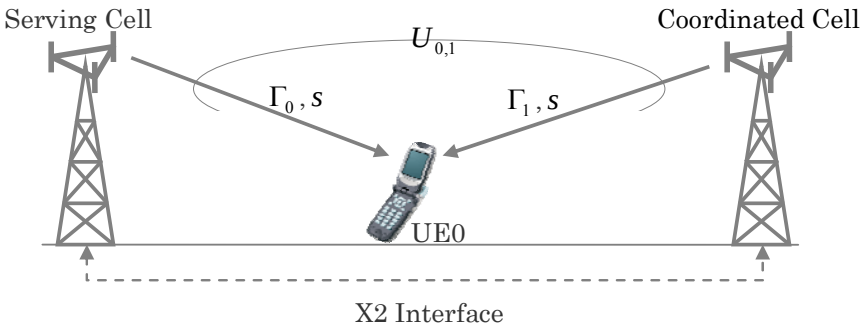

Figure 1: Coherent SU CoMP transmission.

The coherent MU CoMP transmission, on the other hand, is illustrated in Figure 2, where both serving and coordinated cells simultaneously serve both UE0 and UE1 with different code books. In this case, the UE0 and UE1 served by serving and coordinated cells are capable of estimating channels of $\Gamma_{0,0}(k,l)$ and $\Gamma_{0,1}(k,l)$, and $\Gamma_{1,0}(k,l)$ and $\Gamma_{1,1}(k,l)$. According to $\Gamma_{0,0}(k,l)$ and $\Gamma_{0,1}(k,l)$, and $\Gamma_{1,0}(k,l)$ and $\Gamma_{1,1}(k,l)$, the code books $U_{0,0,1}$ and $U_{1,0,1}$ are cooperatively determined, whereby the precoded MU data s_0 and s_1 are transmitted from serving cell and coordinated cell. In the UE receivers, the UE0 and UE1 receives the desired data which is contaminated by a amount of leaked interference due to limited available code books, and AWGN noise.

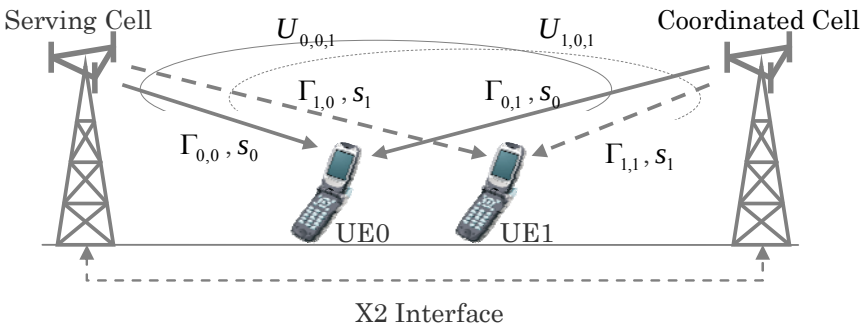

Figure 2: Coherent MU CoMP transmission.

In what follows, we evaluate the system performance and make a comparison between coherent SU and MU CoMP transmission by means of system level simulation.

3. Performance Evaluations

To simplify our discussion, this section summarizes the system level performance under the antenna configurations of 2x2 with coherent SU CoMP and coherent MU CoMP. The detailed information

associated with system level simulation assumptions, link to system mapping MCS table, system level results are elaborated in the appendix 5. In our system level simulation, we select the CoMP UE based on the geometry threshold, that on average, the geometry of 1dB corresponds to 20% CoMP UEs in each serving cell. The RBs assigned for CoMP UEs are fixed either in the first 10RBs (a scheduling bandwidth) or in the first and second 10RBs (20RBs in total).

