Proposal for IEEE 802.16m Uplink PHY Structure with Legacy Support

IEEE 802.16 Presentation Submission Template (Rev. 9)

Document Number:

IEEE C802.16m-08/394r1

Date Submitted:

2008-05-05

Source:

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Venue:

IEEE 802.16m-08/016r1, "Call for Contributions on Project 802.16m System Description Document (SDD)".

Target topic: "Uplink Pilot Structures"; "Uplink Physical Resource Allocation Unit (Resource blocks and Symbol Structures)".

Base Contribution:

This is the base contribution.

Purpose:

To be discussed and adopted by TGm for the 802.16m SDD

Introduction

- This contribution presents our considerations for 802.16m UL PHY design considering legacy support. The following topics are discussed:
  - Multiplexing 16m with 16e
  - Pilot pattern optimization
  - ACK/NAK channel optimization
- Our 16m UL PHY design for green-field is provided in another contribution: C80216m_08/396
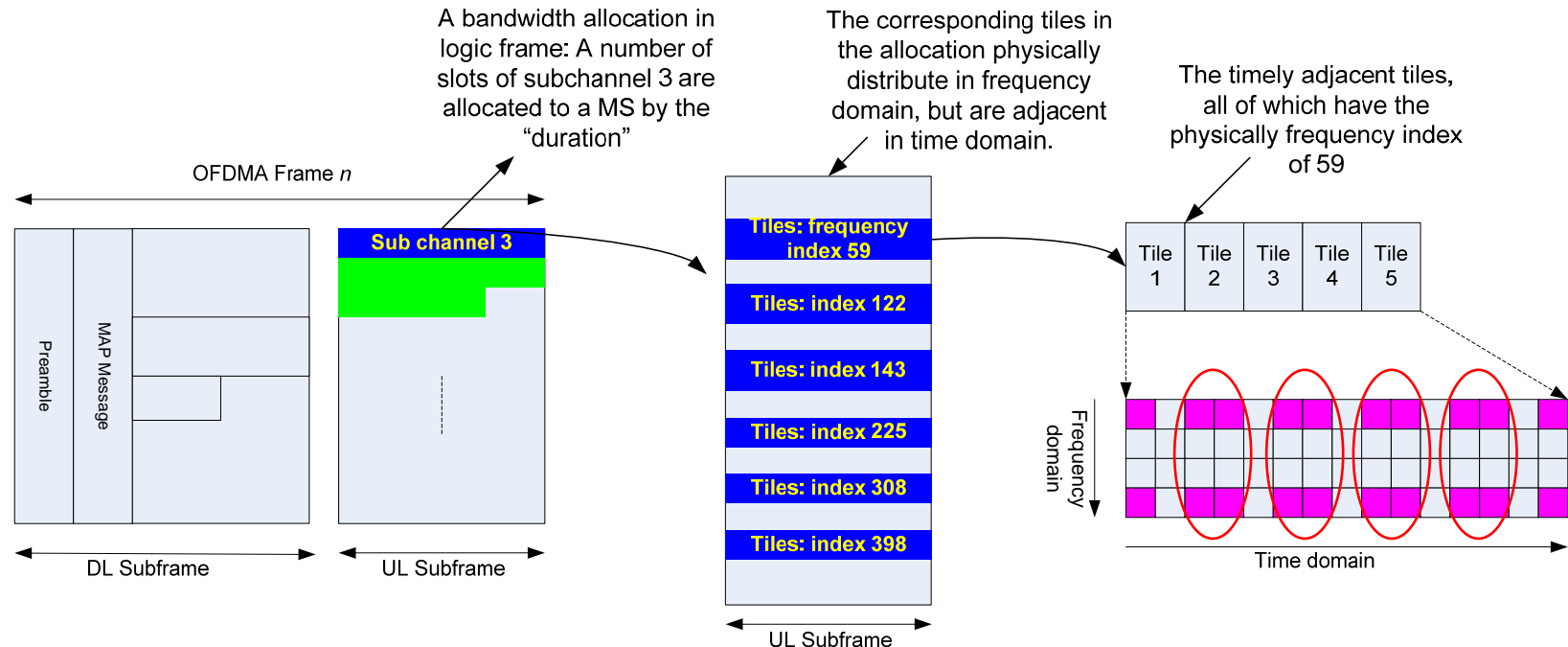
Multiplexing 16m with 16e

