Physical Structure of UL Feedback Channels

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None

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

Physical Structure of UL Feedback Channels

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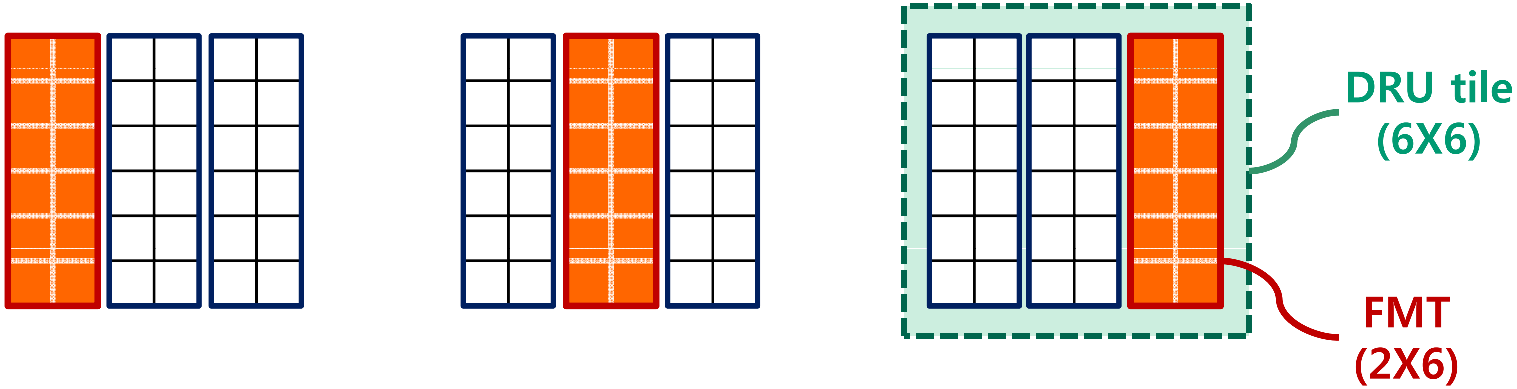
Outline

- **Uplink Feedback Mini-tile (UL FMT)**
- **Semi-orthogonal Sequence for Fast Feedback Channel (UL FBCH)**
- **How to support MIMO feedback**
- **HARQ Feedback Channel (UL ACKCH)**

Feedback Mini-Tile (FMT)

- **Resource Structure of FMT**
  - 1 DRU tile can accommodate 3 FMTs
  - 1 PRU can accommodate 3 Fast Feedback Channels



- **Advantages of FMT**
  - Consists of 12 subcarriers
  - Easy to apply various **(semi-) orthogonal sequences** for non-coherent detection
  - Occupies only half resources of 16e fast feedback CHs
  - Can be used for both Fast feedback CHs and HARQ feedback CHs

