3GPP TSG-RAN WG1 RAN47-BIS **R1-070169**
Sorrento Italy
Meeting Date: January 15th – Januruary 19th 2007

Agenda item: **6.7.2**

Source: **Broadcom Corporation**

Title: **Beamforming Frequency and Time Update Requirements in E-UTRA**

Document for: **Discussion**

1. Introduction

E-UTRA based MIMO systems demand feedback for Beamforming techniques in a mobility based system for increased performance. In this contribution we examine the Beamforming performance based on Singular Value Decomposition (SVD) while varying feedback rate for Pedestrian and Low-Mobility users.

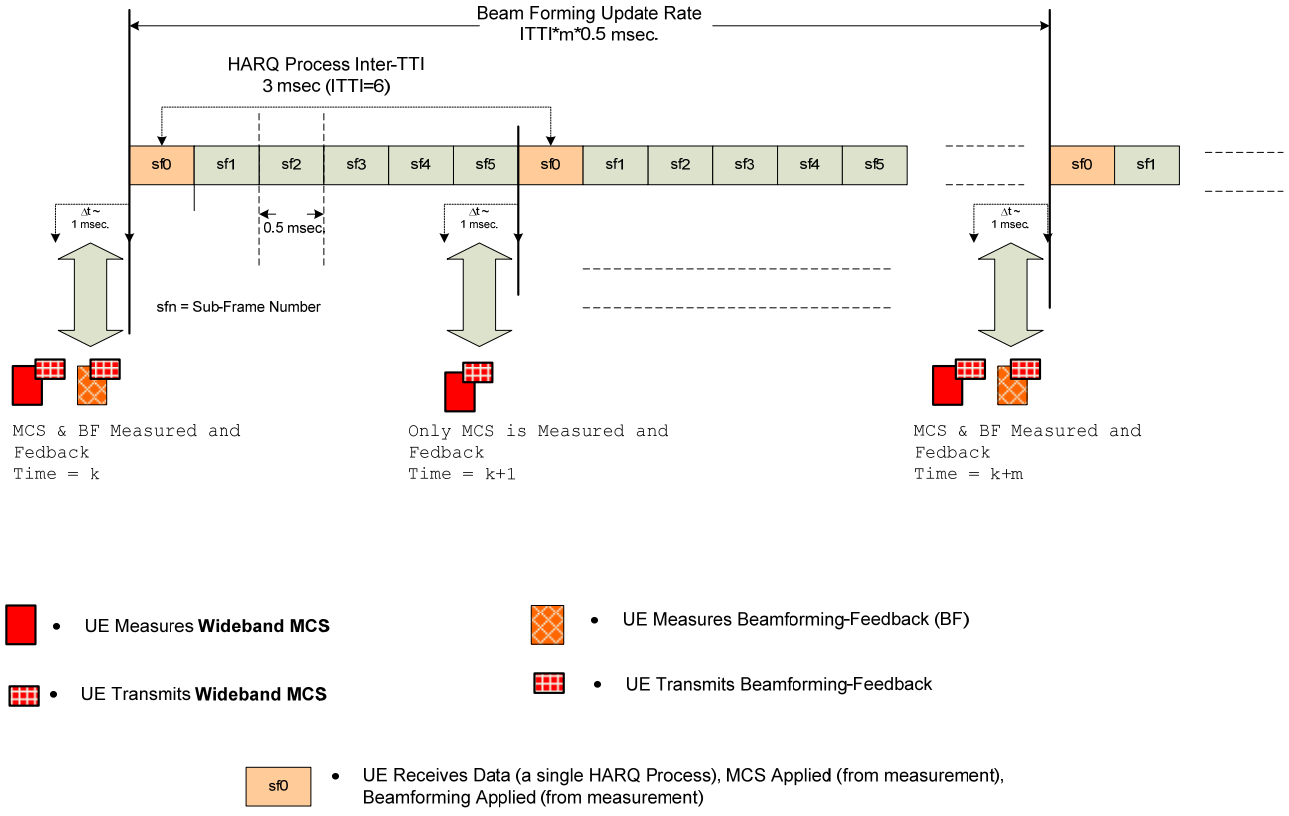
Feedback has both a time and frequency component. It has been proposed in E-UTRA that a PRB size of 12 carriers (tones) be used for Downlink OFDMA. We examine the effect of 12 and 15 carrier PRB size for Beamforming operation. Beamforming overhead in terms of feedback is dependent on both Codebook size and rate of feedback. In this contribution, feedback Rate is examined for Pedestrian and Low-Mobility users.

Figure 1, depicts the Beamforming operation in terms of required feedback in time. The UE is assumed to measure the requested Modulation and Coding Set (i.e. MCS) and Beamforming Codebook entry. Upon completion of measurement the UE transmits codebook entry and MCS to the NODE-B for application upon the next transmitted HARQ Process. The delay between the NODE-B application of the requested MCS and the Codebook entry and their calculation at the UE is approximately 1 msec, i.e. 2-TTI. In the Fig. 1, the Beamforming feedback may be less frequent in time that the MCS feedback in order to reduce potentially large overhead.

Feedback is classified in terms Wideband MCS feedback, see [3].