- FDM between legacy system and 16m system in UL should be supported
  - 802.16m system requirement: An IEEE 802.16m BS shall be able to support a legacy MS while also supporting IEEE 802.16m MSs on the same RF carrier, at a level of performance equivalent to that a legacy BS provides to a legacy MS.
  - Coverage will be an issue for the both 16e and 16m cell-edge users, if 16e and 16m systems are multiplexed by TDM. A good discussion was provided by C80216m-08_063r1.
    - FDM will be a constraint to 16m system design
    - The constraint is especially large when 16e users in the FDM region are doing PUSC/OPUSC.
      - 16m UL subchannelization scheme for distributed resource allocation (including the tile size, etc.) needs to be same with 16e.
    - The constraint is comparatively small when 16e users in the FDM region are doing AMC.
      - 16m UL basic PHY resource unit (RU) should be compatible to 16e AMC structure. An 2*3-bin AMC structure is mandatory according to WiMAX profile. Therefore, the UL basic PHY RU should have the size of 18*6 (freq*time) subcarriers, also considering the subframe structure.
    - **In either case, 16m performance shall be optimized.**
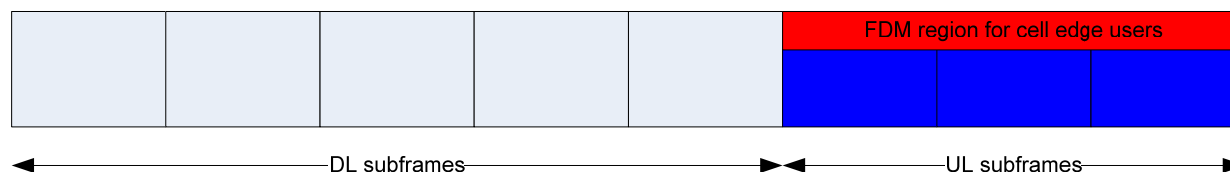
- TDM between legacy system and 16m system in UL should also be supported. In this case, 16m system will behave the same as in green-field.
  - In green-field, the 16m system could be designed much more freely.
  - Regarding the basic UL PHY RU
    - We prefer a 18*6 UL PHY RU, since it is symmetric with our proposed DL PHY RU and is compatible to the mandatory 16e AMC structure.
    - For distributed resource allocation, a UL PHY RU is further split into "tiles".
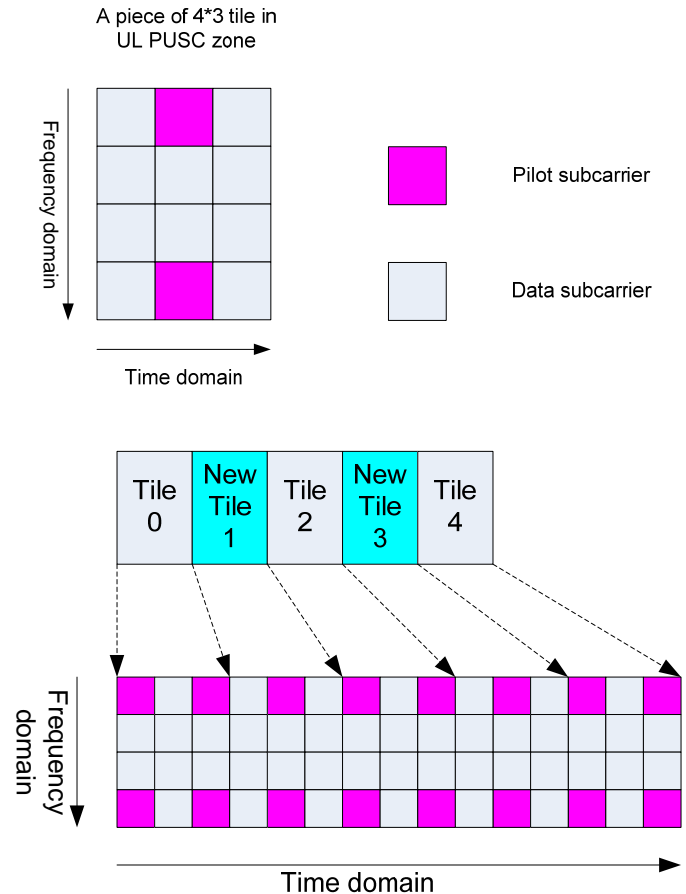   - More details for green-field design are referred to C80216m_08/396.

