

Agenda item: 6.5.4
Source: Broadcom Corporation
Title: Feedback Reduction with Incremental MCS Set for LTE
Document for: Discussion

1 Introduction

In the multiple codeword based MIMO schemes such as PARC-OSIC and S-VAP [1], it was proposed to use Layer Permutation (LP) to reduce the feedback overhead using differential feedback [2], [3], [4], and [5]. In [6] the benefit of LP was shown to help when a single MCS is employed, and yield loss in PER for OSIC type receivers. A small throughput loss for PARC MMSE receivers was also observed at high SNR.

Our observation is that the loss in PER for the OSIC type receivers when LP is employed indicates that the receivers may benefit from the spatial multiplexing streams having separation in SNR values, opposite to LP effect that “equalizes” SNR on the streams. The loss may be mitigated by forcing lower MCS value on one of the streams however, we believe that this results in some performance loss.

In this contribution we propose an MCS set that minimizes UPLINK overhead without using LP while maintaining performance. The proposed MCS set provides good performance for PARC type receivers.

2 Numerology, Simulation, and Channel Model Assumptions

The simulation assumptions are as follows:

Table 1. Throughput Simulation Parameters for OFDM Downlink

LLS Parameter	Details
Channel Bandwidth	5 MHz.
Sub-Frame Duration	0.5E-3
Sub-Carrier-Spacing	15E3 Hz.
Sampling Frequency (time-domain)	7.68E6
FFT Size	512
Useable Carriers	301
TX/RX Antenna Configuration	2x2 MIMO
PRB Used (25-Tones / PRB)	3 / 75 Tones (Distributed)
Bandwidth Occupied	1.125 MHz.
CP Length (μ s/sample) - Short	4.69/36 x6, 5.21/40 x1
Test Geometry (SNR) Throughput Simulations	0,5,10,15,20, 25
TTI – Coded Frame	0.5E-3
DL Modulation	QPSK, 16QAM, 64QAM
Coding	TURBO, R=1/3, Max Block Size = 5114
Code Rates	MCS Set Dependent (See MCS Tables 2-4).
INTER-TTI, for HARQ	6
HARQ Processes	6
MCS Feedback Delay	2-TTI
Maximum Retransmissions	4
HARQ	Incremental Redundancy Per-Transmission
Channel Estimation	Ideal
Receiver Structures	PARC-MMSE, PARC-OSIC
Carrier Frequency	2GHz.
Channel Model	ITU-PED 6-Ray Channel
Doppler Frequency	5 Hz.
TX Antenna Correlation Coefficient	0
RX Antenna Correlation Coefficient	0

3 Results and Discussion

The following definitions are used in the results that follow:

- MMSE – Minimum Mean Square Error
- OSIC – Ordered Successive Interference Cancellation (OSIC)
- PARC – Per Antenna Rate Control
- MCS – Modulation Coding Set (Modulation Order - Code Rate Pair)

We compare the following receiver types:

PARC:MMSE – Per Antenna Rate Controlled MMSE

PARC:OSIC – Per Antenna Rate Controlled Ordered Successive Interference Cancellation Receiver.

We compare three Modulation Coding Sets with 7, 15 and 30 levels. We show the feedback requirement and performance for each, and then suggest a reduced feedback scheme with good performance and low feedback requirement for UPLINK transmission. The MCS sets compared in this contribution are shown in the Table 2, Table 3 and Table 4 for the 30, 15 and 7 Modulation and Coding levels, respectively.

Table 2. MCS30

MCS Parameter	Details
MCS30 – Modulations	QPSK, 16QAM, 64QAM
MCS30 – Spectral Efficiency (QPSK)	6.6667e-001, 7.3689e-001, 8.0711e-001, 8.7733e-001, 9.4756e-001, 1.0178e+000, 1.0880e+000, 1.1582e+000
MCS30 – Spectral Efficiency (16QAM)	1.3333e+000, 1.4738e+000, 1.6142e+000, 1.7547e+000, 1.8951e+000, 2.0356e+000, 2.1760e+000, 2.3164e+000
MCS30 – Spectral Efficiency (64QAM)	2.4213e+000, 2.6320e+000, 2.8427e+000, 3.0533e+000, 3.2640e+000, 3.4747e+000, 3.6853e+000, 3.8960e+000, 4.1067e+000, 4.3173e+000, 4.5280e+000, 4.7387e+000, 4.9493e+000, 5.1600e+000