Beamforming Feedback Rate

- MCS (modulation & code-rate) feedback at the inter-TTI rate (highest rate), per HARQ Process
- Beamforming feedback at lower rate TBD



- UE Measures **Wideband MCS**
- UE Measures Beamforming-Feedback (BF)
- UE Transmits **Wideband MCS**
- UE Transmits Beamforming-Feedback
- sf0 — UE Receives Data (a single HARQ Process), MCS Applied (from measurement), Beamforming Applied (from measurement)

Figure 1: Beamforming Feedback Rate

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, 4x2 MIMO, 4x4 MIMO
PRB Used (12-Tones / PRB)	6 / 72 Tones (Localized)
Bandwidth Occupied	1.125 MHz.
CP Length (μs/sample) – Short	4.69/36 x6, 5.21/40 x1
Test Geometry (SNR) Throughput Simulations	0,5,10,15,20
TTI – Coded Frame	0.5E-3
DL Modulation	QPSK, 16QAM, 64QAM
Coding	TURBO, R=1/3, Max Block Size = 5114
Code Rates	See Reference [1], Table 3.
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
Beamforming	SVD-Based
Carrier Frequency	2GHz.

LLS Parameter	Details
Channel Model	ITU-PED 6-Ray Channel
Doppler Frequency	5 Hz., 50 Hz.
TX Antenna Correlation Coefficient	0
RX Antenna Correlation Coefficient	0

3. Simulation Results: (Pre-Coding) Feedback Granularity in Frequency

The following definitions are used in the results that follow:

PRB – Physical Resource Block (size=1,12, and 25)

FB – Feedback (For Beamforming)

Figures 1, 2 and 3 show Beamforming Performance with Ideal Beamforming. Beamforming results in this section are Floating Point (FP). We compare PRB size of 1, 12, and 25. Per-Tone FB is the reference for each curve. Results are shown for 2x2, 4x2, and 4x4 MIMO systems.

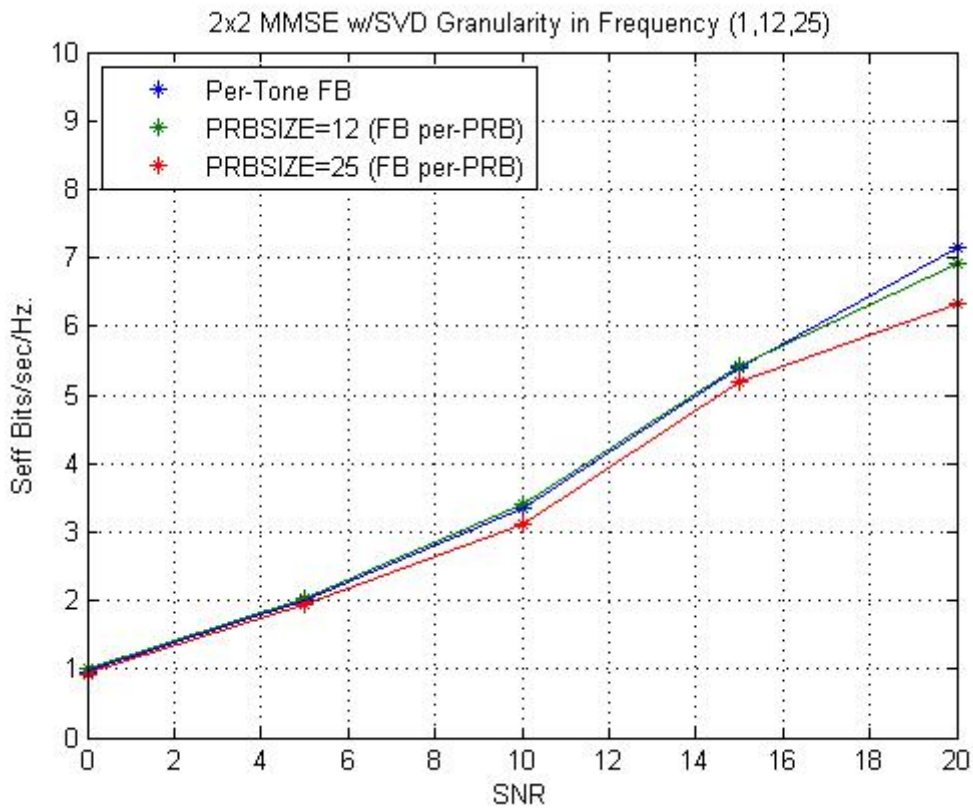


Figure 2: 2x2 MIMO Beamforming FB Performance; (PRB=1, PRB=12, PRB=25)