In CoMU transmission, it is not always that CoMP is implemented with MU scenario even the scheduler tries to do so. In general, it depends on the user pairing, which is available only if the serving and coordinative cells both are able to care two users. That means, if proper pairing users can not be found, CoMP transmission must rely on SU scenario. According to our simulation investigation, with 20% CoMP UEs in each serving cell, the ratio of CoMP MU UEs to all CoMP UEs is about 0.67. Namely, with 20% CoMP UEs, there are only 13% UEs who are purely implemented with MU CoMP transmission.

Table 1 briefly summarizes the system performance results in terms of sector aggregated throughput and user coverage with 5%tile outage requirement for 3D antenna pattern, respectively.

Table 1: Comparison results in terms of sector aggregated throughput and user coverage for simulation case-1 with non CoMP, coherent *SU* CoMP and coherent *MU* CoMP.

Transmission Scheme	CoMP Types	Assigned Number of CoMP RBs	Aggregated Sector Throughput (bps/Hz)	User Coverage (bps/Hz)
Non CoMP	--	--	2.0716	0.0685
Coherent CoMP	SU	10 RBs	2.0609	0.0404
		20 RBs	1.8256	0.0741
	MU	10 RBs	2.0369	0.0483
		20 RBs	1.8189	0.0621

The gain achieved by coherent SU and MU CoMP transmission over non-CoMP transmission (normal 2x2 precoded transmission) is summarized in Table 2, accordingly.

Table 2: Relevant gain of coherent *SU* CoMP and coherent *MU* CoMP over non CoMP.

CoMP Types	Assigned Number of CoMP RBs	Aggregated Sector Throughput (bps/Hz)	User Coverage (bps/Hz)
SU	10 RBs	0.9948	0.5898
	20 RBs	0.8813	1.0818
MU	10 RBs	0.9832	0.7051
	20 RBs	0.8780	0.9066

It can be observed that coherent MU CoMP does not achieve gain in terms of sector throughput and cell coverage under our limited simulation assumptions.

Here, we attempt to give concrete evidence why coherent MU CoMP transmission does not achieve sector throughput and cell coverage gains. We believe that the reasons can be explained by means of the similar way as discussed in [4].

According to unique geometry results, the difference between coherent SU and MU CoMP is above 5dB (see Figure 6, for instance). In addition, the similar amount of offset appears in scheduled effective

SINR metric (see Figure 7, for instance). This huge SINR loss results in the degradation of MU CoMP as opposed to SU CoMP.

4. Conclusions

In this contribution, coherent SU and MU CoMP performance has been evaluated by means of a system level simulation. The conclusions can be listed as follows:

- The trade-off between sector throughput and cell coverage always occurs in SU CoMP transmission. For instance, in order to achieve 8% cell coverage gain, we need to pay the penalty of sector throughput by 12%. However, MU CoMP does not achieve any system throughput gain as opposed to SU CoMP.

- The system level simulation has been performed under the constraints that only two cells are involved in coherent CoMP transmission with 3D antenna pattern. For other simulation scenarios with more cells involved in CoMP, the conclusion may be changed. It should emphasized that, in system level evaluation, we need to utilize more metrics such as geometry and SINR, in order to justify the accuracy in different CoMP scenarios.

5. Appendix: System Level Simulation Details

The detailed simulation assumptions, link to system mapping MCS table, and elaborated simulation results are described in what follows.

5.1. Simulation Assumptions

The system level simulation assumptions are referred to [6] with simulation case-1 only (see Table 3) in which the CF, inter-site distance (ISD), operating bandwidth (BW), penetration loss (PLoss), UE speed, and channel model are specified.

Table 3: UTRA and EUTRA simulation case minimum set.

Simulation Cases	CF (GHz)	ISD (meters)	BW (MHz)	PLoss (dB)	Speed (km/h)	Channel Model
1	2.0	500	10	20	3	SCM

The system level simulation focuses on the down-link with the detailed assumptions listed in Table 4.

Table 4: System Level Simulation Assumptions.

