Power offset compensation schemes between CRS and DRS for downlink dual layer beamforming in LTE system

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Abstract—**LTE Release 9 supports a new DL transmission mode which combines UE specific beamforming and spatial multiplexing. As one option this transmission mode can be operated based on UE (user equipment) feedback of channel rank. However in this case, the rank is in many cases not very accurate due the difference in precoding between the signal used for data demodulation (DRS – dedicated reference signal) and the signal used for estimating rank (CRS – common reference signal). To maintain good performance it is necessary to introduce a compensation factor to inform the UE about the difference between the channel experienced on DRS and CRS to obtain reasonable rank indication (RI). In this paper we study two compensation schemes, named UE-specific scheme and cell-specific scheme. System level simulations are used to validate the performance of the proposed schemes and support the view that cell-specific compensation is sufficient.**

Keywords- LTE, beamforming, power offset between CRS and DRS, RI, CQI

I. INTRODUCTION

Downlink beamforming technology, as known from TD-SCDMA, is a key feature of the LTE standard. Downlink beamforming is exploiting transmit antenna arrays and knowledge of radio channel to boost the system spectral efficiency. One of the key features of the Rel-9 version of the LTE standard is an enhanced downlink beamforming transmission mode which supports also spatial multiplexing of users (MU-MIMO) and data streams transmitted towards a single user (SU-MIMO).

In this paper we study how 3GPP standardized SU-MIMO feedback signaling from the terminal (UE) to the base station (eNodeB) can be combined with radio channel measurements done at the eNodeB to support an effective downlink beamforming transmission with high spectral efficiency. One advantage this scheme is that it works well with popular dual polarized antenna array and can be applied to both FDD and TDD systems. In case of TDD, the channel reciprocity is exploited for the Beamforming part and performance is improved.

The rest of the paper is organized as follows. We first introduce SU-MIMO transmission and feedback signaling as specified in 3GPP release 9 (section II). Then the system model is analyzed in section III. In section IV the proposed power offset compensation scheme and relevant signaling analysis are introduced. We discuss the numerical results in section V. Finally, we draw concluding remarks.

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II. SU-MIMO TRANSMISSION IN 3GPP RELEASE 9

LTE Release 9 supports different types of SU-MIMO transmission. Here we focus on transmission mode 8 which supports dual layer beamforming. This mode could be operated based on UE feedback information, which consists of:

- Channel Quality Indicator (CQI) which measures what SINR the UE is experiencing,

- Precoding Matrix Indicator (PMI) suggesting a transmit precoder and

- Rank Indicator (RI) suggesting how many parallel data streams should be transmitted.

For data transmission a UE specific reference signal is embedded within data to allow UE to demodulate data independently of what precoding was applied at the base station. Other transmission related parameters signalled in the control channel are:

- Allocated Physical Resource Block (PRB)
- Modulation and Coding Scheme (MCS)
-
- Precoding Matrix Indicator (PMI)

For transmission mode 8 the reported PMI and CQI values are calculated conditioned on the reported RI. And the PMI and CQI feedback modes could refer to Table 7.2.1-1 in [2], which means Modes 1-2 (multiple PMI and wideband CQI), 2-2 (multiple PMI and UE selected CQI), 3-1(single PMI and high layer configured CQI) could be supported in this mode. For further details refer to [3] and [4]. The PMI which UE will feedback is selected from codebook specified in 3GPP release 8. In Table 1 the codebook used for the case with two active common reference signal (CRS) ports is shown. Other codebook is available for the case with 4 active CRS ports.

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	$\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-j\end{bmatrix}$	-

Table.1 3GPP release 8 codebook

III. SYSTEM MODEL

In system model, we assume 8x2 MIMO antenna configuration. That means eNodeB has 8 antennas (4 cross polar with half lambda spacing between polarization groups, shown in Figure.1) and UE antenna number is 2.