Issues of 16e PUSC Pilot Pattern

- In the case that 16m and 16e are using FDM and 16e is using PUSC, we propose that 16m also uses the 16e tile structure (4*3 block in freq-time domain) and 16e UL PUSC permutation.
  - When "subchannel rotation" is disabled, the bandwidth allocation is shown in the figure using the subchannel example in section 8.4.6.2.3 of the 802.16 standard.
  - Time-domain adjacent pilots (in the same frequency subcarrier) are somehow redundant.

A bandwidth allocation in logic frame: A number of slots of subchannel 3 are allocated to a MS by the "duration"

The corresponding tiles in the allocation physically distribute in frequency domain, but are adjacent in time domain.

The timely adjacent tiles, all of which have the physically frequency index of 59

OFDMA Frame *n*

Preamble

MAP Message

Sub channel 3

DL Subframe

UL Subframe

Tiles: frequency index 59

Tiles: index 122

Tiles: index 143

Tiles: index 225

Tiles: index 308

Tiles: index 398

UL Subframe

Tile 1 | Tile 2 | Tile 3 | Tile 4 | Tile 5

Frequency domain

Time domain

Pilot Pattern Optimization for Single Tx Antenna

- Assume n (>2) tiles are adjacent in time domain and occupy the same subcarriers in frequency domain. Each of the n tiles has an natural index k, $k=0,1,\ldots,n-1$.

- Define a new pilot pattern for the tile.

- For the tiles whose index $k=2j+1$, $j=0,1,\cdots,\lfloor (n-1)/2 \rfloor -1$, the new pilot pattern is used. The new pilot pattern saves two pilot subcarriers per tile for data.

- For other tiles, the 802.16e pilot pattern is used.

- Then, pilots distribute evenly in the whole bandwidth allocation.

- See the example in the lower figure for $n=5$.
  - In this example, the improvement in spectrum efficiency in terms of available data subcarriers is **4/40=10%**.

- The analysis on the performance of the new pilot pattern could be found in backup slides. Conclusion: **there is minor performance degradation, but an obvious improvement in bandwidth efficiency**.

A piece of 4*3 tile in
UL PUSC zone

Frequency domain

Time domain

Pilot subcarrier

Data subcarrier

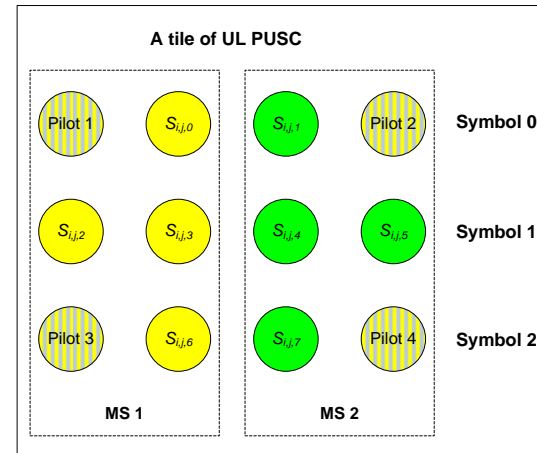| Tile 0 | New Tile 1 | Tile 2 | New Tile 3 | Tile 4 |