Number of Cells	19
Number of Sectors per Cell	3
Number of UEs per sector	10
Antenna Configuration	2x2
Transmit Antenna Correlation	10λ
Receive Antenna Spacing	0.5λ
Maximum Retransmission Number	3
HARQ Type	Incremental Redundancy (IR)
Centre Frequency	2 GHz
Transmission Power	40 Watts (46 dBm)

Lognormal Shadowing	8dB
Noise Figure	9 dB
Transmit Antenna Gain	14 dBi
Receive Antenna Gain	0 dBi
Maximum CIR	30 dB
Number of Cells involved in CoMP	2
Path-Loss	$128.1+37.6\log_{10}(R)$, R in km
Scheduler	Proportional Fair
Channel Estimation	Ideal
Traffic Model	Full Buffer
MCS Table	29 Levels, see Table 5 in section 5.2
Effective SINR	Mutual Information Basis [7]
Overhead	28.57%
MCS Determination	Common Reference Signal Basis
MCS Feedback Interval	5msec
Number of HARQ Process Channel	8
Number of RBs per Tx per UE	10
Channel Model	SCM
Bandwidth	10MHz
Number of Useful Sub-carriers per Symbol	600
FFT Size	1024
Receiver Type	LMMSE
A_m for Horizontal Antenna	25dB
SLA_V for Vertical Antenna	20dB
Threshold for CoMP UE selection	-0.5dB and 1dB in geometry
Number of RBs Assigned to CoMP UE	10RBs and 20RBs

5.2. MCS Table

The MCS format is tabulated in Table 5, with 29 MCS levels considering QPSK, 16QAM and 64QAM, and many different code rates.

Table 5: MCS Format.

MCS Index	Modulation	Code Rate	MCS Index	Modulation	Code Rate
0	QPSK	0.117333333	15	16QAM	0.608
1	QPSK	0.152	16	16QAM	0.64
2	QPSK	0.186666667	17	64QAM	0.426666667
3	QPSK	0.245333333	18	64QAM	0.458666667
4	QPSK	0.298666667	19	64QAM	0.508444444
5	QPSK	0.373333333	20	64QAM	0.551111111
6	QPSK	0.437333333	21	64QAM	0.608
7	QPSK	0.512	22	64QAM	0.643555556
8	QPSK	0.586666667	23	64QAM	0.700444444
9	QPSK	0.661333333	24	64QAM	0.760888889
10	16QAM	0.330666667	25	64QAM	0.803555556
11	16QAM	0.368	26	64QAM	0.871111111

12	16QAM	0.421333333	27	64QAM	0.896
13	16QAM	0.474666667	28	64QAM	0.920888889
14	16QAM	0.544			

Figure 3, Figure 4 and Figure 5 show the BLER results as a function of SNR associated with QPSK, 16QAM, and 64QAM, respectively. These MCSs are used for interface between link-level and system level mapping based on mutual information mapping manner.

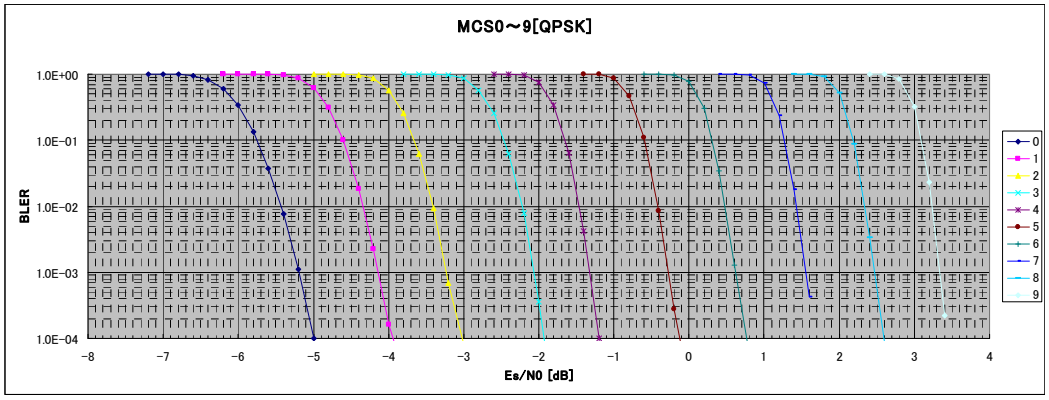

Figure 3: MCSs for QPSK.