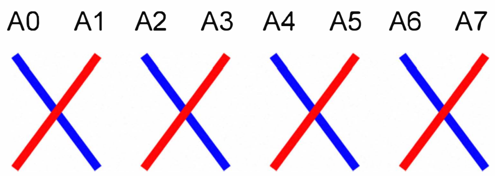

Figure.1 Transmit antenna configuration at the eNodeB

The MIMO scheme is combination of DoA based beamforming (long-term) and 2x2 PMI (short-term). That means for antennas in each group ([A0,A2,A4,A6] or [A1,A3,A5,A7]) DoA beamforming is considered and 2x2 PMI is adopted between groups.

As DoA can be considered slowly varying for typical UE speeds and same for both uplink and downlink, DoA can be estimated by the base station using uplink transmissions from the UE. The PMI reporting is handled by using 2 CRS ports, one for each polarization. To have the optimal coverage for the CRS the mapping of one CRS to four antennas should be done with a suitable static sector beamforming vector, see [5] for further details.

As mentioned above the terminal will report CQI, PMI and RI back to the eNodeB. As this information is estimated from the common reference signal ports it does not take into account the beamforming gain that the data transmission would experience because the two DoA beams can be directed towards the individual UE.

In order to compensate for this difference 3GPP has introduced a specific parameter which can be signaled to the UE and used to offset the CRS signal level when CQI and RI is calculated (little impact to PMI).

To further analyze the effect of this offset we derive now a system model and in later sections we evaluate numerically the performance of different offset compensation solutions.

A. *DoA beamformer*

As a simple and efficient solution we use DoA beamformer to map data signal to four antennas with common polarization

$$W_{DoA} = (W_1^1, W_2^1, \ldots, W_i^j), \quad W_i^j = e^{\frac{-j\cdot 2\pi\cdot(n-1)d}{\lambda}\times\sin\theta} \qquad (1)$$

Where i is antenna number, j is virtualized group number, θ is DoA angle of UE, d is antenna distance.

More advanced precoding based on eigen value decomposition of the channel covariance matrix could be another option (also know as eigen based beamforming or EBB). In case of low azimuth spread radio channel the difference should be minimal (in case of unit transmit antenna correlation DoA and EBB gives the same result).

B. Precoding on data region

In this case eNB needs to calculate a united precoding matrix which considers the DoA precoding vector and PMI precoding vector both. In case of 2x2 PMI plus 4 antenna DoA, the united precoding matrix could be expressed as

$$W_{DRS} = \begin{bmatrix} W_{DoA1} & 0 \\ 0 & W_{DoA2} \end{bmatrix} \times [\alpha 1 \quad \alpha 2] \qquad (2)$$

- W_{DoA1} and W_{DoA2} are the DoA beamforming weighting vector
- $[\alpha 1 \quad \alpha 2]$ is the PMI codeword selected in UE side

C. The metric to select PMI in UE side

$$\arg\max_i \|H \times A \times W_i\|^2 \qquad (3)$$

Where H is ideal channel, A is fixed matrix means sector beam, W_i is selected from Table 1 based on layer number.

D. DRS-CRS offset

Based on the analysis modeling above, we could get the SINR on data region (named $SINR_{DRS}$) and SINR on CRS (named $SINR_{CRS}$)

$$SINR_{DRS} = \frac{u_{DRS}' \times H_e^{DRS} \times H_e^{DRS}{}' \times u_{DRS}}{u_{DRS}' \times R_{DRS} \times u_{DRS}} \qquad (4)$$

Where H_e^{DRS} is effective channel on DRS and equals to $H \times W_{DRS}$, u_{DRS} is equalization vector on DRS and correlated with receiver algorithm, R_{DRS} is interference plus noise covariance matrix.

The steps for CQI calculation are

1) Calculate SINR on CRS

$$SINR_{CRS} = \frac{u_{CRS}{}' \times H_e^{CRS} \times H_e^{CRS}{}' \times u_{CRS}}{u_{CRS}{}' \times R_{CRS} \times u_{CRS}} \quad (5)$$

Where H_e^{CRS} is effective channel on CRS and equals to $H \times W_{fixed}$, u_{CRS} is the equalization vector on CRS and correlated with receiver algorithm, R_{CRS} is the interference matrix which mainly responses inter-cell interference information. W_{fixed} is the fixed matrix which represents the CRS port information used.