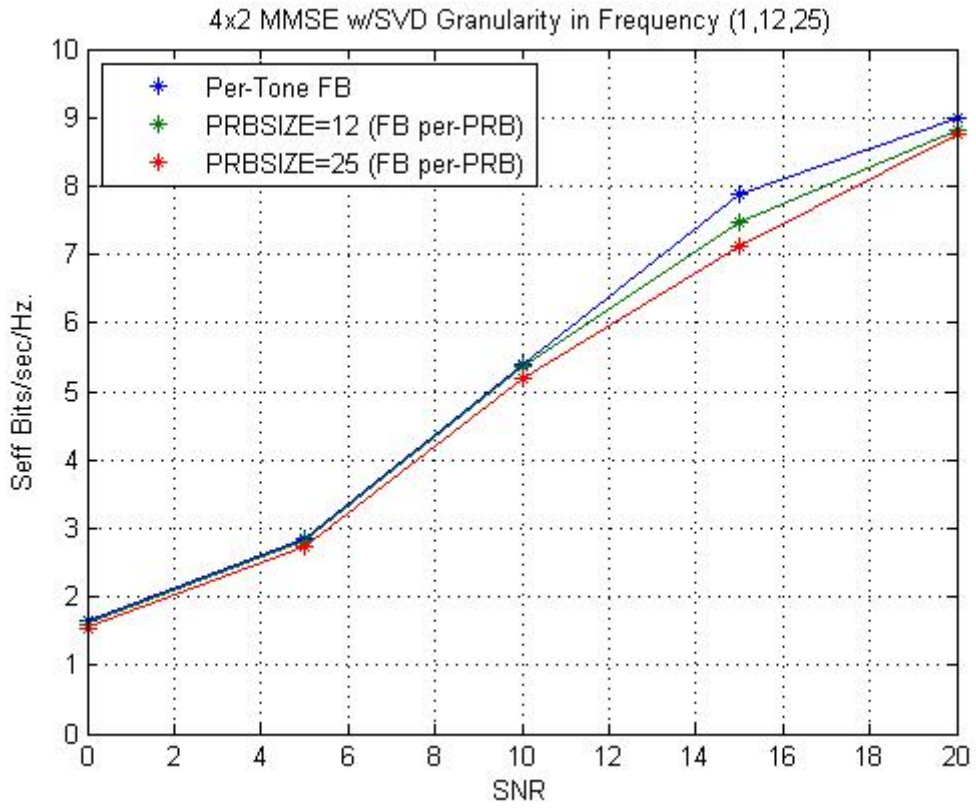


Figure 3: 4x2 MIMO Beamforming FB Performance; (PRB=1, PRB=12, PRB=25)

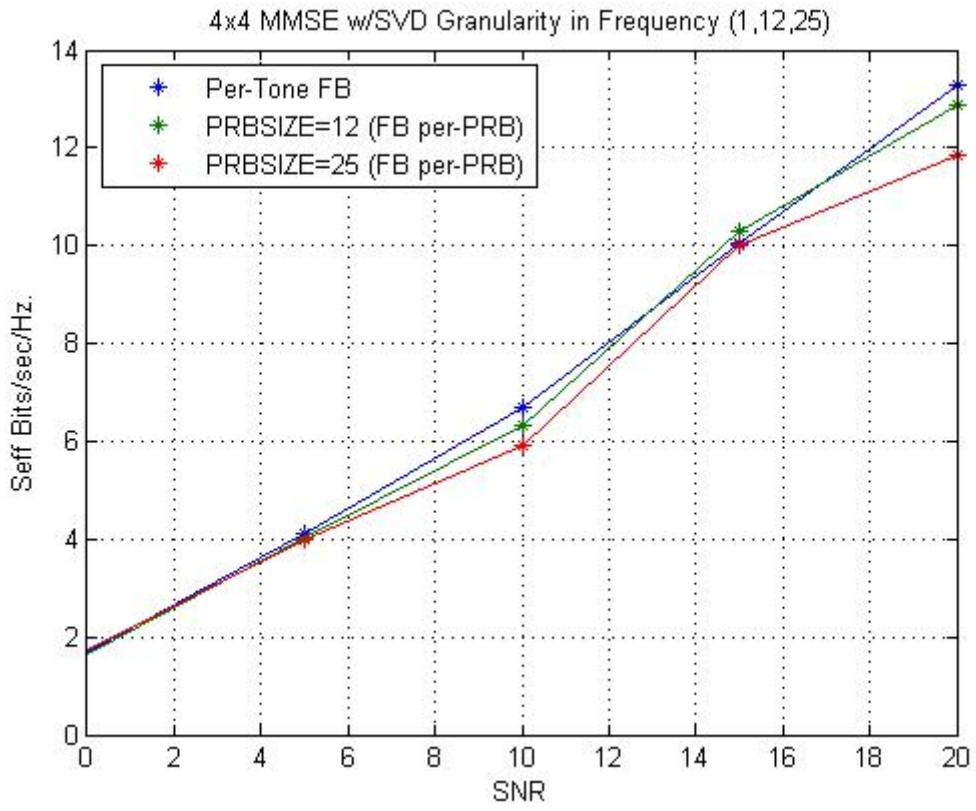


Figure 4: 4x4 MIMO Beamforming FB Performance; (PRB=1, PRB=12, PRB=25)

4. Simulation Results: (Pre-Coding) Feedback Rate in Time (Ideal Feedback)

The following definitions are used in the results that follow:

PRB – Physical Resource Block (size=12)

FB – Feedback (For Beamforming)

FLT – Floating Point Feedback

SVD – Singular Value Decomposition

Figures 5 and 6 show Beamforming performance for 2x2 Systems in Doppler of 5 and 50 Hz, respectively

Figures 7 and 8 show Beamforming performance for 4x2 Systems in Doppler of 5 and 50 Hz, respectively

Figures 9 and 10 show Beamforming performance for 4x4 Systems in Doppler of 5 and 50 Hz, respectively.

Feedback rates of 3, 9, and 15 msec. are simulated. Feedback delay of ~ 1 msec. is introduced for both Wideband MCS and Beamforming Codebook entry for application at the NODE-B (see Fig. 1). All Beamforming feedback results in this section are computed with Floating Point Feedback (FLT). For the FLT Feedback the Beamforming vectors are ideal, only the rate at which they are applied is varied.