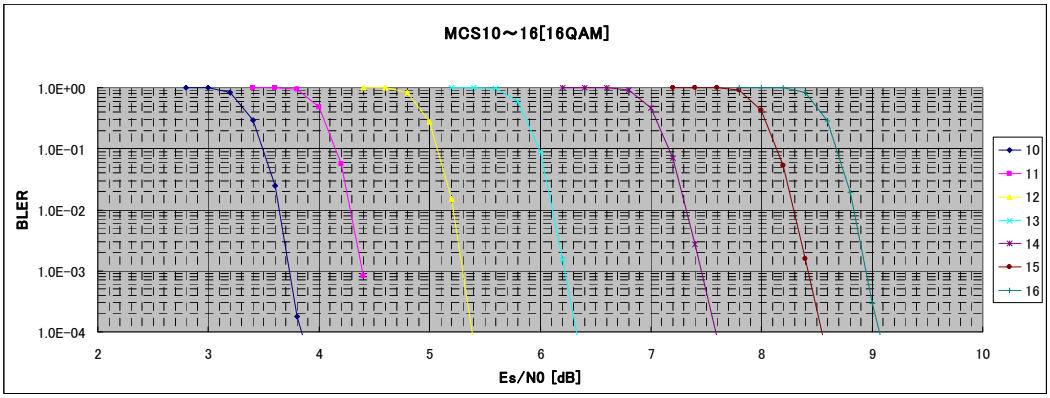

Figure 4: MCSs for 16QAM.

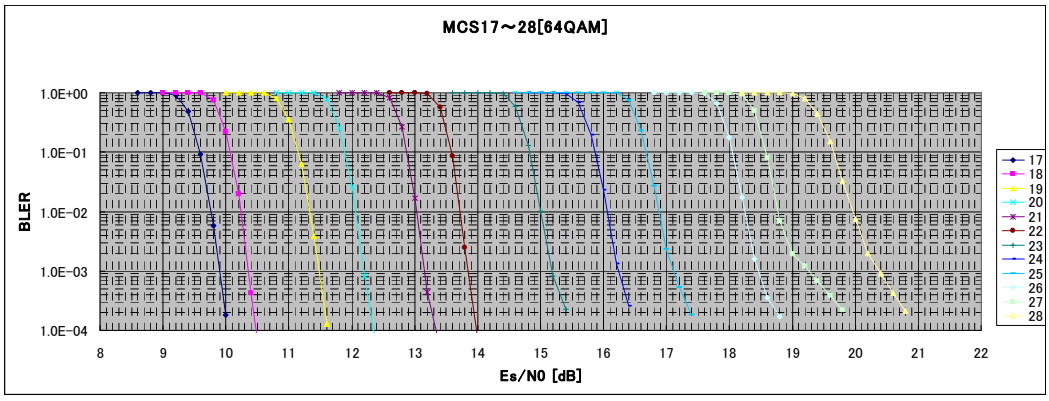

Figure 5: MCSs for 64QAM.

5.3. System Level Simulation Results

Here, we plot the detailed system level simulation results for case-1 only, in terms of geometry CDF, scheduled effective SINR CDF, and user throughput CDF.

Figure 6 illustrates the CDF of geometry with 20% CoMP UEs on average in each cell. It should be noted that the geometry behaviors with 3D antenna pattern is quite different from that with 2D antenna pattern. The details may refer to the contribution [8].