2) Compensate the SINR on CRS using PMI information. Thus CQI without CRS-DRS offset compensation could be expressed by

$$CQI = SINR_{CRS} \times \frac{W_{PMI}}{W_{\text{sector}}} \quad (6)$$

Where W_{PMI} means the PMI precoding gain and W_{sector} means the sector beam gain. So CRS-DRS offset is

$$Offset = SINR_{DRS} - CQI \quad (7)$$

IV. The Proposed Schemes and Signalling Analysis

A. Proposed schemes

In this paper we propose two CRS-DRS offset compensation schemes, one of which is named UE-specific scheme and another is named cell specific scheme, for CQI to improve the rank adaptation.

Scheme 1: Cell-specific compensation at UE side

In this scheme an average offset for all the UEs in the sector is used for compensation at UE side.

Scheme 2: UE-specific compensation at UE side

Here the beamforming gain of the individual UEs is estimated and signaled individually.

B. Estimating the power offset

The time average of CRS-DRS power offset mainly depends on properties of the radio channel. In the following we assume unit transmit correlation and can thus use a simple superposition of phase weighted antenna element patterns to model the effect of the beamforming to the radio channel. The CDF of the offsets from different UE is shown in figure 2. From this we can see that the typical offset is as expected around 5 dB. For detailed simulation assumptions see appendix.

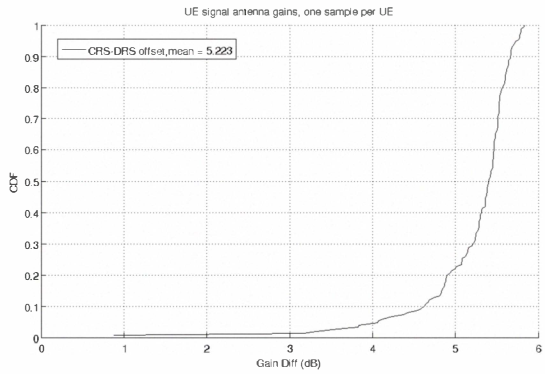

Figure.2 CDF if the CRS-DRS offset measured in dB scale assuming unitary transmit correlation

V. Numerical Results

To benchmark the performance of the two schemes, we simulate a radio network at system level following the methodology agreed by 3GPP in [6]

A. Simulation setup Assumptions

In the following we simulate three different simulation cases. One setup where no compensation offset is applied, one with cell specific offset and one with UE specific offset. The simulated DL transmission mode is discussed previously in this paper, the Rel-9 transmission mode 8 with MIMO style RI/CQI/PMI feedback assuming two active CRS port each of them virtualized to one polarization.

For detailed assumptions please refer to Appendix and [6].

B. Results and Discussion

In Figure 3, we show the average and 5 percentile UE spectral efficiency for the three simulated cases. We find that the performance improvement is about 10% in term of average throughput for UE-specific scheme and cell-specific scheme, respectively. But these two compensation schemes have similar performance so the cell-specific scheme is recommended as it achieves similar performance compared to the more complicated UE-specific scheme. The reason of performance improvement is that rank-2 probability gets increased from 10% to more than 40%, which is shown in Figure 4. This shows the importance of applying the offset at UE side because it has to be included when the rank is selected. eNB could potentially override the rank but as CQI reporting is conditioned on the reported rank, the CQI for rank 2 transmission would not be available for selecting the proper transmission parameters.