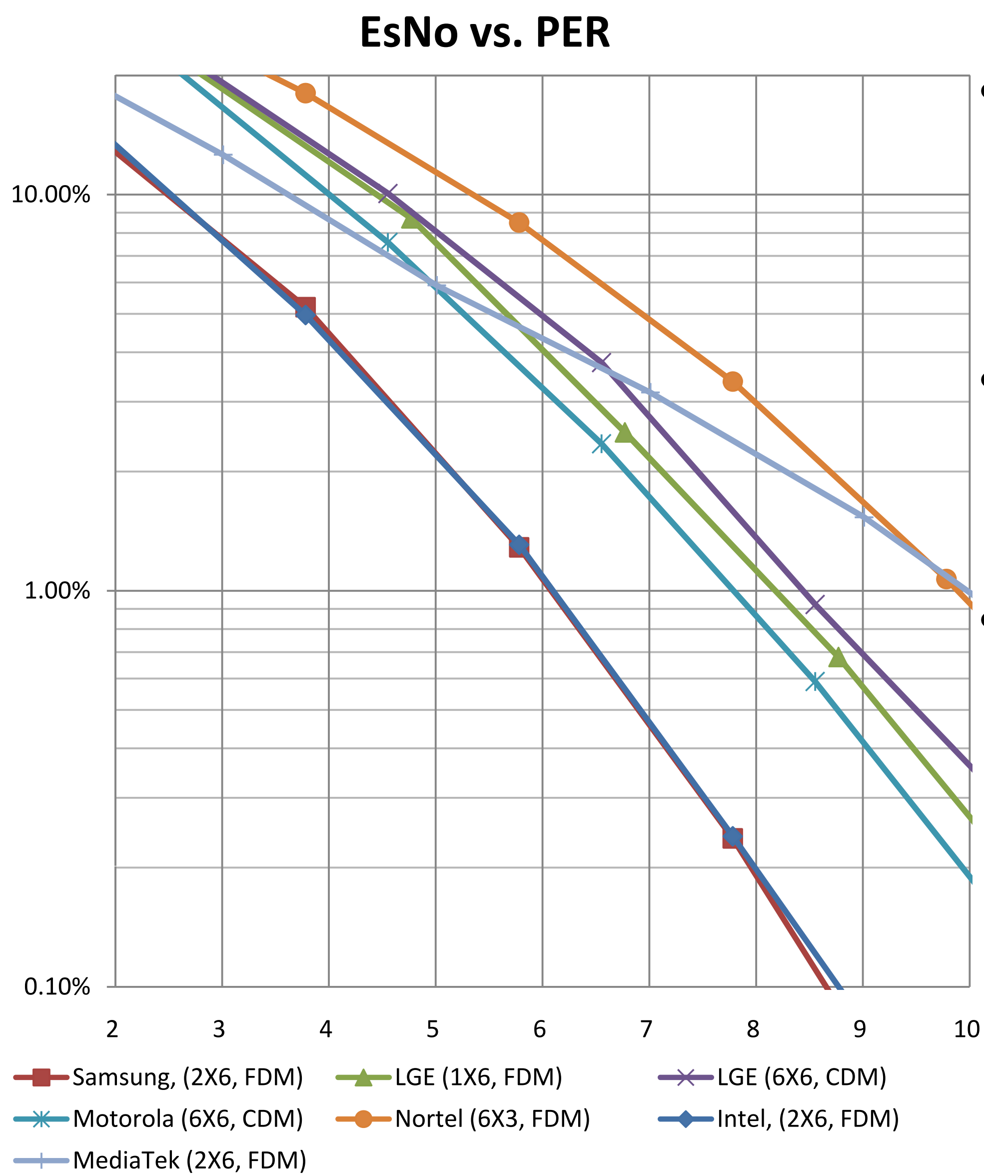
Semi-orthogonal Sequence for UL FBCH

- **Objective**
  - Can be detected **w/o pilots**
  - Minimize cross-correlation between different sequences
- **How to generate semi-orthogonal sequence**
  - Refer to Appendix 1
- **Properties of Proposed Sequence**
  - Maximum cross-correlation ≤ 4,
  - Number of Codewords is **64 (= 6 bits)**
- **Benefits of Semi-orthogonal Sequence**
  - Operable at low target CNR w/o CH. estimation error
  - Fully exploiting frequency diversity
  - Optimal ML detector is a bank of binary correlators