Figure 7 shows the CDF of scheduled effective SINR for common reference signal with 20% CoMP UEs (13% MU CoMU UEs) on average in each cell.

Figure 8 and Figure 9 show the CDF of user throughput with 10 and 20 CoMP RBs, respectively.

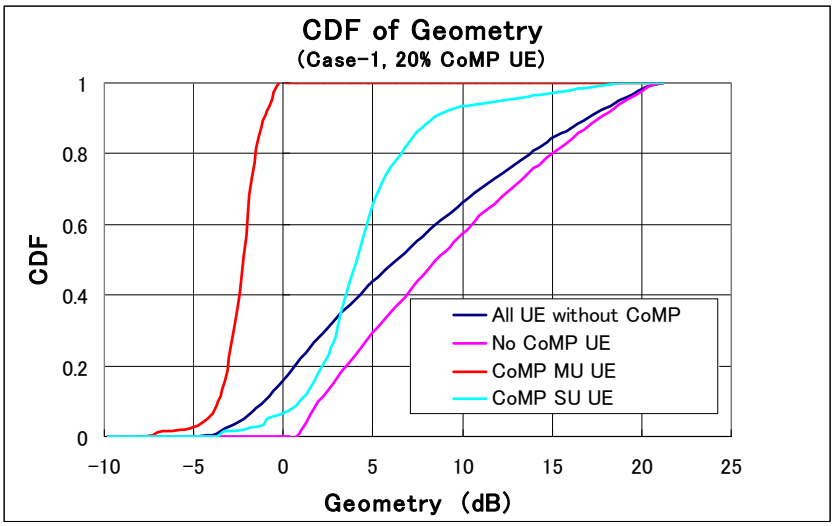

Figure 6: CDF of Geometry with 20% CoMP UEs on average in each cell.

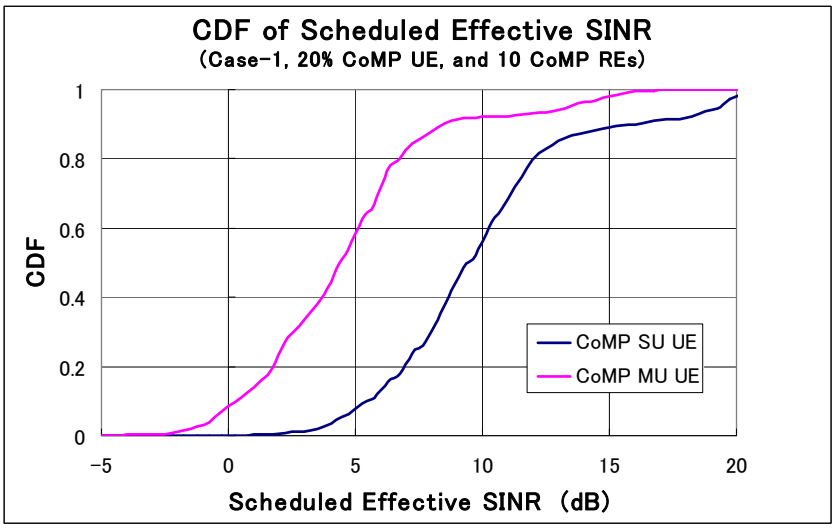

Figure 7: CDF of scheduled effective SINR for common reference signal with 20% CoMP UEs on average and 10 CoMP RBs.