Frequency domain

Time domain

Pilot Pattern Optimization for Double Tx Antenna

- The tile with new pilot pattern when 2 transmit antennas are defined in the upper figure.
- We use the pilot patterns for 2 UL Tx antennas of a MS when $n=5$ (5 timely-continuous tiles are allocated to one MS's UL) as an example.
  - The location of the tiles with new pilot pattern keeps to the same rule with the case of single transmit antenna.
  - The 2nd and 4th tiles use the new pilot pattern.
  - The 1st, 3rd and 5th tiles use the 802.16e UL PUSC pilot pattern (section 8.4.8.1.5) with the modification that in the 3rd tile antenna #1 and #2 exchange the pilot positions.
  - The improvement in bandwidth efficiency is same with single antenna scenario.
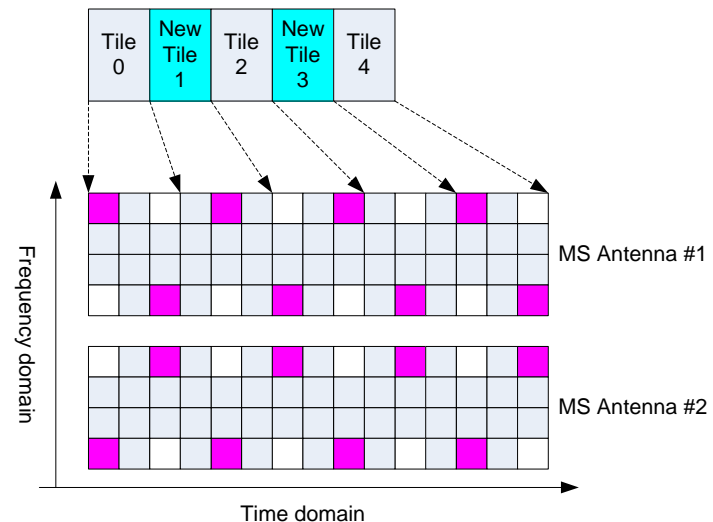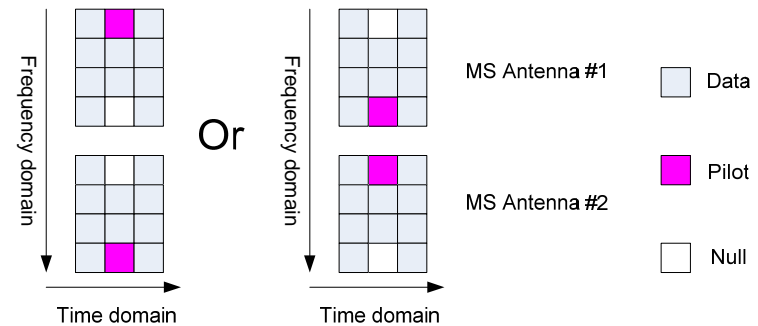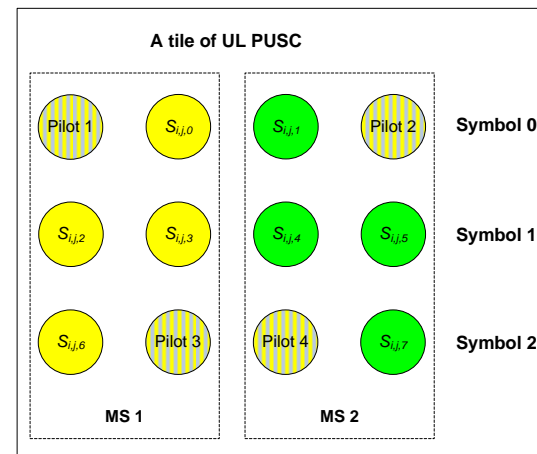
ACK/NAK channel optimization

- The coding/modulation scheme of 16e ACK/NAK channel is borrowed directly from the CQICH design without optimization.

- In the case of 16e PUSC, we have two directions to improve the 802.16 ACK channel:

    – Improving the ACK channel's efficiency without performance degradation (proposal I): we propose to allow two MSs to share one ACK channel (half a slot of 16e PUSC), as shown in the figure.

    – Improving the ACK channel's performance by using the best possible coding/modulation scheme (best ACK coding in brief) (proposal II)

A tile of UL PUSC

Pilot 1 | $S_{i,j,0}$ | $S_{i,j,1}$ | Pilot 2 — Symbol 0
$S_{i,j,2}$ | $S_{i,j,3}$ | $S_{i,j,4}$ | $S_{i,j,5}$ — Symbol 1
Pilot 3 | $S_{i,j,6}$ | $S_{i,j,7}$ | Pilot 4 — Symbol 2

MS 1 · MS 2

2 MSs sharing one ACK channel
Option 1: pilot pattern same with 16e PUSC

A tile of UL PUSC

Pilot 1 | $S_{i,j,0}$ | $S_{i,j,1}$ | Pilot 2 — Symbol 0
$S_{i,j,2}$ | $S_{i,j,3}$ | $S_{i,j,4}$ | $S_{i,j,5}$ — Symbol 1
$S_{i,j,6}$ | Pilot 3 | Pilot 4 | $S_{i,j,7}$ — Symbol 2

MS 1 · MS 2

2 MSs sharing one ACK channel
Option 2: pilot pattern different with 16e PUSC

ACK/NAK channel optimization

- The proposed Coding/Modulation Scheme is shown in a similar manner with the ACK/NAK channel defined in 802.16e spec.:
  - 2 MSs sharing one ACK channel (P0 and P2 have the same definition with 16e.)

