

IEEE 802.16m Uplink Control Channel Design Details and Updates

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Base Contribution:

IEEE C802.16m-09/066

Abstract:

Provide technical justification/details for UL PHY control structure contributions C802.16m-09/239, 240, 241.

Purpose:

Provide technical justification/details for UL PHY control structure contributions C802.16m-09/239, 240, 241

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LTE CQICH Overhead

- ❑ CQICH allocation size (minimum unit)
 - 12 subcarriers by 14 symbols (1ms)
- ❑ CQICH load
 - 6 CQI channels by CDM
- ❑ CQICH overhead: 28 tones/CQICH channel

16m Fast Feedback (CQICH) Design

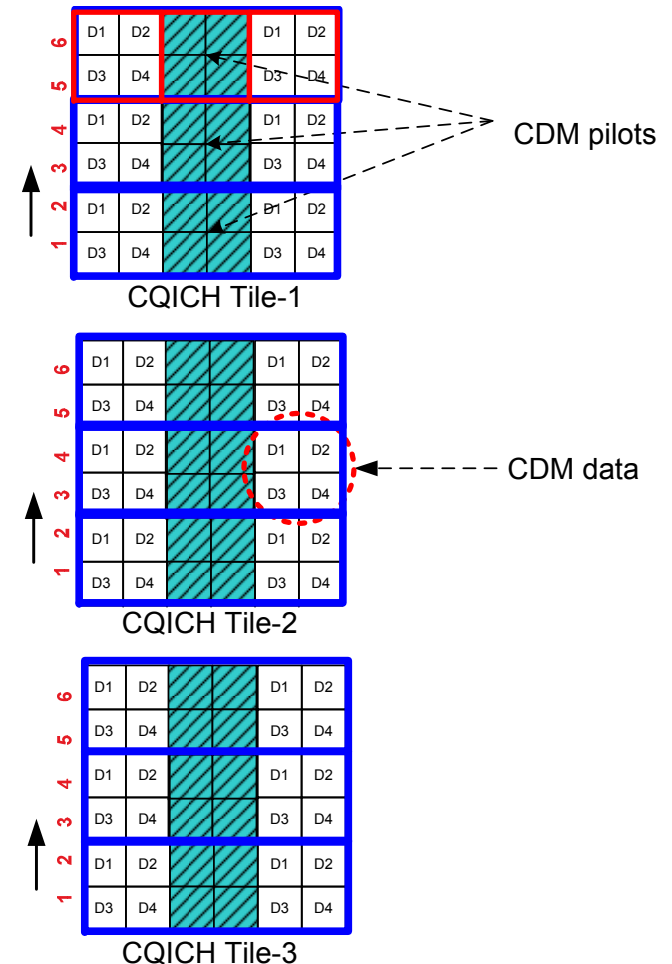
- ❑ 1 LRU (3 distributed tiles) shared by 4 CQICH
 - Pilot subcarriers are shared using CDM
 - Data subcarriers are shared using CDM
 - CDM has link budget advantage over TDM/FDM
 - **CQICH overhead: 27 tones/CQICH channel → Slightly lower overhead than LTE**
 - With only 3 CQICH (Samsung/Intel design), CQICH overhead 36 tones/CQICH → 28.6% higher than LTE
- ❑ To improve coverage, the tiles are allocated “time first”
 - Tile hopping in different subframes
 - Details in the next slides
- ❑ Support WB and NB CQICH feedback
- ❑ CQICH can also be transmitted with data using in-band control

Hierarchical CDM/TDM/FDM

- ❑ 2x2 block support 4 CQICH with CDM
 - 4 CQICH symbols CDM over 2x2 time/frequency contiguous tones → immune to time/frequency selective fading
- ❑ 2x6 block by concatenating 3 2x2 blocks with TDM
 - The middle 2x2 block can carry pilot symbols in order to support coherent detection
- ❑ 6x6 DRU tile by concatenating 3 2x6 blocks with FDM
- ❑ 3 DRU tiles form one control channel PRU
 - DRU tiles should be allocated “time first” in order to improve control channel coverage → take full advantage of MS tx power
 - DRU tiles should be allocated at different frequency in order to provide frequency diversity

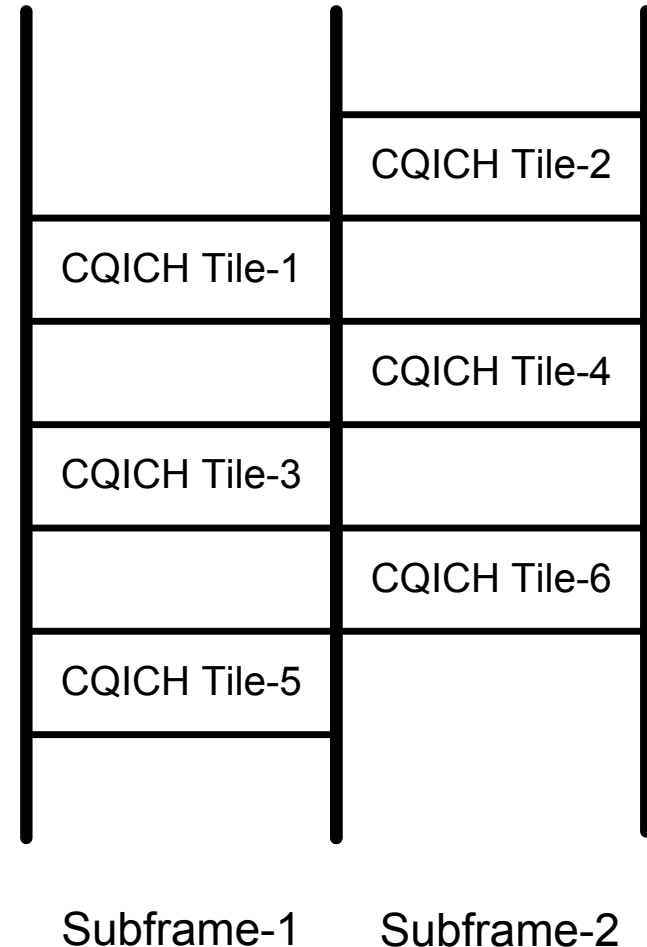
16m CQICH Control Tile

- ❑ Coherent detection with pilot
- ❑ 1 control PRU shared by 4 CQICH channel
 - Spreading codes from MUB are used to further reduce the adjacent cell interference
- ❑ Each CQICH consists of 18 data symbols
 - Each symbol is QPSK modulated
 - Each symbol is further spread by a 4-bit orthogonal sequence
- ❑ Primary/basic CQICH
 - 72 18-symbol QPSK sequences
 - 64 sequences for 6-bit CQI information
 - 8 sequences for other purposes: BR indicator, etc.
- ❑ Secondary/enhanced CQICH
 - 12-bit enhanced CQICH
 - TB-CC (R=1/3) with QPSK modulation



16m CQICH Tile Allocation

- ❑ 3 control tiles are allocated for each control PRU
- ❑ Tiles are allocated time-first
 - Link budget advantage in taking full advantage of MS tx power
 - Improved coverage



Adjacent Cell Interference Reduction using Spreading Codes from MUB

- ❑ Spreading codes from MUB provides least cross interference
- ❑ Five sets of MUB can be used for the length-4 CDM codes
 - For example: sector-1 uses Matrix-A, sector-2 uses Matrix-B, etc.

$$\mathbf{A} = \mathbf{U} \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \\ 1 & -1 & 1 & -1 \end{bmatrix}, \mathbf{B} = \mathbf{U} \begin{bmatrix} 1 & 1 & 1 & 1 \\ -1 & -1 & 1 & 1 \\ -i & i & i & -i \\ -i & i & -i & i \end{bmatrix}, \mathbf{C} = \mathbf{U} \begin{bmatrix} 1 & 1 & 1 & 1 \\ -i & -i & i & i \\ -i & i & i & -i \\ -1 & 1 & -1 & 1 \end{bmatrix}, \mathbf{D} = \mathbf{U} \begin{bmatrix} 1 & 1 & 1 & 1 \\ i & i & -i & -i \\ 1 & -1 & -1 & 1 \\ -i & i & -i & i \end{bmatrix}, \mathbf{E} = \mathbf{U} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