Comparison Summary of UL FBCH

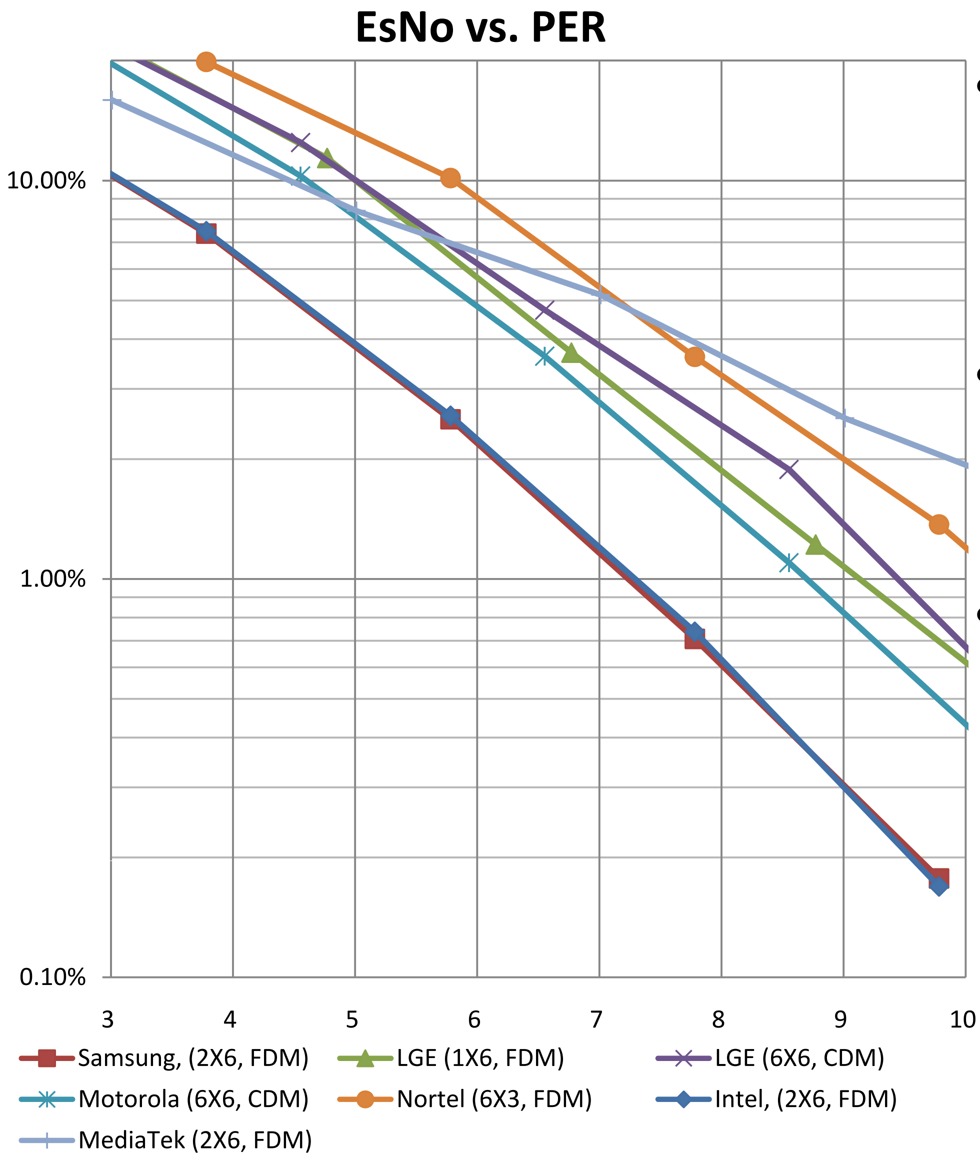
UL FBCH	#982 (Samsung)	#919[4] (Motorola)	#1071[5] (Nortel)	#927[6] (LGE)	#937[7] (Intel)	#1037[8] (MediaTek)
FMT size	(2X6)	(6X6)	(6X3)	(1X6), (6X6)	(2X6)	(2X6)
MUX	FDM	CDM	FDM	FDM, CDM	FDM	FDM
Detection	Non-Coherent	Coherent	Both	Coherent	Non-Coherent	Coherent
# of tiles	3	3	2 (or 4, 6)	3	3	variable
Pilots per tile	None (2)	3	2	2	None (2)	2
Channel Coding	Semi-orthogonal	FFS	Block Code	Block Code	Semi-orthogonal	CC
(Minimum) inform. bits	6	FFS	4~5	5	4~5	5
# of FBCHs per PRU	3	4	4	6	3	9

Detection Performance of UL FBCH



- **EsNo vs. PER**
  - For fair comparison between different tile sizes
  - 5 bits of information bits
- **Simulation Condition**
  - **Ped B 3km**, 2Rx
  - ML detection, No erasure
- **Analysis**
  - Semi-orthogonal sequence on (2X6) is best
  - Performance gap : more than **1.8dB** @1% PER
  - **CH estimation error** degrades coherent detection
  - CDMed Fast FBCHs suffer from **multi-user interference**

Detection Performance of UL FBCH

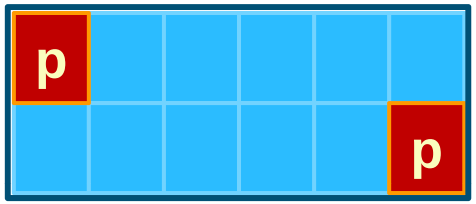


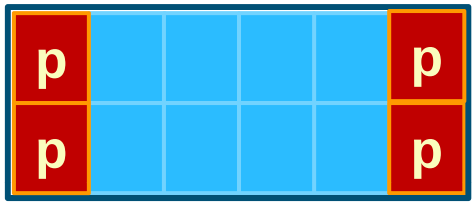
- **EsNo vs. PER**
  - For fair comparison between different tile sizes
  - 5 bits of information bits
- **Simulation Condition**
  - **Veh A 120km**, 2Rx
  - ML detection, No erasure
- **Analysis**
  - Semi-orthogonal sequence on (2X6) is best
  - Performance gap : more than **1.5dB** @1% PER
  - **CH estimation error** degrades coherent detection
  - CDMed Fast FBCHs suffer from **multi-user interference**

UL Enhanced FBCH

- **Why Enhanced Feedback Channel (Enhanced FBCH)?**
  - More information bits for CL-MIMO feedback
  - [Option 1] Multiple FBCHs
  - [Option 2] Link adaptation of Fast FBCH
    - **Low indication/signaling overhead**