ACK/NAK from two MSs	Coding/modulation scheme (Index of new tile vectors)
MS 1, ACK	0,0,0
MS 1, NAK	1,1,1
MS 2, ACK	2,2,2
MS 2, NAK	3,3,3

Tile index	$s_{i,j,0}, s_{i,j,1}, \cdots, s_{i,j,7}$
0	P0, X, P0, P0, X, X, P0, X
1	P2, X, P2, P2, X, X, P2, X
2	X, P0, X, X, P0, P0, X, P0
3	X, P2, X, X, P2, P2, X, P2

  - The "best ACK channel coding" using one 16e ACK/NAK channel (half a slot).

ACK 1-bit symbol	Index of new tile vectors
ACK	0,0,0
NAK	1,1,1

| Tile index	$s_{i,j,0}, s_{i,j,1}, \cdots, s_{i,j,7}$
0	P0, P0, P0, P0, P0, P0, P0, P0
1	P2, P2, P2, P2, P2, P2, P2, P2

  - The performance of the proposals have been verified by simulation results in the backup slides. Conclusion: Proposal I significantly improves the efficiency of ACK channels by allowing two MSs to share one ACK channel to transmit two ACK feedbacks simultaneously, with ~ 1dB performance degradation; Proposal II improves the BER performance by 1~2dB.

Proposed text changes for 802.16m SDD

- ## Section 11.x: Uplink PHY Structure
  - ### Section 11.x.x: Uplink PHY Structure with legacy support
    - Both FDM and TDM between legacy system and 16m system in UL should be supported.
    - In the case that 16m and 16e are using FDM and 16e is using PUSC, we propose that 16m also uses the 16e tile structure (4*3 block in freq-time domain) and 16e UL PUSC permutation.
      - The new pilot pattern for PUSC. (Add the figures in slides 5-6 here.)
      - The new ACK/NAK channel for PUSC. (Add the figures in slides 7-8 here.)

Backup Slides Part I: Analysis on performance degradation due to the reduction of pilots, MMSE channel estimation