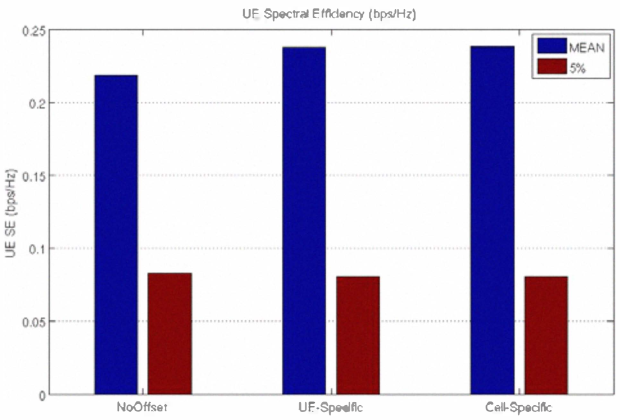

Figure.3 Mean and cell edge UE spectral efficiency for different higher-layer signaling options.

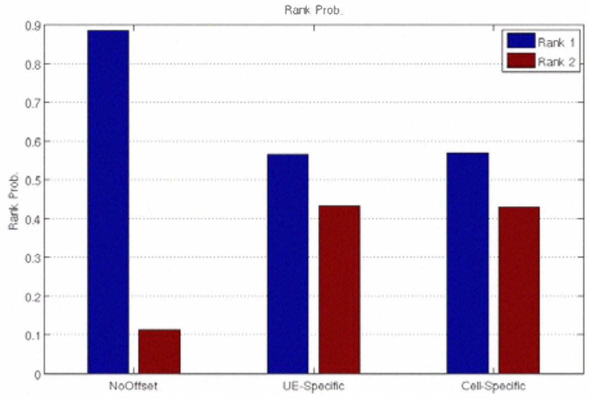

Figure.4 Rank probability for different higher layer signaling options

VI. CONCLUSION

In this paper we analyze the operation of LTE Release 9 DL transmission mode 8 together with spatial multiplexing style RI/PMI/CQI reporting. We highlight the need for CRS-DRS offset compensation scheme in the UE and study the performance of different schemes from system level point of view. From the simulation results and above analysis, we could find cell-specific scheme with high-layer signaling is recommended as more complex UE-specific offset does not improve the performance over cell-specific scheme.

Transmission mode 8 also supports spatial multiplexing of up to 4 users. In this case offset compensation would be further studied and this is one of our current research interests.

REFERENCE

[1] http://en.wikipedia.org/wiki/3GPP_Long_Term_Evolution
[2] 3GPP TS 36.213 V8.6.0
[3] 3GPP TS 36.211 V8.6.0
[4] 3GPP TS 36.212 V8.6.0
[5] R1-091983," Way forward for beamforming antenna gain pattern", CATT, CMCC, Potevio
[6] 3GPP TR 25.814

Appendix

Parameter		Assumption
Cellular Layout		Hexagonal grid, 19 cell sites, 3 sectors per site
Inter-site distance		500m
Distance-dependent path loss		L=128.1 + 37.6log10(.R), R in Kilometers
Lognormal Shadowing		Log Normal
Shadowing standard deviation		8 dB
Correlation distance of Shadowing		50 m
Shadowing correlation	Between cells	0.5
	Between sectors	1
Penetration Loss		20dB
Antenna pattern (horizontal) (For 3-sector cell sites with fixed antenna patterns)		Θ3dB= 70 degrees, Am = 20 dB 2D antenna
Antenna configuration		8x2 Dual polarized, 0.5 lambda spacing in co-polar domain
Carrier Frequency / Bandwidth		2.0 GHz
Channel model		SCM
UE speeds of interest		3km/h
Total BS TX power (Ptotal)		46dBm - 10MHz carrier
Minimum distance between UE and cell		>= 35 meters
PS Algorithm		Proportional fair
Rank adaptation		Dynamic
Control channel		3 OS (including some common reference signals)
Reference signal configuration		CRS: Port 0 and 1 enabled URS: 12 RE per PRB for single layer beamforming, 6+6 RE for dual layer.
UE Channel estimation		Realistic
Feedback signaling		CQI and PMI reported per subband, PMI and CQI subband size is 3 PRB RI based on wideband Reporting period is 5 ms
CRS-DRS offset setting		For UE-specific scheme, this value is obtained by table and this offset is about 5 dB for cell-specific scheme