The MCS30 has fine granularity, ending at spectral efficiency of ~ 5.16 Bits/Sec./ Hz. MCS15 is:

Table 3. MCS15

MCS Parameter	Details
MCS15 – Modulations	QPSK, 16QAM, 64QAM
MCS15 – Spectral Efficiency (QPSK)	6.6667e-001, 8.1714e-001, 9.6762e-001, 1.1181e+000
MCS15 – Spectral Efficiency (16QAM)	1.3333e+000, 1.6343e+000, 1.9352e+000, 2.2362e+000
MCS15 – Spectral Efficiency (64QAM)	2.4514e+000, 2.9029e+000, 3.3543e+000, 3.8057e+000, 4.2571e+000, 4.7086e+000, 5.1600e+000

The MCS7 set is as follows:

Table 4. MCS7

MCS Parameter	Details
MCS7 – Modulations	QPSK, 16QAM, 64QAM
MCS7 – Spectral Efficiency (QPSK)	6.6667e-001, 1.0178e+000
MCS7 – Spectral Efficiency (16QAM)	1.3333e+000, 2.0356e+000
MCS7 – Spectral Efficiency (64QAM)	3.0533e+000, 4.1067e+000, 5.1600e+000

The MCS7 set has a coarse granularity over the expected range of operation (i.e. 0-25 dB. SNR), MCS7 has a significant jump in spectral efficiency from 16QAM to 64QAM. Feedback requirements for the MCS30 and MCS15 are as follows:

Table 5. MCS30 and MCS15 Feedback Requirements

MCS SET	Feedback Requirement
MCS30	1 – ACK/NAK, 5 – MCS Feedback Total = $2*1+2*5 = 12$ 24E3 Bits/Sec (Per HARQ Process)
MCS15	1 – ACK/NAK, 4 – MCS Feedback Total = $2*1+2*4 = 10$ 20E3 Bits/Sec (Per HARQ Process)
MCS7	1 – ACK/NAK, 4 – MCS Feedback Total = $2*1+2*3 = 8$ 16E3 Bits/Sec (Per HARQ Process)

NOTE: With Inter-TTI of 6, Feedback would be 144E3 Bits/Sec for MCS30, 120E3 for MCS15, and 96E3 for MCS7.

Figures 1 and 2 show throughput results comparison for the MCS sets delineated with Per Antenna Rate Control (PARC) and MMSE receiver.

The MCS set 7 suffers some throughput in the region of 10-20 dB due to the coarse structure of the MCS7 set. The MCS30 Set offers a fine granularity that does not benefit the high SNR operation or add provide gain to the lower SNR region. MCS15 offers a compromise, with sufficient granularity and good performance across the operating geometry. For high SNR, the results suggest MCS granularity to be coarse and moderately fine for low SNR.