(72, 18) QPSK Sequences

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Q3	Q1	Q0	Q0	Q2	Q2	Q1	Q2	Q3	Q2	Q1	Q1	Q2	Q0	Q1	Q2	Q3	Q3
2	Q3	Q2	Q3	Q2	Q3	Q1	Q2	Q3	Q1	Q3	Q0	Q2	Q1	Q1	Q2	Q3	Q3	Q2
3	Q3	Q0	Q0	Q0	Q3	Q0	Q3	Q2	Q2	Q0	Q2	Q3	Q1	Q0	Q0	Q0	Q3	Q1
4	Q3	Q3	Q0	Q3	Q1	Q2	Q2	Q1	Q1	Q3	Q2	Q2	Q3	Q2	Q0	Q3	Q0	Q0
5	Q0	Q2	Q0	Q3	Q3	Q2	Q0	Q3	Q3	Q3	Q3	Q2	Q1	Q3	Q1	Q1	Q1	Q0
6	Q1	Q2	Q0	Q1	Q0	Q2	Q3	Q2	Q0	Q1	Q1	Q2	Q1	Q2	Q0	Q1	Q0	Q2
7	Q0	Q0	Q3	Q1	Q0	Q1	Q2	Q3	Q0	Q3	Q1	Q0	Q3	Q0	Q0	Q0	Q1	Q3
8	Q1	Q1	Q0	Q2	Q1	Q0	Q2	Q3	Q2	Q0	Q1	Q3	Q2	Q3	Q2	Q2	Q0	Q0
9	Q0	Q2	Q3	Q1	Q2	Q1	Q0	Q0	Q2	Q0	Q2	Q2	Q3	Q3	Q0	Q2	Q2	Q2
10	Q2	Q0	Q0	Q1	Q3	Q0	Q1	Q2	Q1	Q1	Q3	Q2	Q3	Q1	Q3	Q2	Q1	Q3
11	Q1	Q1	Q3	Q3	Q2	Q1	Q2	Q1	Q2	Q2	Q2	Q0	Q0	Q1	Q3	Q1	Q0	Q2
12	Q0	Q0	Q3	Q1	Q1	Q3	Q0	Q2	Q2	Q3	Q1	Q2	Q2	Q2	Q2	Q0	Q0	Q2
13	Q0	Q0	Q0	Q2	Q1	Q0	Q1	Q0	Q0	Q2	Q2	Q2	Q1	Q1	Q1	Q1	Q2	Q1
14	Q2	Q3	Q0	Q2	Q1	Q1	Q0	Q0	Q2	Q1	Q0	Q0	Q2	Q1	Q0	Q0	Q3	Q3
15	Q3	Q1	Q3	Q3	Q0	Q1	Q0	Q3	Q1	Q1	Q3	Q1	Q0	Q3	Q1	Q1	Q0	Q0
16	Q0	Q2	Q0	Q0	Q1	Q3	Q3	Q3	Q1	Q1	Q2	Q0	Q0	Q1	Q2	Q3	Q2	Q3
17	Q2	Q1	Q0	Q1	Q3	Q2	Q1	Q0	Q0	Q0	Q2	Q0	Q3	Q2	Q2	Q0	Q3	Q1
18	Q3	Q3	Q3	Q0	Q1	Q2	Q2	Q3	Q1	Q0	Q3	Q3	Q2	Q2	Q1	Q2	Q1	Q1
19	Q2	Q3	Q0	Q3	Q0	Q3	Q1	Q3	Q2	Q3	Q1	Q1	Q0	Q3	Q3	Q1	Q2	Q2
20	Q2	Q0	Q3	Q3	Q0	Q2	Q3	Q0	Q3	Q1	Q2	Q2	Q2	Q0	Q2	Q3	Q1	Q2
21	Q1	Q0	Q3	Q3	Q2	Q3	Q3	Q3	Q0	Q0	Q0	Q1	Q3	Q1	Q0	Q2	Q3	Q1
22	Q3	Q3	Q3	Q2	Q2	Q3	Q0	Q1	Q0	Q0	Q1	Q3	Q0	Q0	Q2	Q1	Q0	Q3
23	Q0	Q1	Q0	Q3	Q0	Q0	Q0	Q1	Q0	Q2	Q0	Q3	Q3	Q3	Q3	Q3	Q3	Q2
24	Q3	Q0	Q0	Q1	Q2	Q2	Q3	Q0	Q1	Q2	Q0	Q0	Q1	Q3	Q3	Q2	Q1	Q1
25	Q1	Q3	Q0	Q3	Q2	Q1	Q1	Q2	Q0	Q0	Q3	Q0	Q1	Q3	Q1	Q3	Q1	Q2
26	Q1	Q0	Q3	Q2	Q3	Q2	Q0	Q2	Q2	Q2	Q1	Q3	Q0	Q2	Q1	Q3	Q2	Q0
27	Q2	Q2	Q3	Q2	Q2	Q0	Q3	Q2	Q0	Q2	Q2	Q1	Q2	Q3	Q3	Q0	Q2	Q0
28	Q2	Q2	Q3	Q0	Q0	Q0	Q0	Q1	Q1	Q3	Q1	Q0	Q2	Q1	Q1	Q2	Q1	Q1
29	Q1	Q3	Q3	Q0	Q3	Q3	Q2	Q0	Q1	Q2	Q3	Q3	Q2	Q3	Q1	Q1	Q3	Q3
30	Q3	Q1	Q3	Q2	Q0	Q3	Q2	Q1	Q3	Q0	Q3	Q0	Q1	Q2	Q0	Q2	Q2	Q3
31	Q2	Q1	Q0	Q0	Q2	Q0	Q3	Q0	Q3	Q3	Q0	Q2	Q0	Q2	Q1	Q0	Q1	Q3
32	Q1	Q1	Q3	Q0	Q1	Q2	Q1	Q1	Q1	Q0	Q0	Q2	Q1	Q0	Q3	Q0	Q2	Q0
33	Q2	Q2	Q3	Q1	Q1	Q3	Q1	Q3	Q3	Q2	Q3	Q3	Q0	Q0	Q0	Q3	Q0	Q1
34	Q0	Q3	Q3	Q0	Q3	Q0	Q1	Q0	Q3	Q1	Q1	Q1	Q1	Q2	Q3	Q3	Q0	Q0
35	Q0	Q2	Q0	Q2	Q3	Q3	Q2	Q1	Q2	Q1	Q0	Q1	Q3	Q0	Q1	Q0	Q1	Q1
36	Q1	Q3	Q0	Q1	Q0	Q1	Q3	Q1	Q3	Q3	Q3	Q1	Q0	Q0	Q2	Q2	Q3	Q0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
37	Q1	Q3	Q2	Q2	Q0	Q0	Q3	Q0	Q1	Q0	Q3	Q3	Q0	Q2	Q3	Q0	Q1	Q1
38	Q1	Q0	Q1	Q0	Q1	Q3	Q0	Q1	Q3	Q1	Q2	Q0	Q3	Q3	Q0	Q1	Q1	Q0
39	Q1	Q2	Q2	Q2	Q1	Q2	Q1	Q0	Q0	Q2	Q0	Q1	Q3	Q2	Q2	Q2	Q1	Q3
40	Q1	Q1	Q2	Q1	Q3	Q0	Q0	Q3	Q3	Q1	Q0	Q0	Q1	Q0	Q2	Q1	Q2	Q2
41	Q2	Q0	Q2	Q1	Q1	Q0	Q2	Q1	Q1	Q1	Q1	Q1	Q1	Q0	Q3	Q1	Q3	Q2
42	Q3	Q0	Q2	Q3	Q2	Q0	Q1	Q0	Q2	Q3	Q3	Q0	Q3	Q0	Q2	Q3	Q2	Q0
43	Q2	Q2	Q1	Q3	Q2	Q3	Q0	Q1	Q2	Q1	Q3	Q2	Q1	Q2	Q2	Q2	Q3	Q1
44	Q3	Q3	Q2	Q0	Q3	Q2	Q0	Q1	Q0	Q2	Q3	Q1	Q0	Q1	Q0	Q0	Q2	Q2
45	Q2	Q0	Q1	Q3	Q0	Q3	Q2	Q2	Q0	Q2	Q0	Q0	Q1	Q1	Q2	Q0	Q0	Q0
46	Q0	Q2	Q2	Q3	Q1	Q2	Q3	Q0	Q3	Q3	Q1	Q0	Q1	Q3	Q1	Q0	Q3	Q1
47	Q3	Q3	Q1	Q1	Q0	Q3	Q0	Q3	Q0	Q0	Q2	Q2	Q3	Q1	Q3	Q1	Q3	Q0
48	Q2	Q2	Q1	Q3	Q3	Q1	Q2	Q0	Q0	Q1	Q1	Q3	Q0	Q0	Q0	Q2	Q2	Q0
49	Q2	Q2	Q2	Q0	Q3	Q2	Q3	Q2	Q2	Q0	Q0	Q0	Q3	Q3	Q3	Q3	Q0	Q3
50	Q0	Q1	Q2	Q0	Q3	Q3	Q2	Q2	Q0	Q3	Q2	Q2	Q0	Q3	Q2	Q2	Q1	Q1
51	Q1	Q3	Q1	Q1	Q2	Q3	Q2	Q1	Q3	Q3	Q1	Q3	Q2	Q1	Q3	Q3	Q2	Q2
52	Q2	Q0	Q2	Q2	Q3	Q1	Q1	Q1	Q3	Q3	Q0	Q2	Q2	Q3	Q0	Q1	Q0	Q1
53	Q0	Q3	Q2	Q3	Q1	Q0	Q3	Q2	Q2	Q2	Q0	Q2	Q1	Q0	Q0	Q2	Q1	Q3
54	Q1	Q1	Q1	Q2	Q3	Q3	Q0	Q0	Q1	Q3	Q2	Q1	Q1	Q0	Q0	Q3	Q0	Q3
55	Q0	Q1	Q2	Q1	Q2	Q1	Q3	Q1	Q0	Q1	Q3	Q3	Q2	Q1	Q1	Q3	Q0	Q0
56	Q0	Q2	Q1	Q1	Q2	Q0	Q1	Q2	Q1	Q3	Q0	Q0	Q0	Q2	Q0	Q1	Q3	Q0
57	Q3	Q2	Q1	Q1	Q0	Q1	Q1	Q1	Q2	Q2	Q2	Q3	Q1	Q3	Q2	Q0	Q1	Q3
58	Q1	Q1	Q1	Q0	Q0	Q1	Q2	Q3	Q2	Q2	Q3	Q1	Q2	Q2	Q0	Q3	Q2	Q1
59	Q2	Q3	Q2	Q1	Q2	Q2	Q2	Q3	Q2	Q0	Q2	Q1	Q1	Q1	Q1	Q1	Q1	Q0
60	Q1	Q2	Q2	Q3	Q0	Q0	Q1	Q2	Q3	Q0	Q2	Q2	Q3	Q1	Q1	Q0	Q3	Q3
61	Q3	Q1	Q2	Q1	Q0	Q3	Q3	Q0	Q2	Q2	Q1	Q2	Q3	Q1	Q3	Q1	Q3	Q0
62	Q3	Q2	Q1	Q0	Q1	Q0	Q2	Q0	Q0	Q0	Q3	Q1	Q2	Q0	Q3	Q1	Q0	Q2
63	Q0	Q0	Q1	Q0	Q0	Q2	Q1	Q0	Q2	Q0	Q0	Q3	Q0	Q1	Q1	Q2	Q0	Q2
64	Q0	Q0	Q1	Q2	Q2	Q2	Q2	Q3	Q3	Q1	Q3	Q2	Q0	Q3	Q3	Q0	Q3	Q3
65	Q3	Q1	Q1	Q2	Q1	Q1	Q0	Q2	Q3	Q0	Q1	Q1	Q0	Q1	Q3	Q3	Q1	Q1
66	Q1	Q3	Q1	Q0	Q2	Q1	Q0	Q3	Q1	Q2	Q1	Q2	Q3	Q0	Q2	Q0	Q0	Q1
67	Q0	Q3	Q2	Q2	Q0	Q2	Q1	Q2	Q1	Q1	Q2	Q0	Q2	Q0	Q3	Q2	Q3	Q1
68	Q3	Q3	Q1	Q2	Q3	Q0	Q3	Q3	Q3	Q2	Q0	Q3	Q2	Q1	Q2	Q1	Q2	Q0
69	Q0	Q0	Q1	Q3	Q3	Q1	Q3	Q1	Q1	Q0	Q1	Q1	Q2	Q2	Q2	Q1	Q2	Q3
70	Q2	Q1	Q1	Q2	Q1	Q2	Q3	Q2	Q1	Q3	Q3	Q3	Q3	Q0	Q1	Q1	Q2	Q2
71	Q2	Q0	Q2	Q0	Q1	Q1	Q0	Q3	Q0	Q3	Q2	Q3	Q1	Q2	Q3	Q2	Q3	Q3
72	Q3	Q1	Q2	Q3	Q2	Q3	Q1	Q3	Q1	Q1	Q3	Q2	Q2	Q0	Q0	Q1	Q2	Q2