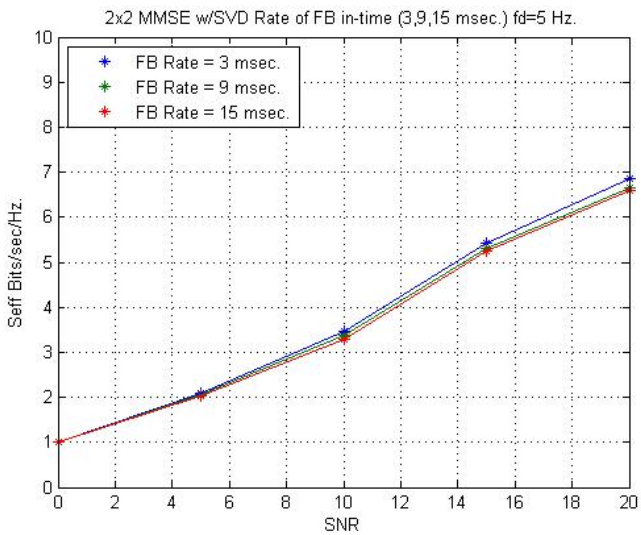


Figure 5: 2x2 MIMO Beamforming FB Rate (3, 9, 15 msec.), fd = 5 Hz.

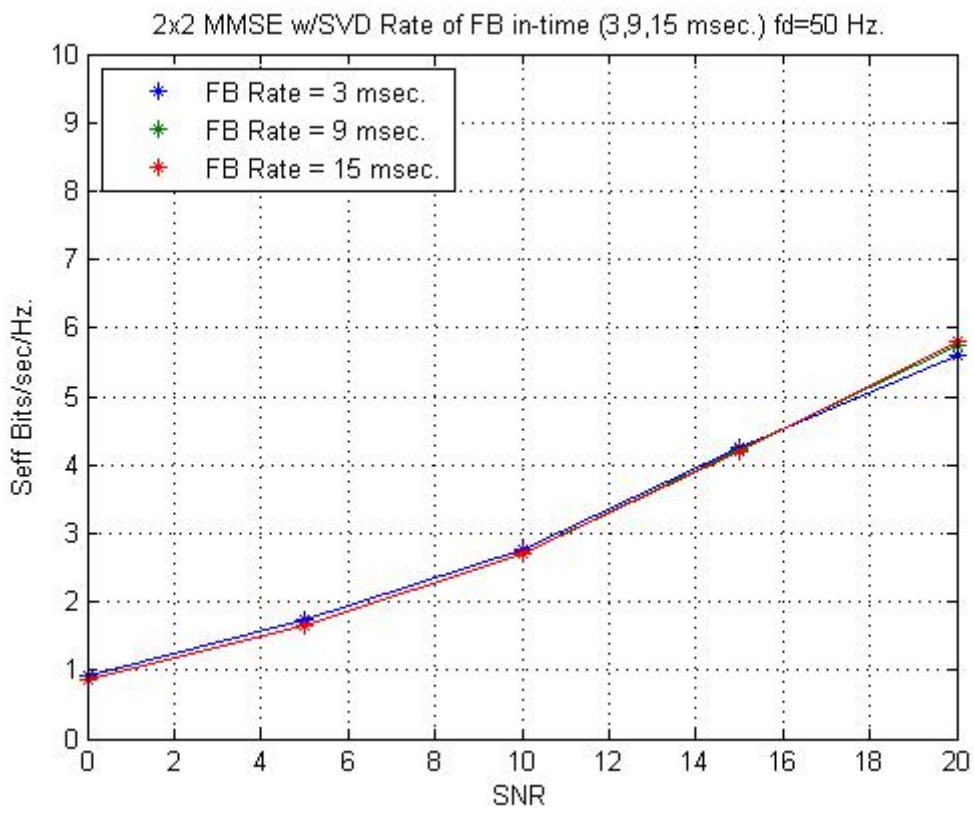


Figure 6: 2x2 MIMO Beamforming FB Rate (3, 9, 15 msec.), fd = 50 Hz.

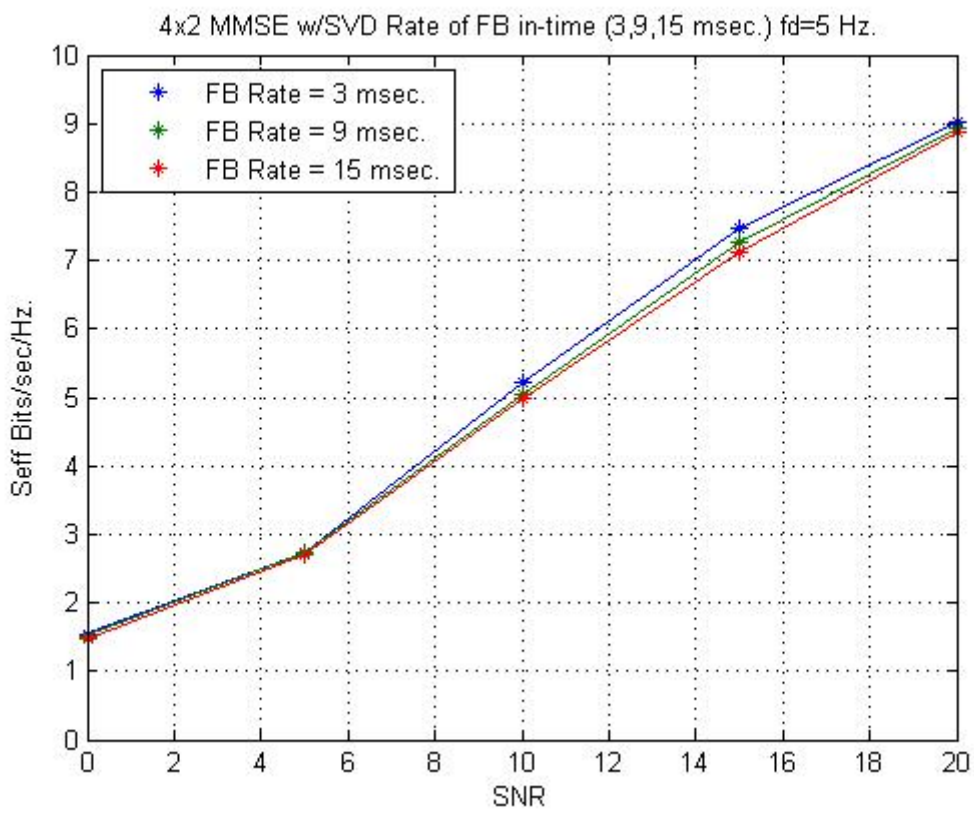


Figure 7: 4x2 MIMO Beamforming FB Rate (3, 9, 15 msec.), fd = 5 Hz.