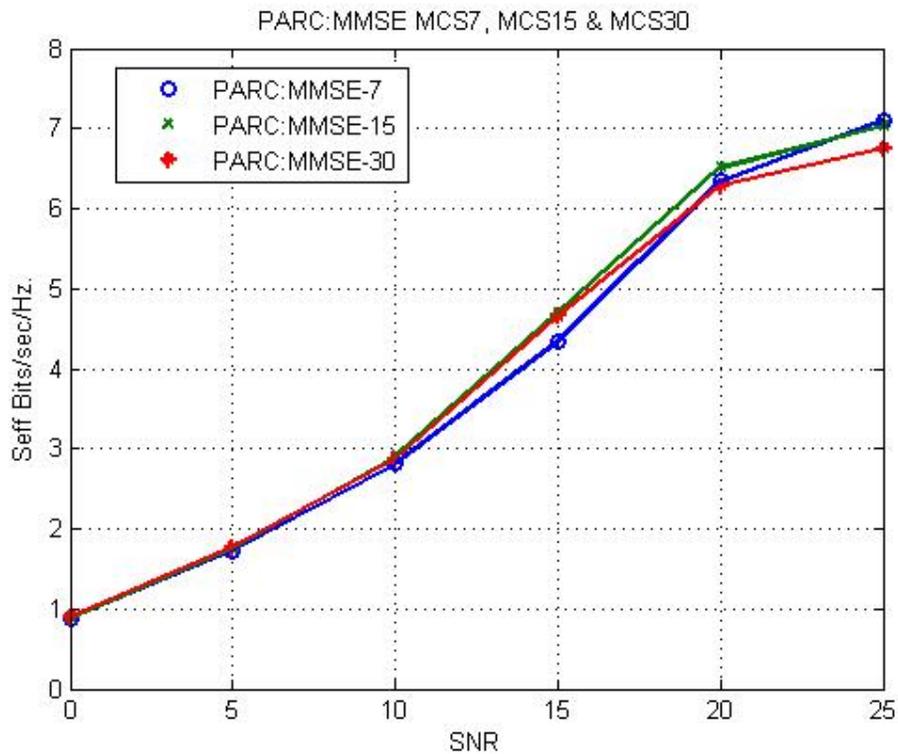


Figure 1 Throughput PARC:MMSE MCS30 vs. MCS15 vs. MCS7

Figure 2 show throughput results comparison for the MCS sets delineated with Per Antenna Rate Control (PARC) and OSIC receiver, the effect of the coarse MCS7 set is exacerbated by the OSIC receiver in the region of operation where there is a large step size in the MCS levels.

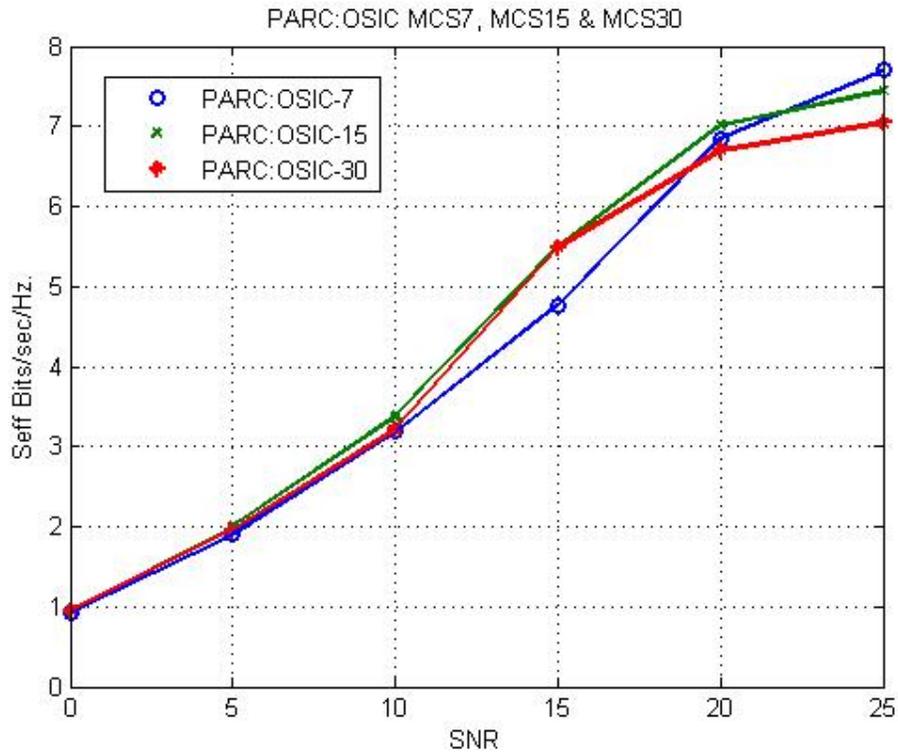


Figure 2 Throughput PARC:OSIC MCS30 vs. MCS15 vs. MCS7

4 Reduced Feedback with Incremental MCS Feedback

We propose the following Incremental MCS feedback Scheme parameters (Table 5):

Table 6. Incremental MCS Feedback Parameters

MCS1	DMCS=MCS2-MCS1	ACK/NAK2	ACK/NAK1
4-Bits, Values =0,1,2,...,15	3-Bits, Values=-4,-3,-2,-1,0,1,2,3	1-Bit, Values 0/1	1-Bit, Values 0/1

We define the following rule at the receiver:

Receiver Rule:

$$MCS1 = MCS1$$

$$DMCS = MCS2 - MCS1$$

Transmitter Rule (NODE-B):

$$MCS1 = MCS1$$

$$MCS2 = MCS1 + DMCS$$

The feedback requirement for the scheme is the following:

Table 7. MCS30 and MCS15 Feedback Requirements

MCS SET	Requirements w/Incremental Feedback
MCS15	1 – ACK/NAK, 4/3 – MCS Feedback Total = $2*1+4+3 = 9$ 18E3 Bits/Sec (Per HARQ Process)

NOTE: With Inter-TTI of 6, Feedback would be 108E3 Bits/Sec.