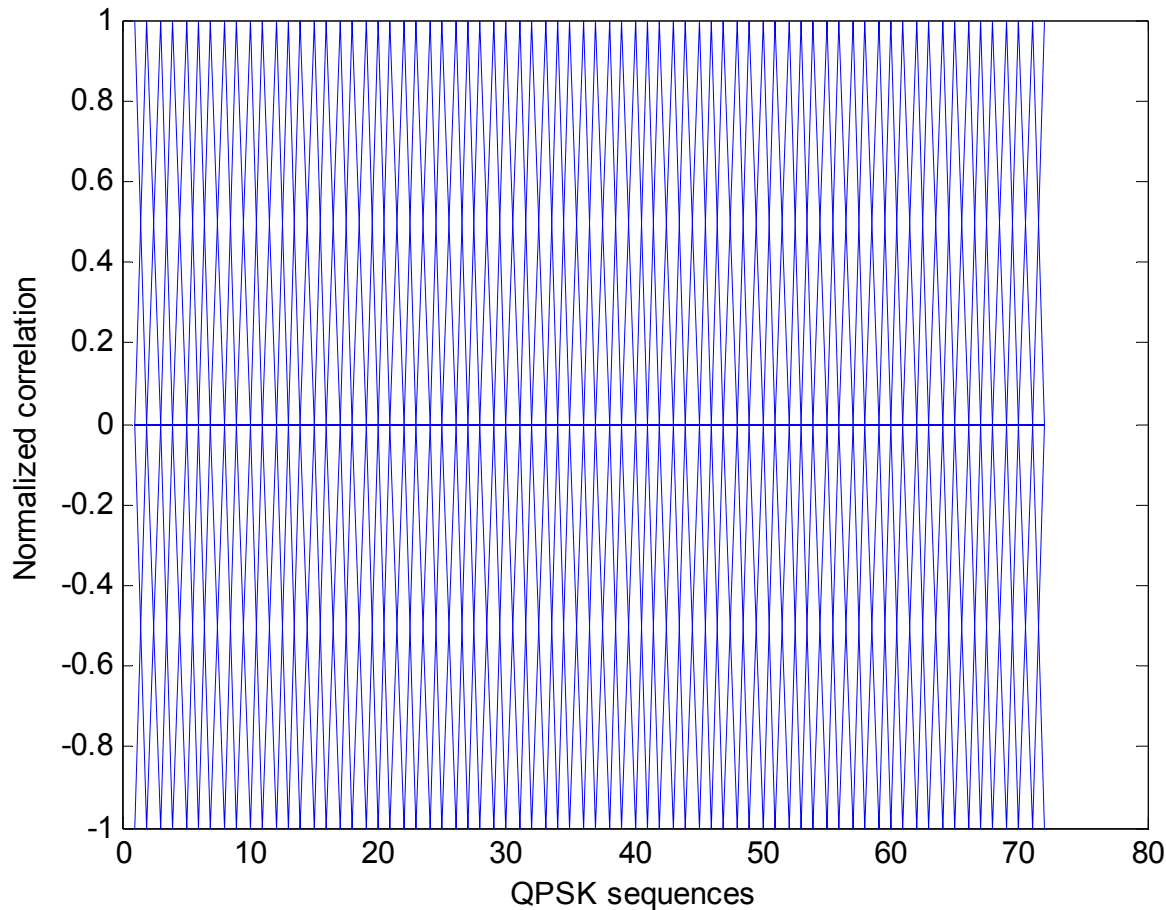
$$Q0 = \exp\left(j \frac{\pi}{4}\right);$$

$$Q1 = \exp\left(j \frac{3\pi}{4}\right);$$

$$Q2 = \exp\left(-j \frac{3\pi}{4}\right);$$

$$Q3 = \exp\left(-j \frac{\pi}{4}\right);$$

Cross Code Interference



- ❑ Cross correlation between any pair of 72 sequences ≤ 0
- ❑ Slightly better link performance than the (64, 18) sequences in C80216m-UL_PHY_Ctrl-08_058