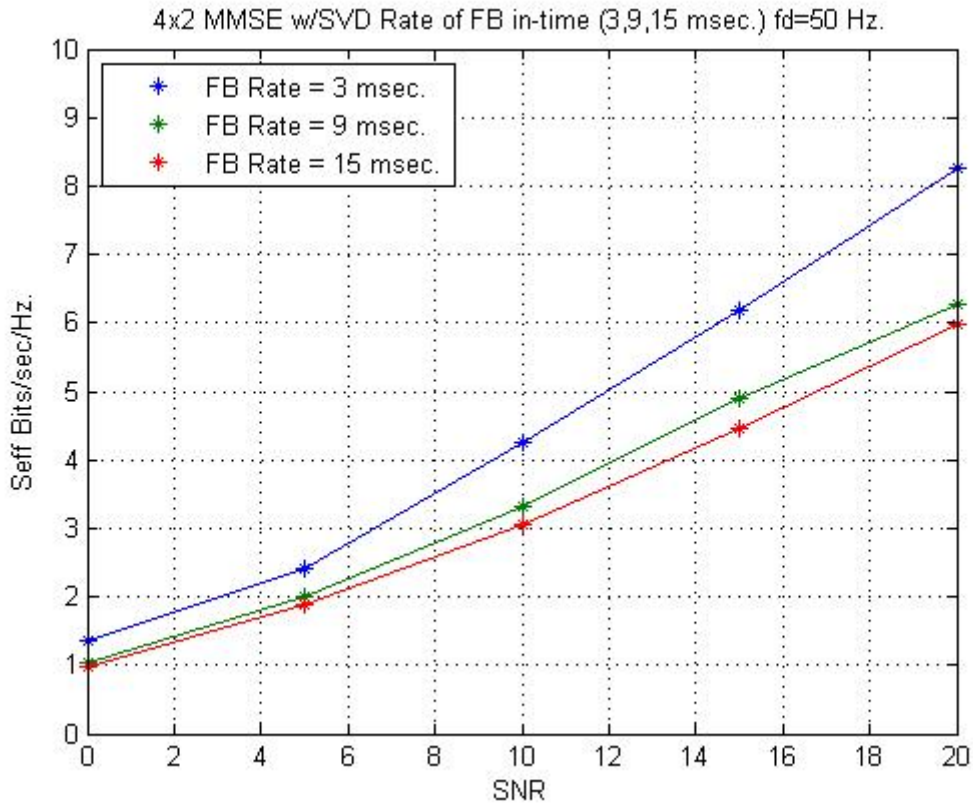


Figure 8: 4x2 MIMO Beamforming FB Rate (3, 9, 15 msec.), fd = 50 Hz.

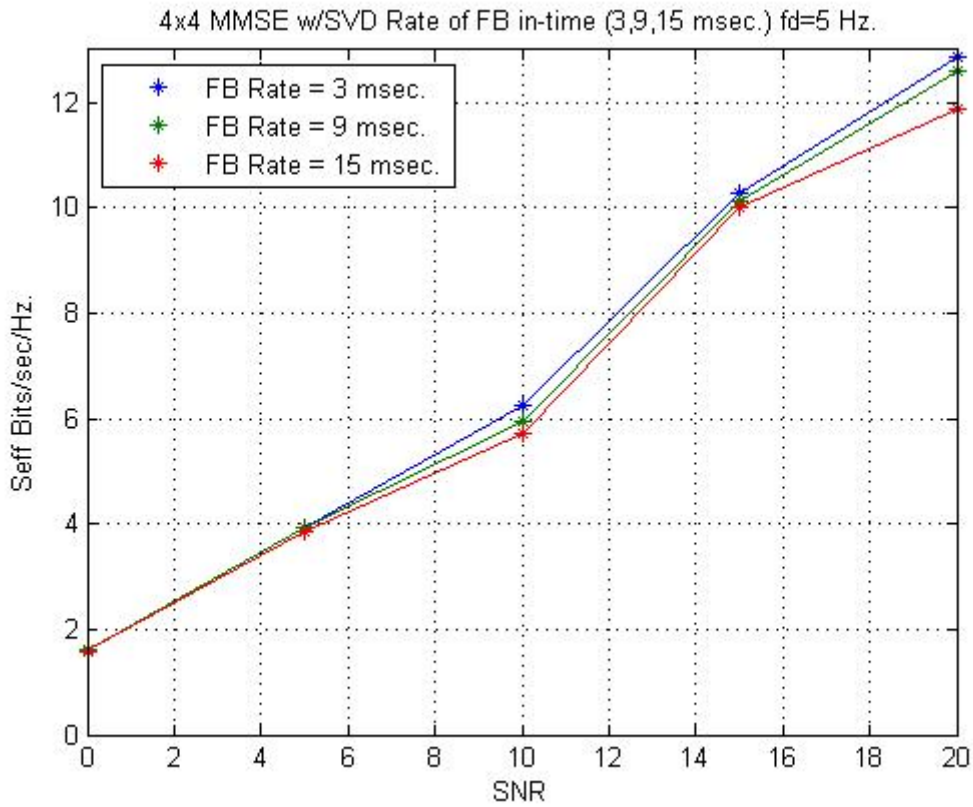


Figure 9: 4x4 MIMO Beamforming FB Rate (3, 9, 15 msec.), fd = 5 Hz.