- BER and FER performance of the proposed pilot pattern are compared with 16e PUSC.
- Note that in the comparison all the pilots in the right figure are utilized to do the channel estimation. Which means
  - PUSC: 12 pilots are used
  - Proposed method: 10 pilots are used
- Simulation parameters:
  - 10MHz bandwidth
  - VehA channel model
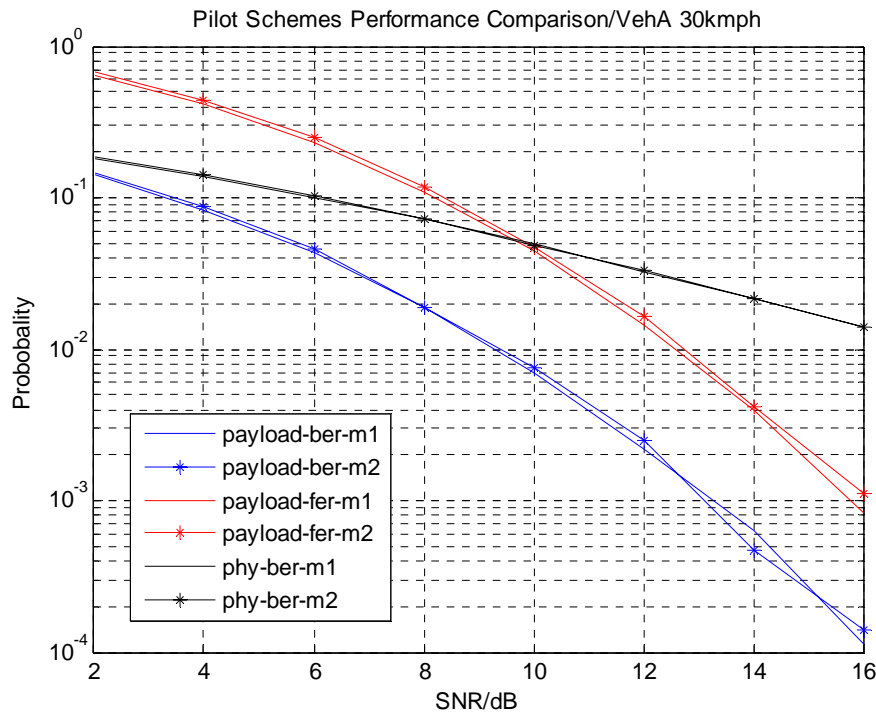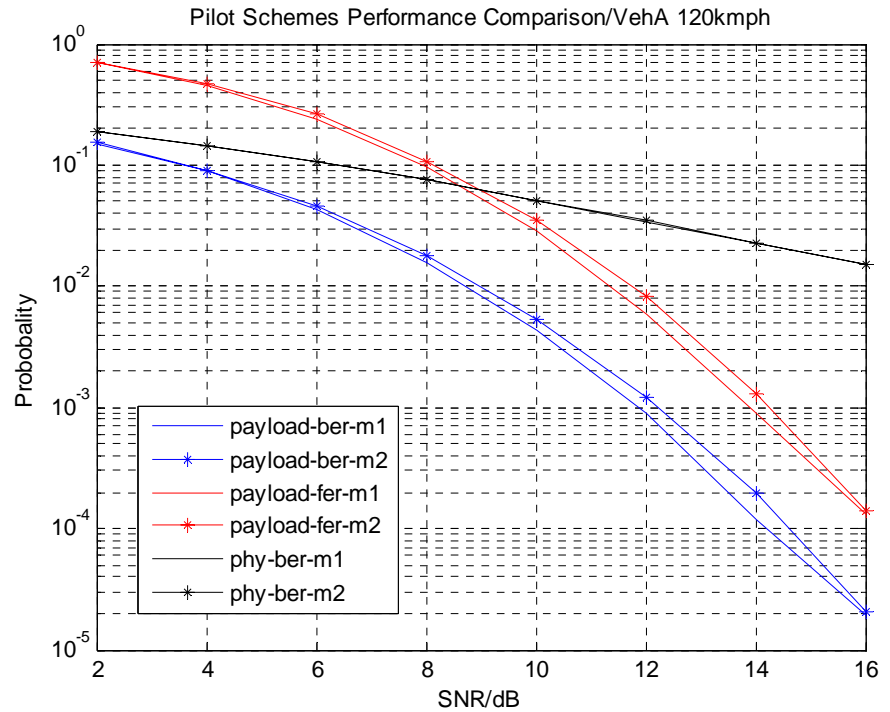 - MMSE channel estimation
  - 16e CTC channel coding
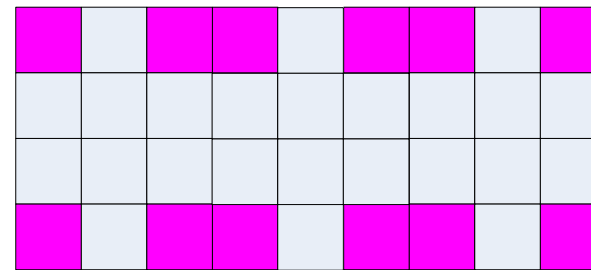
16e PUSC
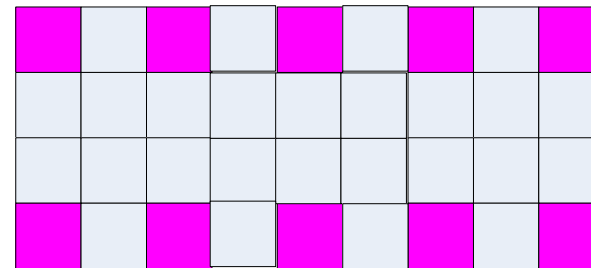
Proposed method