An Alternative Set of Sequences

- ❑ An alternative set of complex sequences that have similar property can be made by DFT matrix $[F; -F; jF; -jF]$ where F is the 18×18 DFT matrix
- ❑ Link performance is slightly worse than the set of $(72, 18)$ QPSK sequences

16m CQI Information Content (Primary Fast Feedback)

- ❑ Support 72 values (sequences)
- ❑ 64 values for CINR feedback
 - Physical CINR feedback
 - 48 values for mean CINR (-10 dB to 38 dB with 1dB step)
 - 8 values for standard deviation of CINR over frequency
 - Provide a better characterization of frequency selective fading channel
 - 8 values standard deviation of CINR over time
 - Provide a better characterization of time selective fading channel
 - Effective CINR feedback
 - Up to 64 values of MCS
 - Narrow band CINR feedback (B-AMC type)
 - Best-6 subband differential feedback
- ❑ 4 values for rank indication (RI=1, 2, 4, 8)
- ❑ 1 value for bandwidth request indicator
- ❑ 3 values reserved

16m CQI Information Content (Standard Deviations of Physical CINR)

- ❑ Standard deviation of CINR over time
 - Provide a characterization of time varying fading channel
 - 16e spec provides two options:
 - dB based STD is preferred
 - Linear value based STD needs to be normalized

- ❑ Standard deviation of CINR over frequency
 - Provide a characterization of frequency selective fading channel

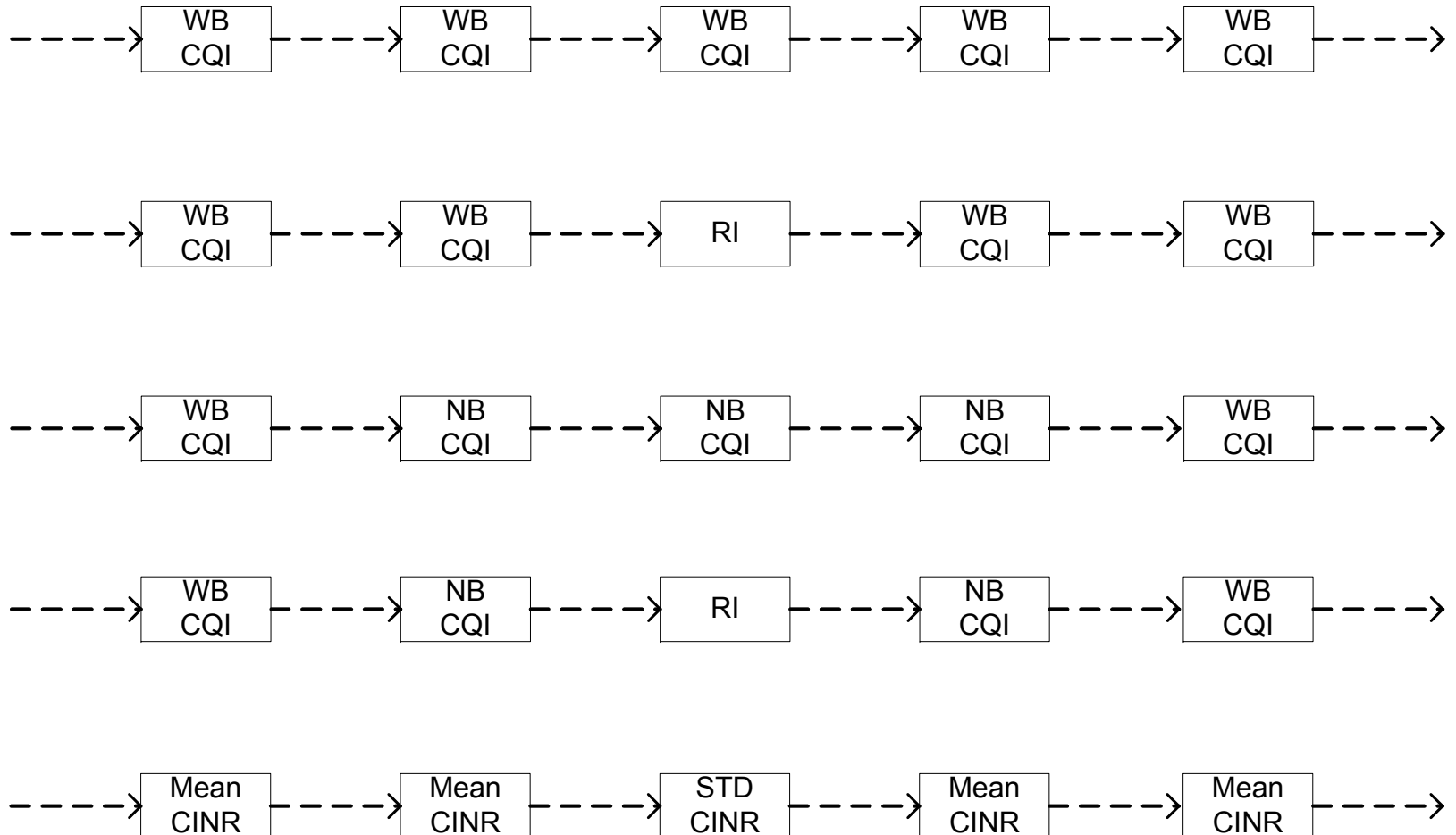
16m CQI Information Content (Secondary Fast Feedback)

- ❑ Closed loop MIMO CQI feedback
 - 6-bit CQI, 4-bit PMI (rotate for best-6 bands), 2-bit rank indication
 - Additional PMI (such as narrow band PMI) can be feedback with in-band control
 - Other contents are FFS

CQICH Timing

- ❑ MS (or by the request of Bs) may choose to feedback mean of CINR, standard deviations of CINR, rank indication, narrow band CINR, etc
- ❑ CQI is feedback on CQICH periodically
 - Standard deviation can be inserted with lower frequency
- ❑ RI (rank indicator) can be inserted with low frequency
- ❑ WB CQI and NB CQI can be interlaced, with NB CQI report having higher frequency