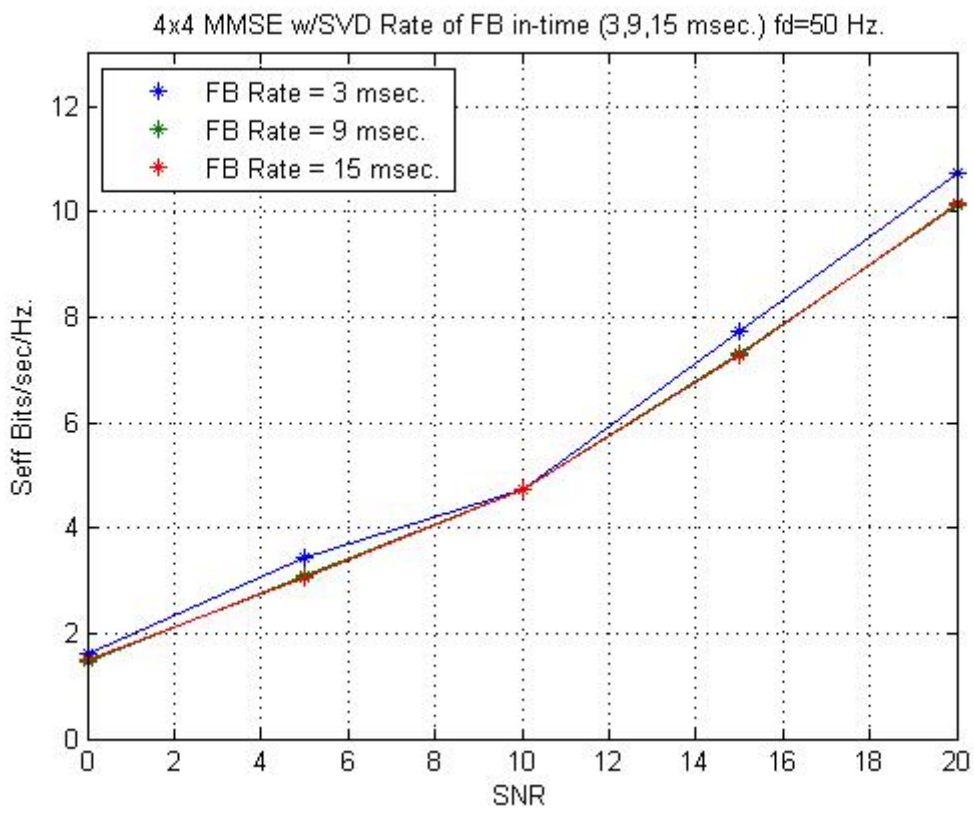


Figure 10: 4x4 MIMO Beamforming FB Rate (3, 9, 15 msec.), fd = 50 Hz.

For the low-mobility scenarios, the results in Figs. 3-10 suggest that feedback may be reduced with respect to Wideband MCS, thus classifying a different rate of feedback than the Wideband MCS.

5. Simulation Results: (Pre-Coding) Feedback Rate in Time (Compact Codebook Feedback)

The results in this section use the codebook defined in [2]. In this section we examine Beamforming performance when using the compact codebook.

The following definitions are used in the results that follow:

Figures 11 and 12 show Beamforming performance for 2x2 Systems in Doppler of 5 and 50 Hz.

Figures 13 and 14 show Beamforming performance for 4x2 Systems in Doppler of 5 and 50 Hz.