Savings over MCS30, and MCS15 is 36E3, and 12E3 respectively for UE w/INTER-TTI = 1.

Simulation Results for the PARC-OSIC and PARC-MMSE receiver types are shown in Fig. 3.

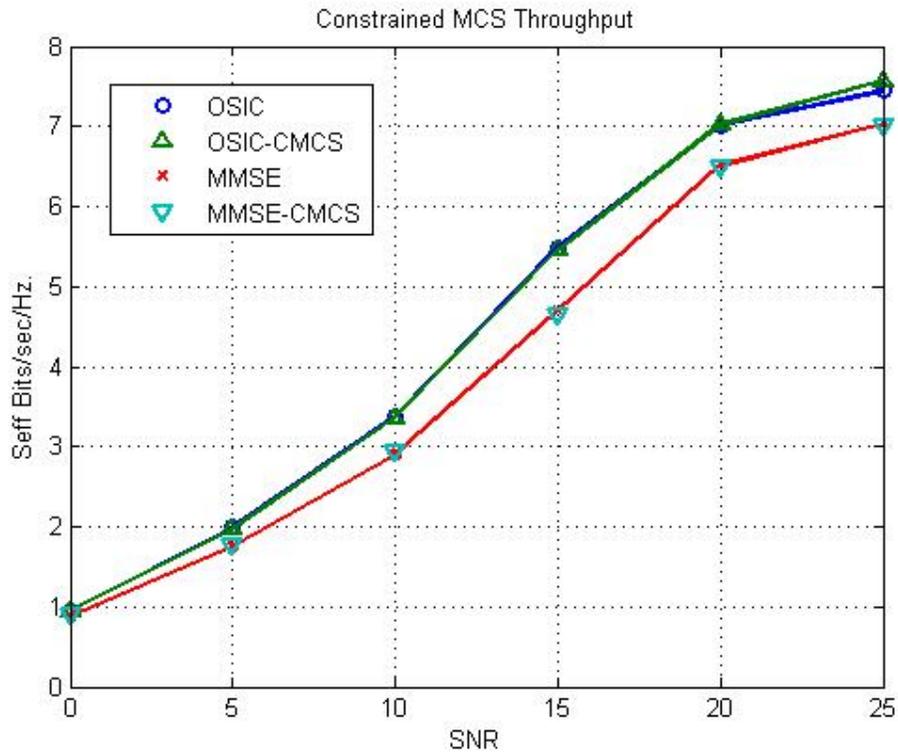


Figure 3 Throughput PARC:OSIC w/Incremental MCS Feedback

The simulation results show no-degradation for the scheme. It should be noted that the scheme supports correct feedback when a single Codeword is ACK.

4 Conclusions and Further Discussion

The Incremental MCS Feedback scheme reduces UPLINK overhead while maintaining good performance. In the case of the OSIC receiver utilization of the Incremental MCS feedback scheme yields slight throughput benefit for high SNR.

It is recommended that E-UTRA considers the Incremental MCS feedback scheme for use, and adopts MCS15 for usage in downlink transmission for E-UTRA.

5 References

- [1] R1-050903 Qualcomm - Description and link simulations of MIMO schemes for OFDMA based E-UTRA downlink evaluation
- [2] R1-060456 Qualcomm - Link Analysis of Single and Multi Codeword Schemes – No Precoding
- [3] R1-060458 Intel - Link Analysis of Single and Multi Codeword Schemes - Precoding
- [4] R1-061127 Qualcomm - Comparison between Single and Multiple Codewords for Precoded MIMO
- [5] R1-061505 Qualcomm - Link Analysis of Single User MIMO - Single Codeword vs. Multi Codeword MIMO with HARQ Resynchronization
- [6] R1-062940 Broadcom - Effects on throughput when using Layered Permutation for LTE Based RXCVR Structures