CQICH Timing



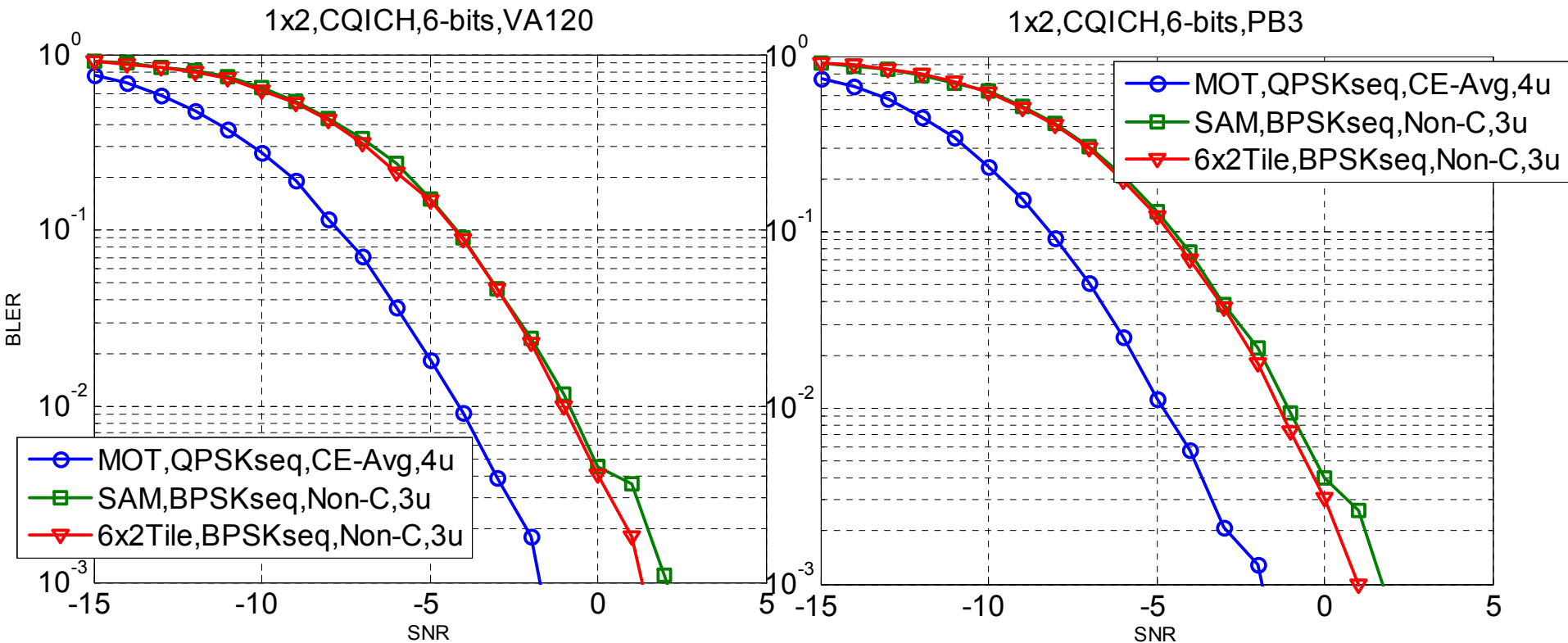
Link Simulation Parameters

Parameter	Value
NFFT	1024
Carrier frequency	2.6 GHz
# Tx antennas	1
# Rx antennas	2
Antenna spacing	4λ
CCH design	Motorola, Samsung-982r2 (Intel 937r2)
Channel model	PB3, VA120, VA350
Pilots	no pilot boost, orthogonal pilots for 4 UL users
Receiver	MRC for CQICH, correlator for ACK
UL channel estimator	average
Packet size	6 info-bits for CQICH

CQICH Performance 1

□ VA120 (per-tone SNR)

□ PB3 (per-tone SNR)

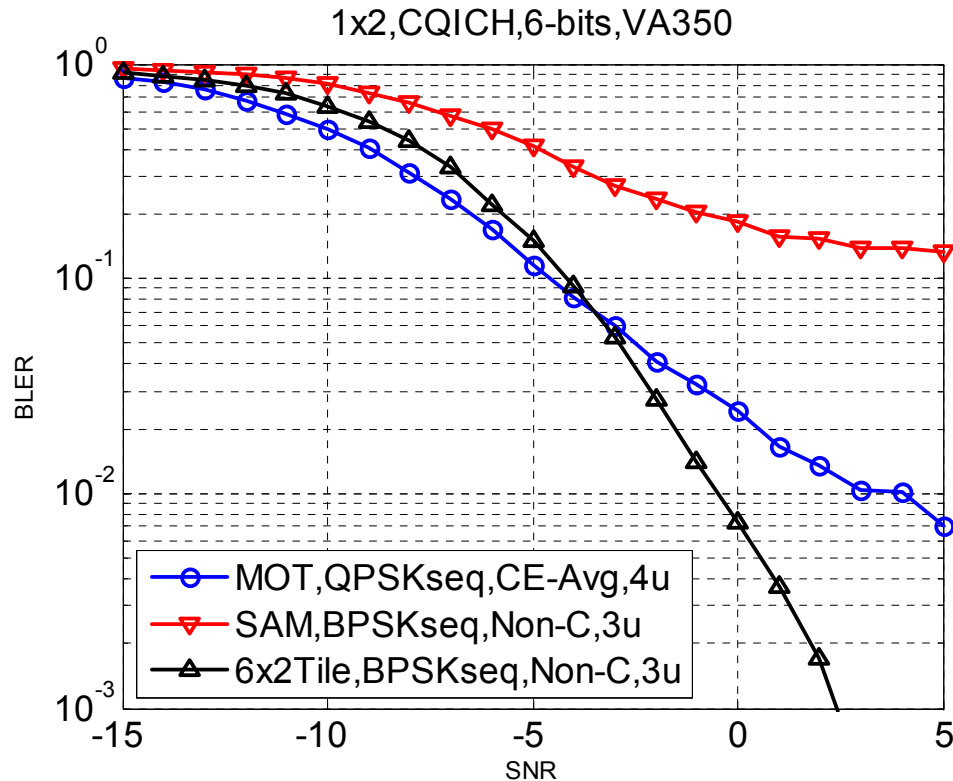


□ Motorola proposal CDM over 3x subcarriers

- Relative performance shifted by $10 \cdot \log_{10}(3) = 4.78$ dB between per_tone_SNR and per_infobit_SNR

CQICH Performance 2

VA350

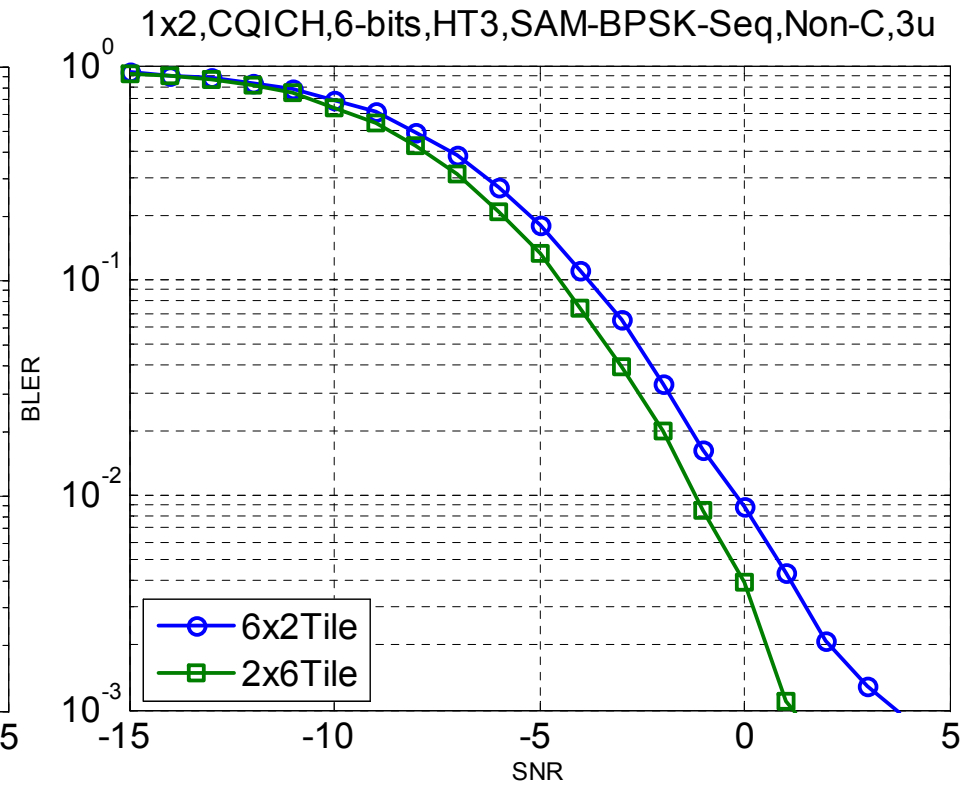
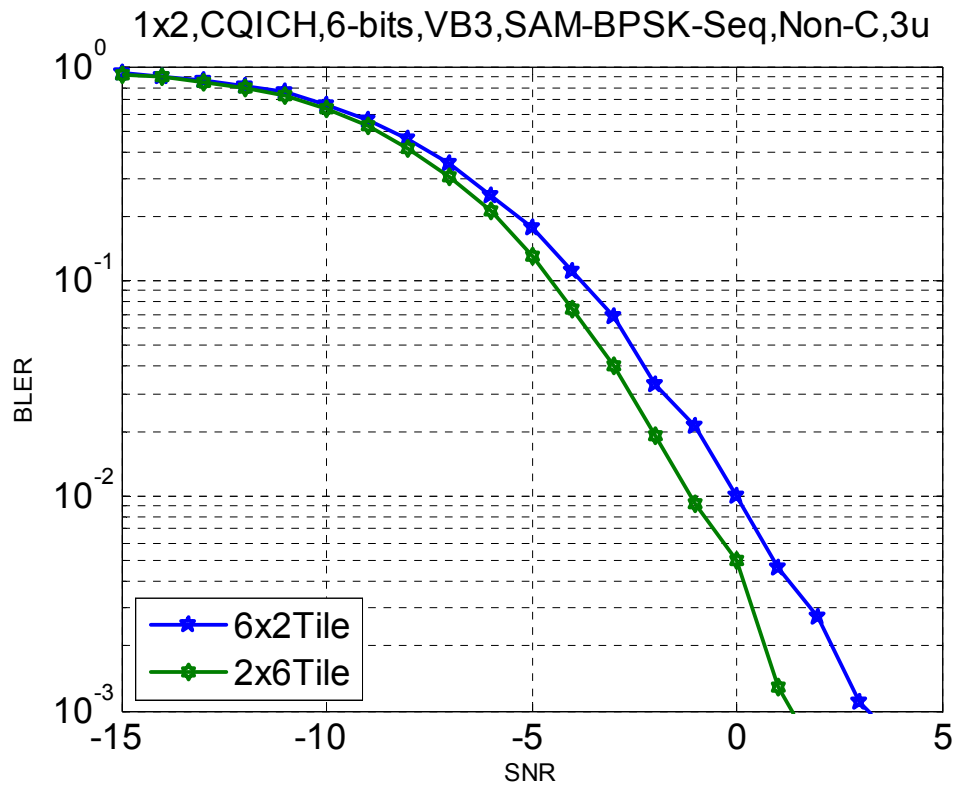