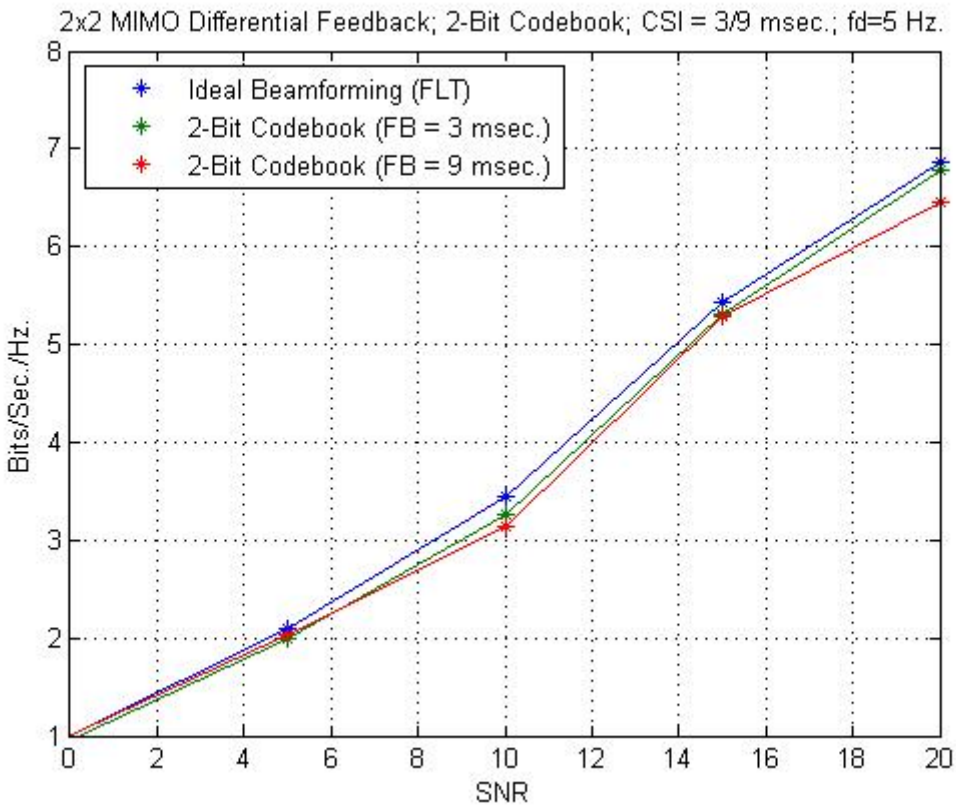


Figure 11: 2x2 MIMO Beamforming FB Rate vs. Ideal (5 Hz. Doppler)

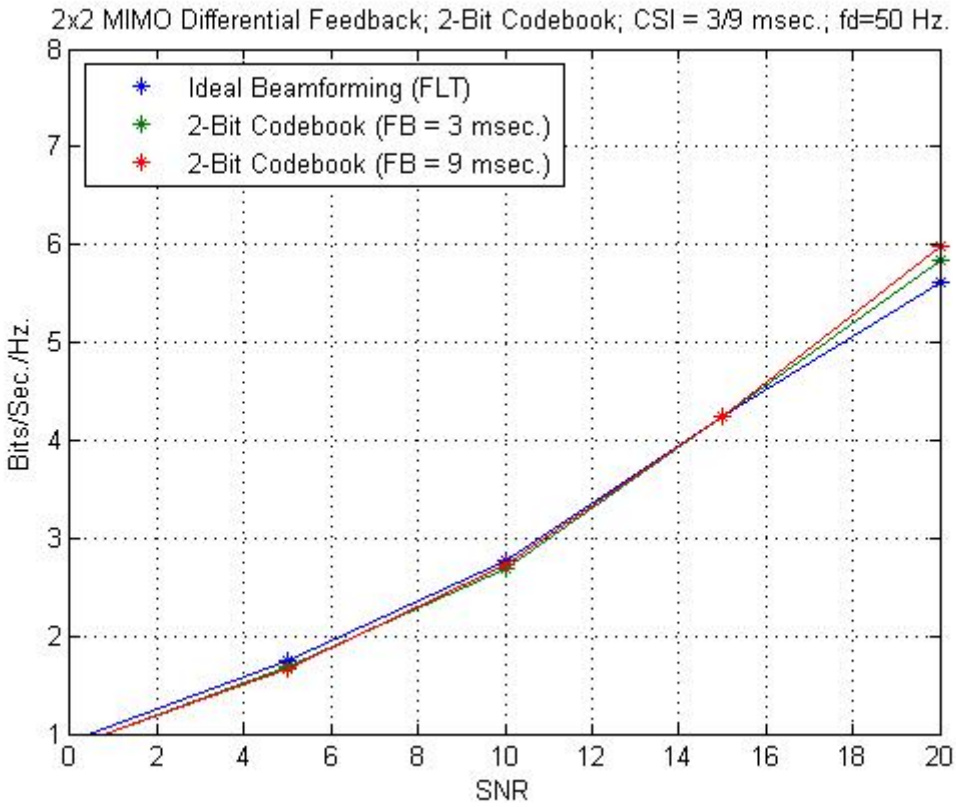


Figure 12: 2x2 MIMO Beamforming FB Rate vs. Ideal (50 Hz. Doppler)