Backup Slides Part I: Simulation results

Veh A: 30 km/h

120 km/h

phy-ber: BER after equalization before channel decoding
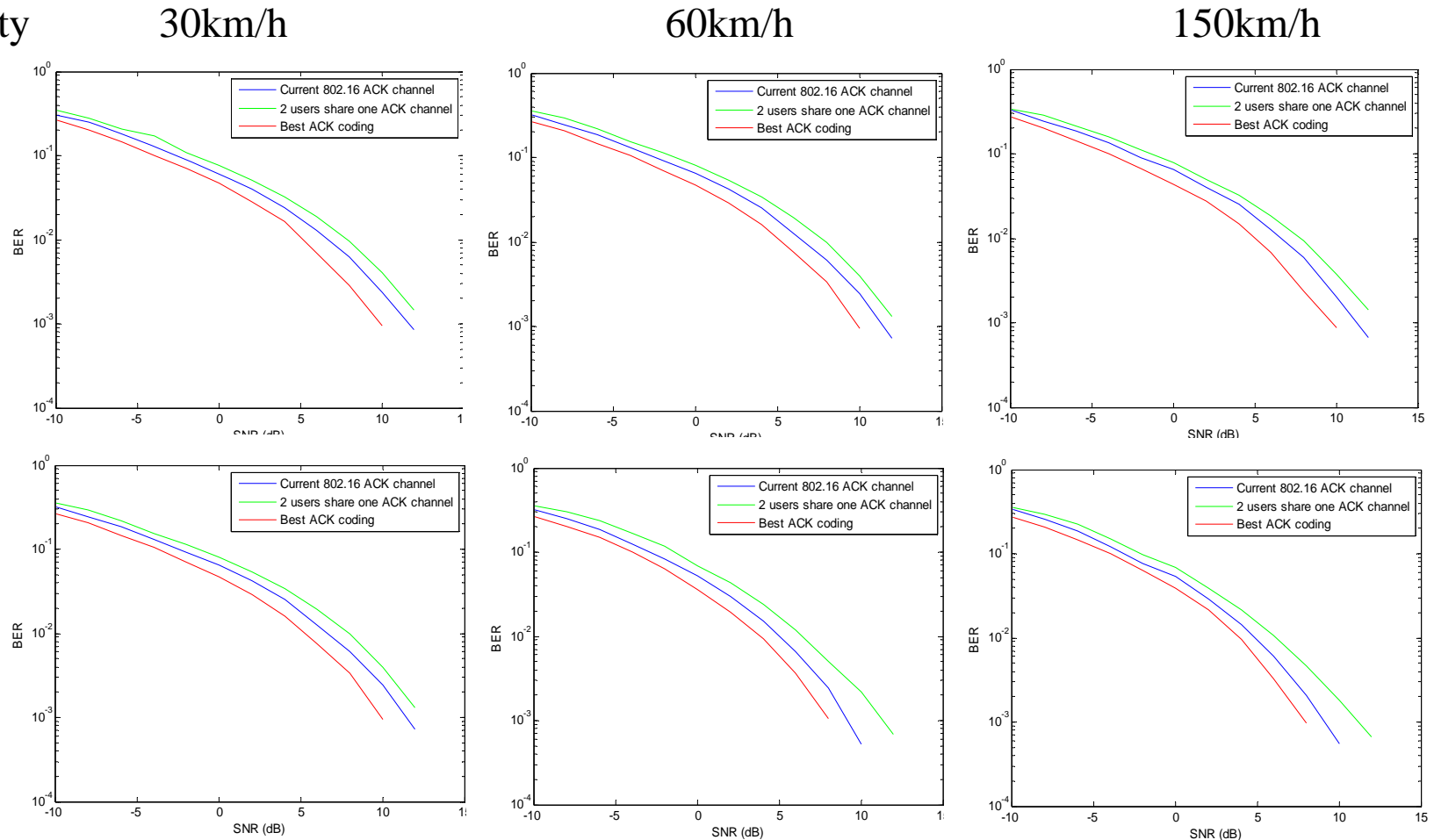payload-ber: BER after channel decoding
payload-fer: FER after channel decoding
m1: 16e PUSC
m2: the proposed pilot pattern

Backup Slides Part II: Analysis on performance of the proposed ACK channel

- Velocity 30km/h 60km/h 150km/h
- Veh-A

- Veh-B

- By using proposal I to obtain the twice efficiency over Veh-A channel, we will have a ~ 1dB performance degradation in the considered BER range. If the channel model changes to Veh-B, the degradation is enlarged to less than 2 dB.
- Proposal II always outperforms the current 802.16 ACK CM by 1~2 dBs.