- ❑ MOT design avoids interference floor at high speed
- ❑ 2x6 design results can be further improved with more advanced receiver

CQICH Performance 3

□ VB3

□ HT3



Performance Comparison

- ❑ Non-coherent (BPSK) vs Coherent (QPSK) w/ CDM
 - Non-coherent (BPSK) is about 1dB better in SNR per info bit
 - Coherent (QPSK) w/ CDM provides 33% more user capacity
 - ~1.25 dB gain over non-coherent design
 - Further, Coherent (QPSK) w/ CDM supports 72 sequences vs 64 sequences in non-coherent (BPSK)

2x6 vs 6x2

- ❑ All 2x6 design can be adapted for 6x2 tile structure
- ❑ 2x6
 - Advantages
 - Same tile structure for both green field & legacy modes
 - Disadvantage
 - Performance degradation in extreme high speed (350 kmph)
- ❑ 6x2
 - Advantages
 - Better performance in extreme high speed (350 kmph)
 - Disadvantages
 - Require a new tile structure for legacy mode → Complicate 16m design
 - Possibly 4x3 or 4x6
 - Performance degradation in high delay spread channels

High Speed vs High Delay Spread

- ❑ High speed impact
 - 350kmph, 2.6 GHz $\rightarrow f_d=843$ Hz \rightarrow coherence time $\sim 1/f_d=1.3$ ms
 - 6 OFDM symbols $\rightarrow 0.62$ ms
 - High speed channel degrades 2x6 performance
- ❑ High delay spread impact
 - Some fading channels (e.g. Veh-B, COST 259 HT) have delay spread up to 10 to 20 μ s
 - Channel models are not in 16m EVM, but well-known in real world
 - Ped-B, Veh-A have only delay spread up to 3~4 μ s
 - 16m CP 11.4 μ s
 - DS 10 μ s \rightarrow coherence frequency $\sim 1/DS=100$ kHz
 - 6 subcarriers $\rightarrow 65.6$ kHz
 - High delay spread channel may degrade 6x2 performance

HARQ Feedback Channel

LTE ACK/NACK Overhead

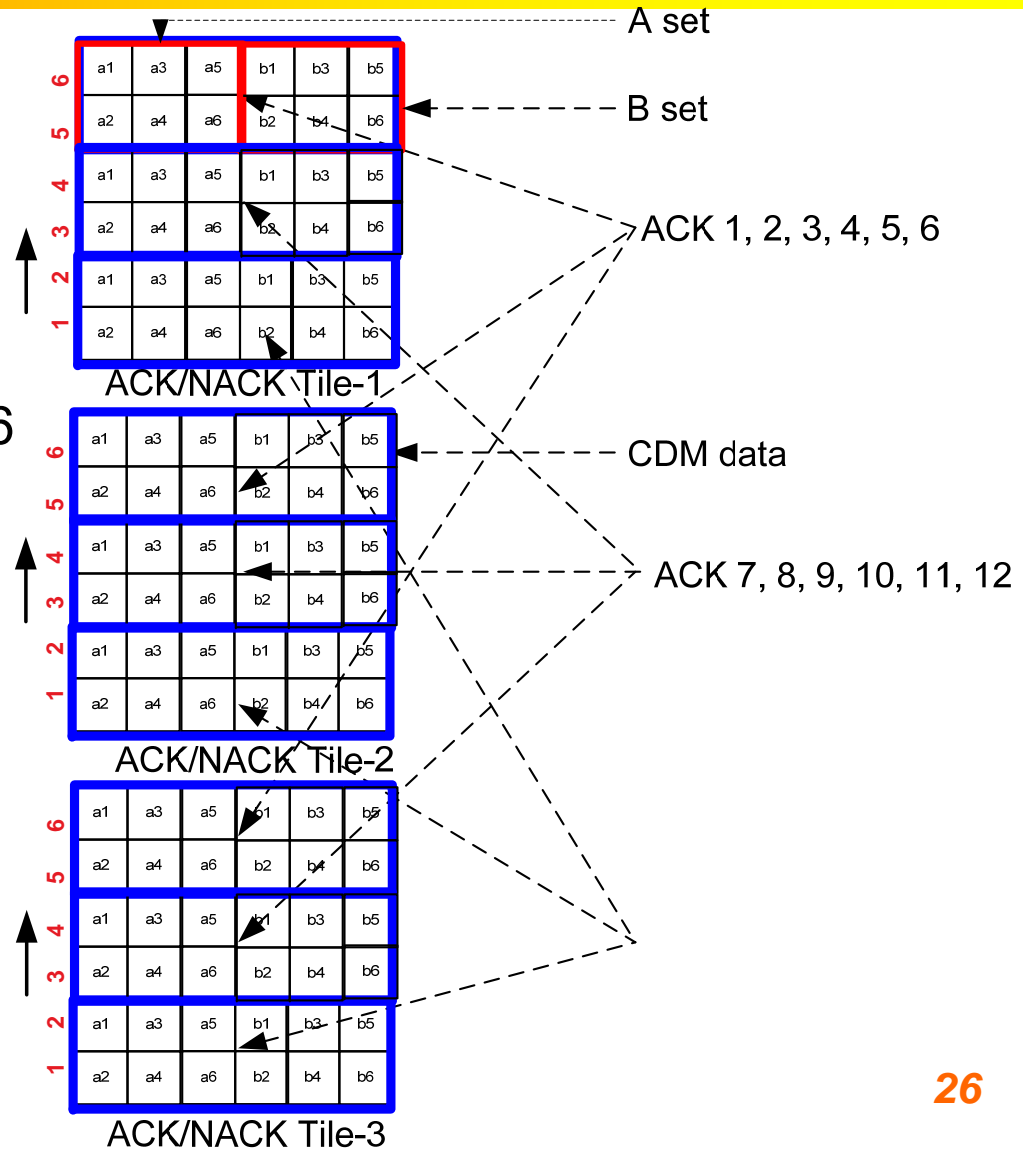
- ❑ ACK/NACK allocation size (minimum unit)
 - 12 subcarriers by 14 symbols (1ms)
- ❑ ACK/NACK load
 - 18 ACK/NACK channels by CDM
- ❑ **ACK/NACK overhead: 9.3 tones/ACK/NACK channel**

16m ACK/NACK Design

- ❑ 1 PRU (3 distributed tiles) shared by 18 ACK/NACK
 - Data subcarriers are shared using CDM
 - CDM has link budget advantage over TDM/FDM
 - ACK/NACK overhead: 9 tones/ACK/NACK channel
- ❑ To improve coverage, the tiles are allocated “time first”
 - Tile hopping in different subframes
 - Details in the next slides
- ❑ ACK/NACK can also be transmitted with data
- ❑ Support non-coherent detection on ACK/NACK channel