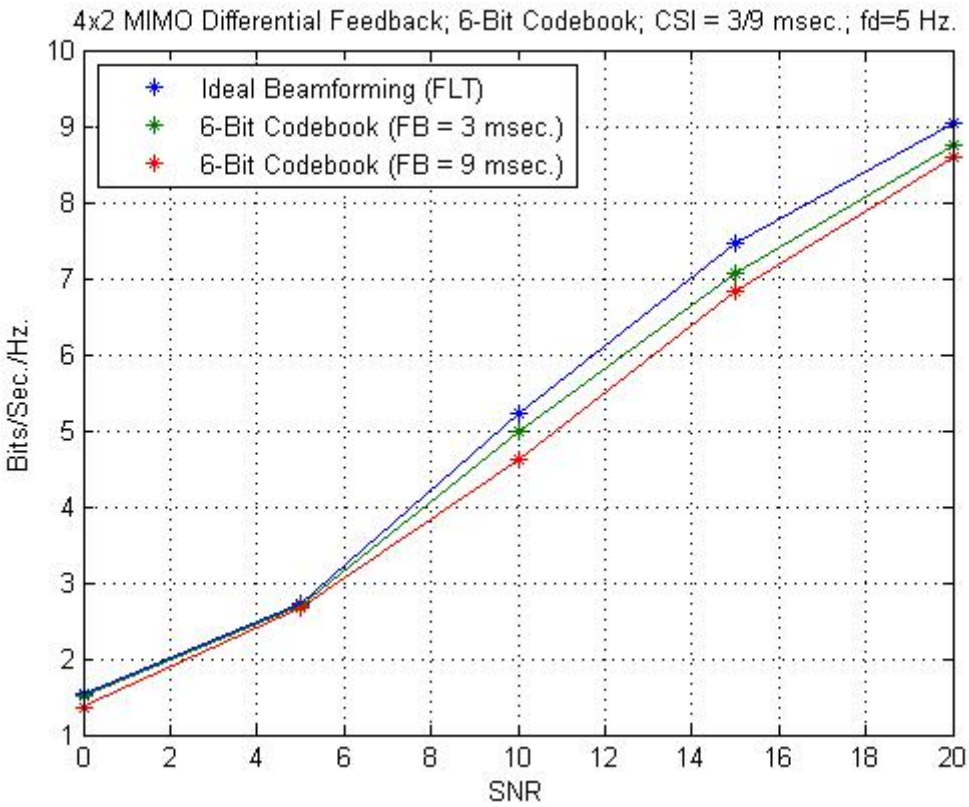


Figure 13: 4x2 MIMO Beamforming FB Rate vs. Ideal (5 Hz Doppler)

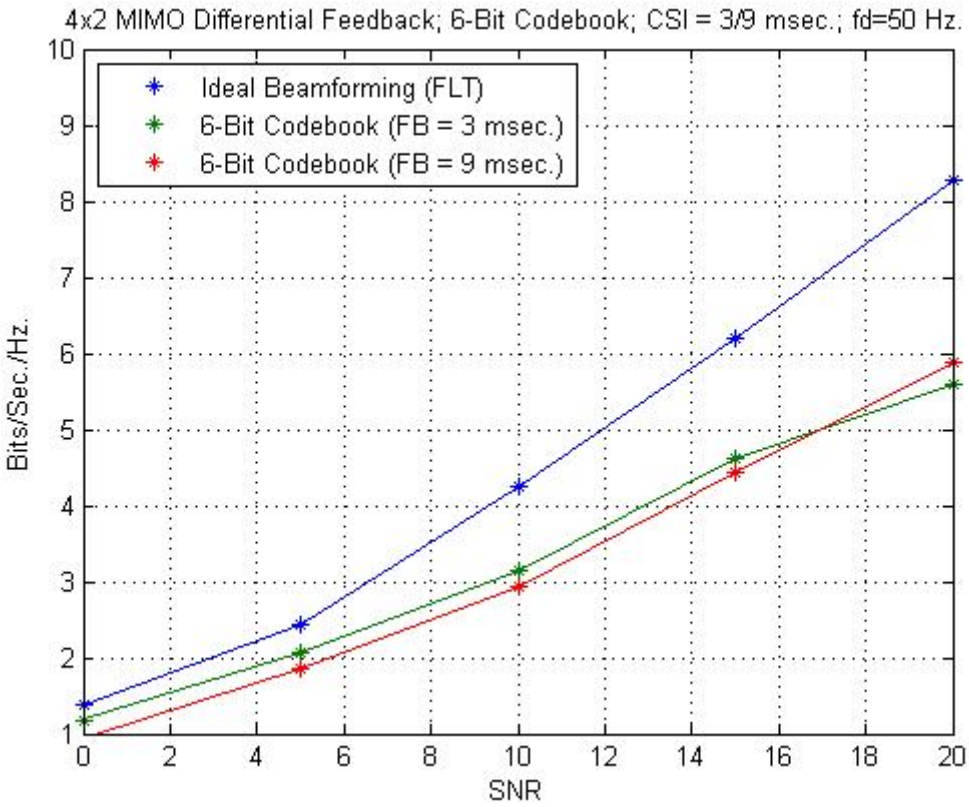


Figure 14: 4x2 MIMO Beamforming FB Rate vs. Ideal (50 Hz. Doppler)

The results in Figures 11-14 show performance results with the Compact Codebook [2] that again suggest a reduction in feedback rate for the low-mobility scenarios.

6. Conclusions and Further Discussion

Beamforming was examined in terms of both granularity in frequency domain and time domain. Beamforming gain beyond Low-Mobility users is diminished, depending on the Doppler frequency and rate of feedback.

The Compact Codebook for Beamforming [2] was shown to have good performance with a reduced update rate, thus reducing overhead for Beamforming feedback. We propose a reduced rate of feedback per HARQ process and usage of the Compact Codebook for MIMO Beamforming operations.

We believe Beamforming gain should be targeted for the Pedestrian or Low-Mobility user, suggesting a reduction in feedback rate compared to Wideband MCS [3].

7. References

[1] R1063241 Broadcom – Feedback Reduction with Incremental MCS Set for LTE

[2] R1-070169 Broadcom – Beamforming Compact Codebook Method and Results in E-UTRA

[3] R1-070169 Broadcom – UE Feedback Classification and CQI Characterization in E-UTRAN

[4] R1-063058 Motorola – Frequency Domain Adaptive Precoding for E-UTRA

[5] R1-063238 Texas Instruments – Aspects of Codebook-based Pre-coding for E-UTRA MIMO

[6] R1-063154 Freescale Semiconductor – Cluster size for codebook based Precoding in downlink MIMO for EUTRA

[7] R1-063203 NEC Group – On the Precoding codebook design for EUTRA MIMO NEC Group

[8] R1-063311 NTT DoCoMO – Investigations on Pre-coding Schemes for MIMO in E-UTRA Downlink

[9] R1-060458 Intel - Link Analysis of Single and Multi Codeword Schemes - Precoding

[10] R1-061127 Qualcomm - Comparison between Single and Multiple Codewords for Precoded MIMO

[11] R1-063372 NOKIA – Linear Precoding for 2TX Antenna