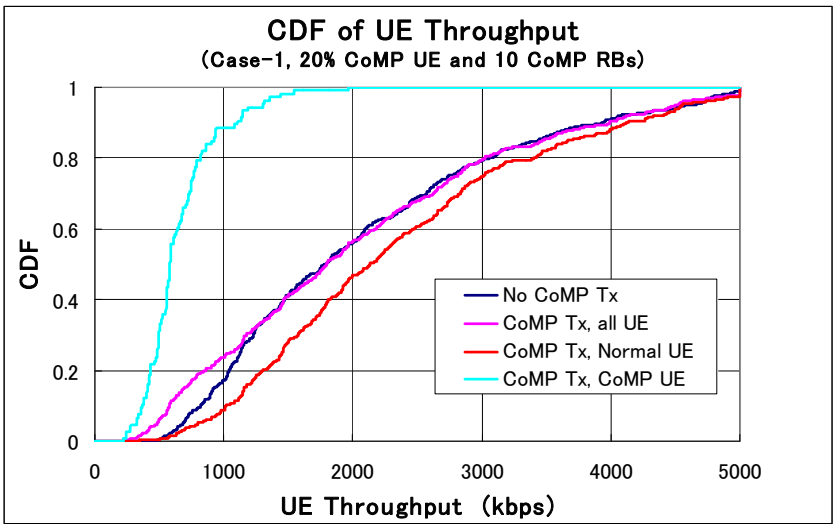

Figure 8: CDF of user throughput with 20% CoMP UEs on average and 10 CoMP RBs.

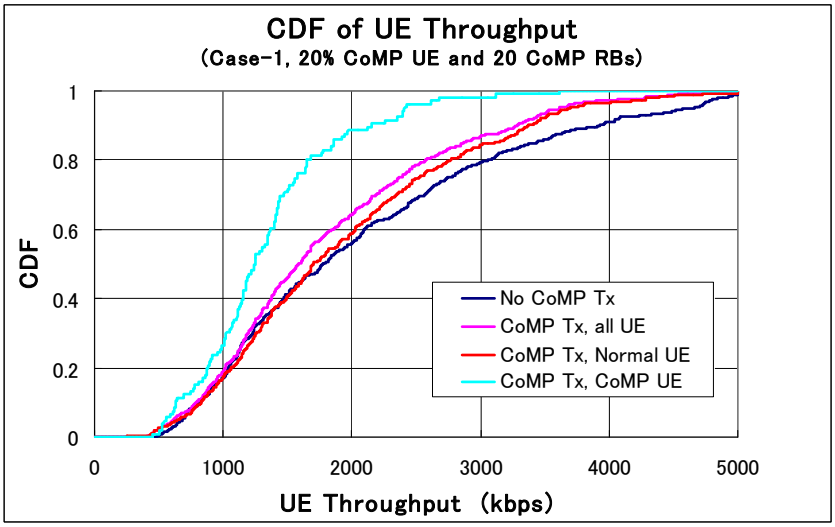

Figure 9: CDF of user throughput with 20% CoMP UEs on average and 20 CoMP RBs.

Reference

[1] 3GPP TR 36.814, "Further Advancements for E-UTRA Physical Layer Aspects", Release-9, V0.4.1, February 2009.

[2] 3GPP TSG RAN1 #56, R1-090613, Samsung, "Discussions on CoMP SU-MIMO", Feb. 9-13, 2009.

[3] 3GPP TSG RAN1 #56, R1-090822, Huawei, "System Performance Evaluation of Downlink CoMP", Feb. 9-13, 2009.

[4] 3GPP TSG RAN1 #56, R1-091494, Fujitsu, "Performance Evaluation of Coherent and Non-Coherent CoMP for LTE-A", March 23-27, 2009.

[5] 3GPP TSG RAN1 #57, R1-091954, Fujitsu, "Different Types of DL CoMP Transmission for LTE-A", May 4-8, 2009.

[6] 3GPP TR 36.814 v0.3.1, Further Advancements for E-UTRA Physical Layer Aspects, January 2009.

[7] IEEE C802.16m-07/080r3, Draft IEEE 802.16m Evaluation Methodology Document, August 28, 2007.

[8] 3GPP TSG RAN1 #56Bis, R1-091498, Fujitsu, "DL System Level Performance Evaluation with 3-Dimensional Antenna Pattern for Advanced E-UTRA", March 23-27, 2009.