16m ACK/NACK Control Tile

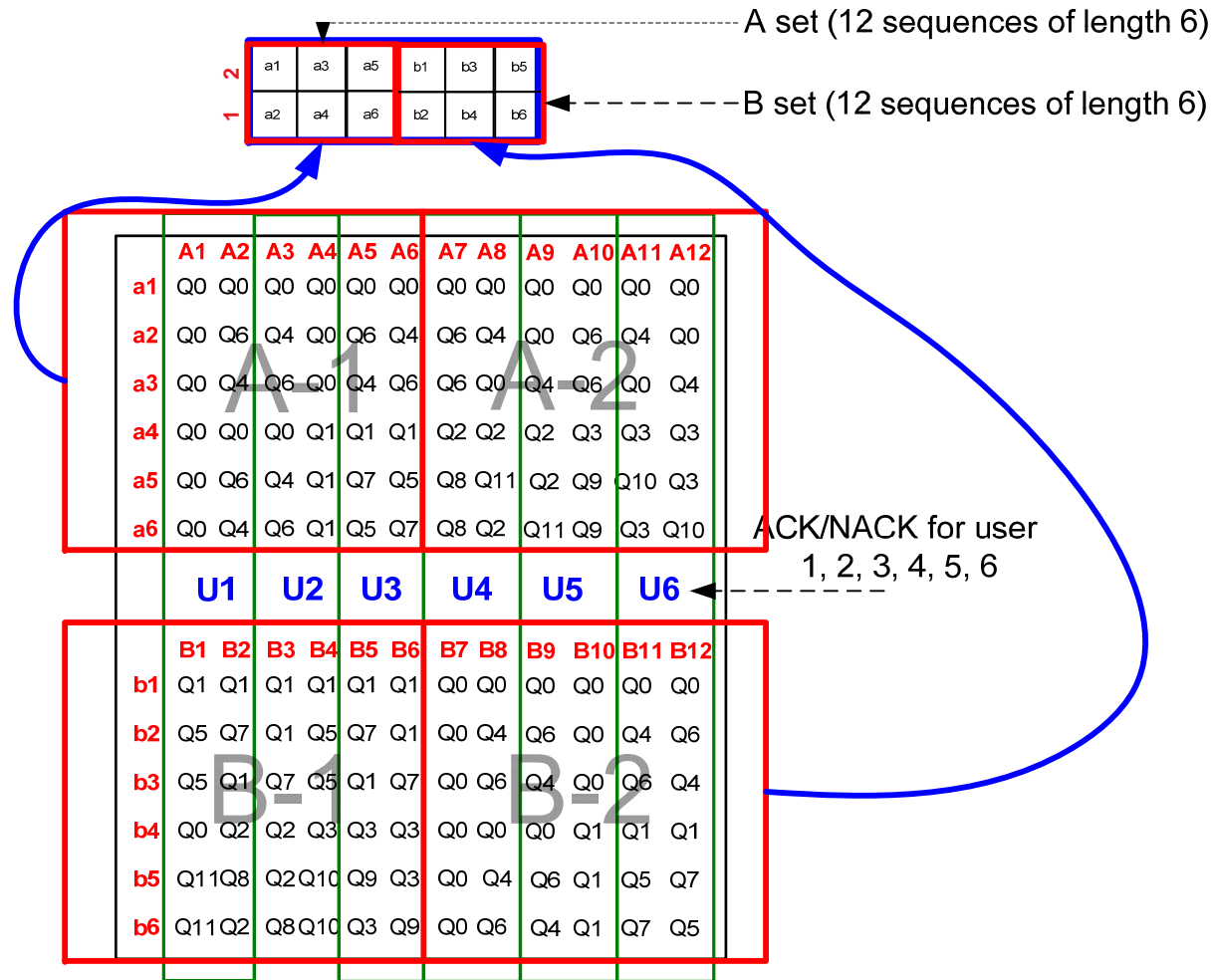
- ❑ Non-coherent detection
- ❑ 1 control PRU shared by 18 ACK/NACK channel
- ❑ Each FMT (2x6) consists of two 2x3 blocks
- ❑ Each 2x3 block is shared by 6 ACK channels with CDM
 - 1st 2x3 block contains a sequence from set A
 - 2nd 2x3 block contains a sequence from set B
- ❑ 3 FMTs are spread in frequency for diversity



Sequence and Symbol Mapping

- For partially loaded cells users are allocated sequences in order from **U1** to **U6**
- Each user has two sequences: ACK & NACK

$$\begin{aligned}
 Q_0 &= 1 \\
 Q_1 &= -1 \\
 Q_2 &= j \\
 Q_3 &= -j \\
 Q_4 &= \exp(-j2\pi/3) \\
 Q_5 &= \exp(j\pi/3) \\
 Q_6 &= \exp(2\pi/3) \\
 Q_7 &= \exp(-j\pi/3) \\
 Q_8 &= \exp(-j5\pi/6) \\
 Q_9 &= \exp(j\pi/6) \\
 Q_{10} &= \exp(j5\pi/6) \\
 Q_{11} &= \exp(-j\pi/6)
 \end{aligned}$$

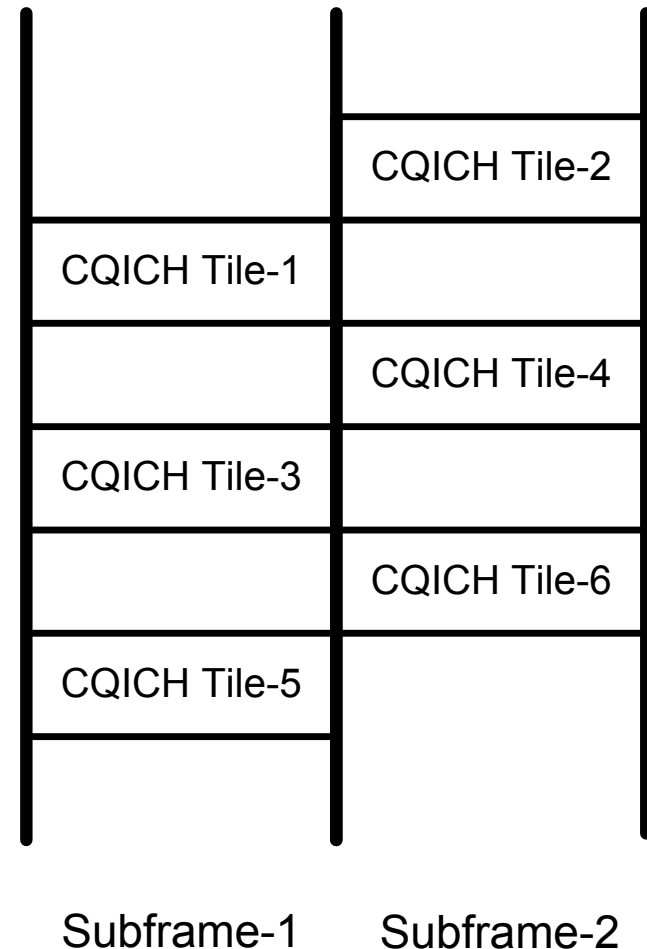


Cross sequence interference

- ❑ Twelve 12-symbol sequences to transmit ACK/NACK for up to 6 users
 - E.g. Two sequence in U1, ACK/NACK for user-1
- ❑ Low cross sequence interference for slow-fading channel
 - Twelve sequences are mutually orthogonal
- ❑ Low cross sequence interference for fast-fading channel
 - Four sets of orthogonal 6-symbol sequences (A-1, A-2, B-1, B-2)
 - Cross interference between any pair of sequences from A-1 and A-2 is low
 - Cross interference between any pair of sequences from B-1 and B-2 is low
 - Only requires channel to be time-coherent over 3 OFDM symbol-time
 - Robust design for high speed MS
- ❑ Users should be allocated in the order from U1 to U6 to minimize the cross user interference for high speed MS

16m ACK/NACK Control Tile Allocation

- ❑ 3 control tiles are allocated for each control PRU
- ❑ Tiles are allocated time-first
 - Link budget advantage in taking full advantage of MS tx power
 - Improved coverage



16m ACK/NACK Detection

- ❑ ACK: packet has been received correctly
- ❑ NACK: packet has been received, but incorrectly
- ❑ DTX: DL allocation signal might be missed by MS, or MS ACK/NACK signal is missed

Support Subframe Bundling

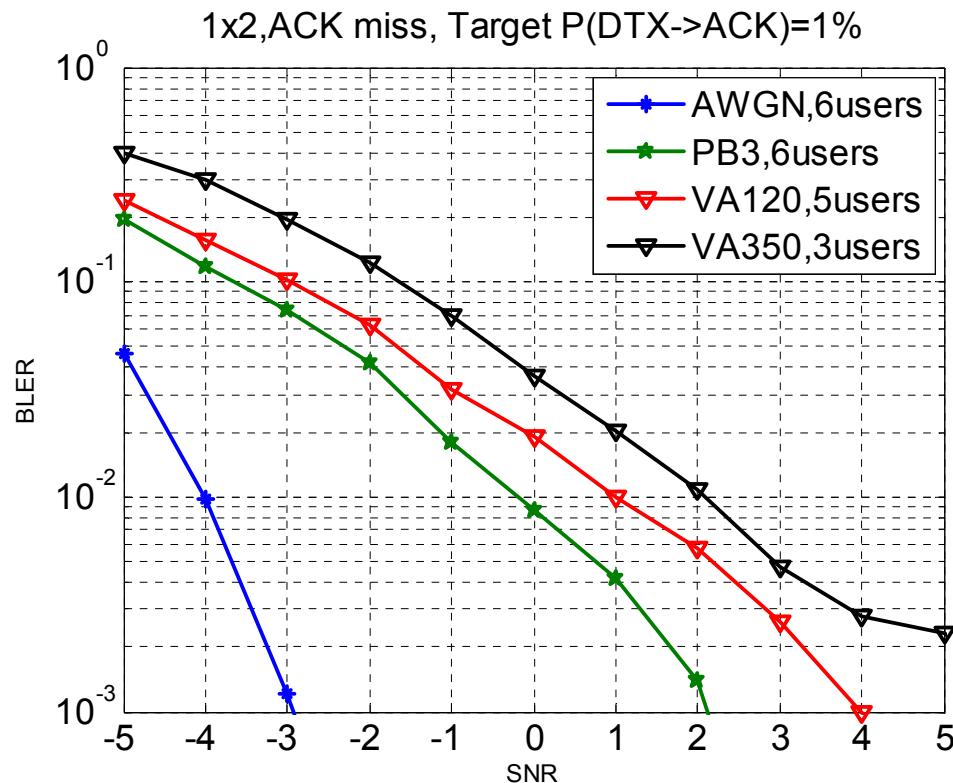
- ❑ Multiple DL subframes can be bundled together
- ❑ One ACK/NACK is assigned for each DL allocation across the bundled subframes
 - One allocation corresponds to one DL allocation message
 - 1-bit for SCW
- ❑ Location of ACK/NACK is indicated in DL resource allocation → DL allocation index
 - ACK/NACK for persistent allocation should be allocated before regular allocations
 - DL allocation index should include number of persistent allocations

Link Simulation Parameters

Parameter	Value
NFFT	1024
Carrier frequency	2.6 GHz
# Tx antennas	1
# Rx antennas	2
Antenna spacing	4 λ
Receiver	correlator for ACK
Channel model	PB3, VA120, VA350

ACK performance

ACK miss

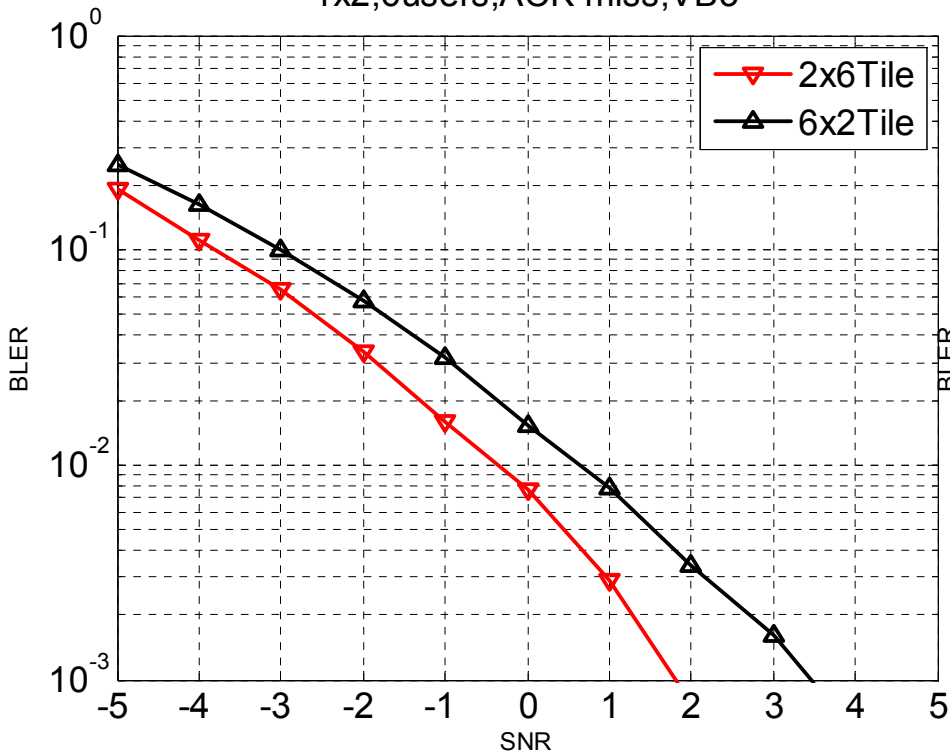


- ❑ MOT design avoids interference floor at high speed
- ❑ Performance can be further improved with more advanced receiver

ACK performance

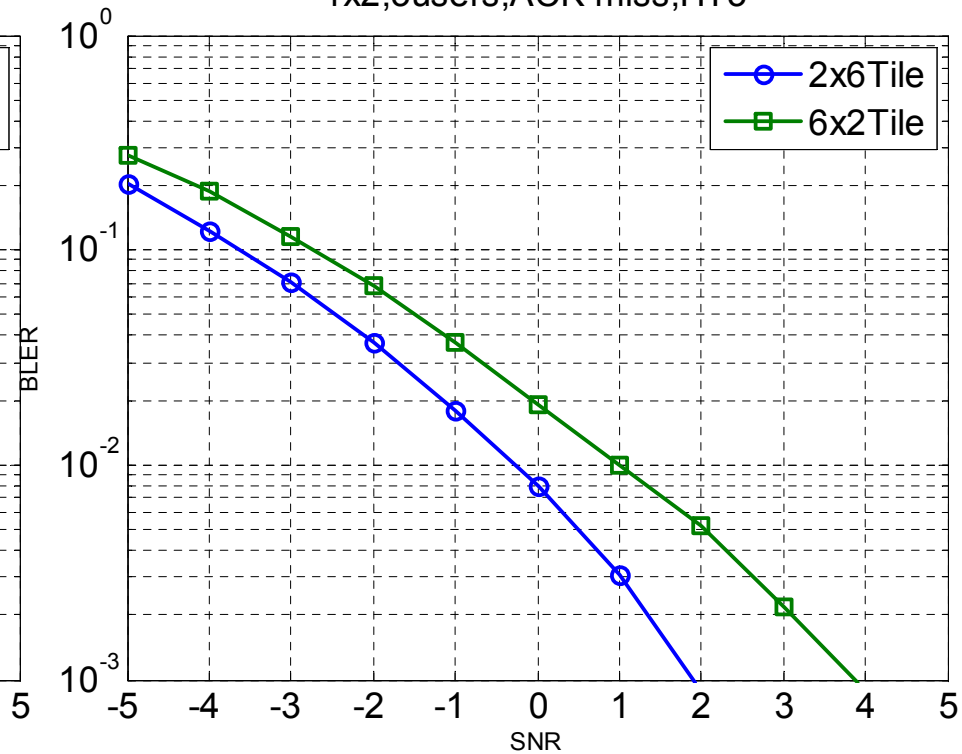
□ VB3

1x2,6users,ACK miss,VB3



□ HT3,3users

1x2,3users,ACK miss,HT3



Performance Summary

- ❑ In general agreement of using non-coherent design for ACK/NACK
- ❑ Proposed complex sequences have minimum cross user interference at high speed
 - Orthogonal over 2×3 block if less than 3 users
 - Slight increasing of cross user interference if more than 3 users

Bandwidth Request Indicator Channel

16m Bandwidth Request Channel Design

- ❑ Bandwidth request channel prefer to have same PHY structure for green field mode (16m only) and legacy mode (FDM with legacy UL PUSC)
 - Simplify transmitter and receiver design w/o too many operation modes and configurations
 - Same design philosophy as UL fast feedback channel and HARQ feedback channel
- ❑ Bandwidth request indicator is transmitted using a similar control channel structure as UL HARQ feedback (slide-17)
- ❑ 12 users per 2x6 tile is supported to transmit 1-bit/user BWR indicator