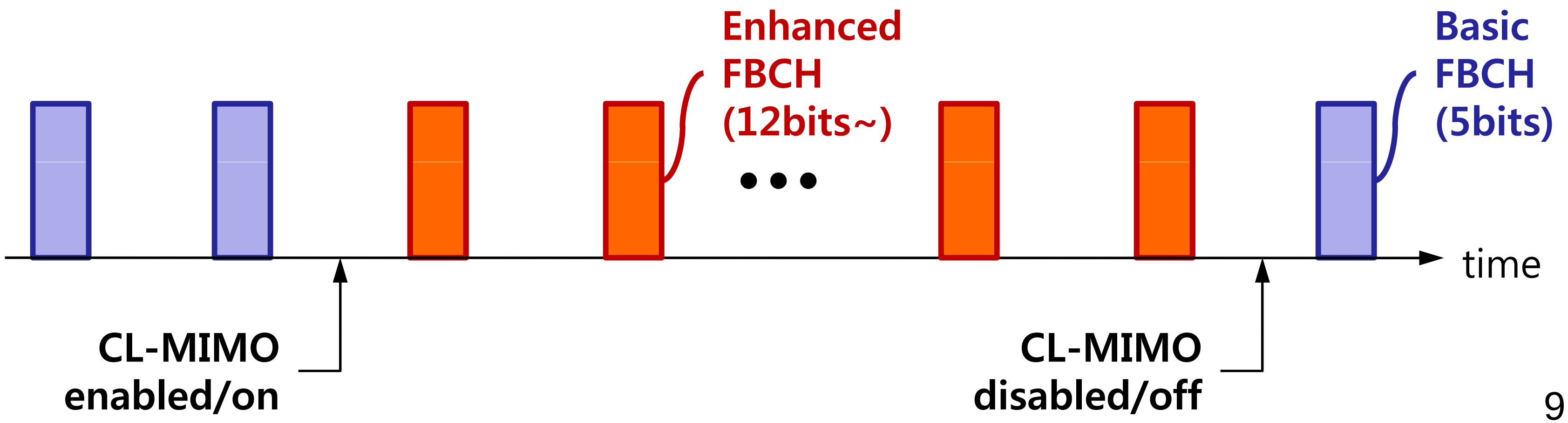
- **Physical Structure of Enhanced FBCH**
  - QPSK modulation on each tile with 2 (or 4) pilots
  - Block Code / Tail-Biting CC
  - Number of Information bits : More than 12 (Max 24 bits)
  - Code rate : 1/5 ~ 1/2





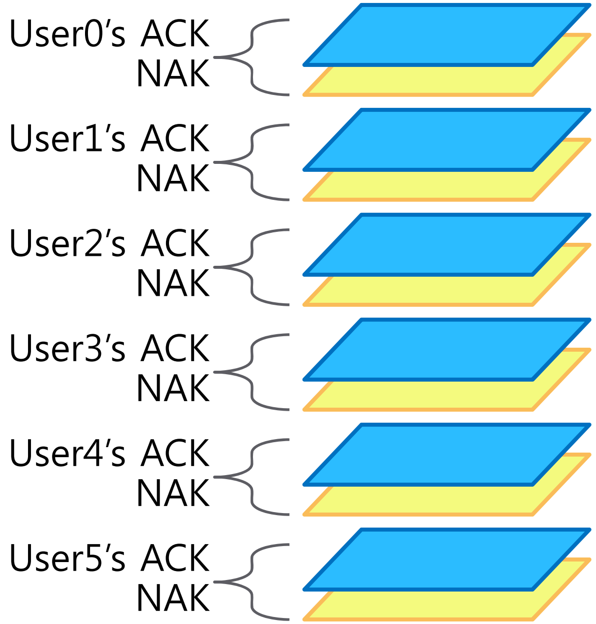
Link Adaptation of Fast FBCH

- **(Basic) Feedback Channel**
  - [6bits] Can support SIMO, OL-MIMO, and Beam-forming
- **Enhanced Feedback Channel**
  - [12bits~] Can fully support CL-MIMO, band selection operation, etc
- **Switch from basic FBCH to Enhanced FBCH**
  - Depend on **MS's DL transmission scheme**, not on short-term fading
  - Basic FBCH can be regarded as a special MCS of Enhanced FBCH
  - High Bandwidth Efficiency, Low indication/signaling overhead



HARQ Feedback CH (UL ACKCH)

- **Orthogonal Sequence**
  - 12 Orthogonal Sequences
  - 3 times repetition on 3 FMTs
- **Code Division Multiplexing**
  - High spectral efficiency
  - 1 PRU can accommodate 18 ACKCHs
- **Rationale for UL FMT with size (2X6)**
  - Better frequency diversity
  - FMTs are used for both UL FBCHs and UL ACKCH
    - **Low signaling overhead, Little resource waste**
  - A large CDM tile may introduce severe interference to neighboring cells
  - Multi-user interference by frequency/time selectivity



Overhead Comparison Example

- **Assumption for Overhead Calculation**

Active Users	100	
Period of FBCH	4	= superframe
Period of ACKCH	1	Every frame

Channel BW	10	[MHz]
DL/UL ratio	4:4	
# of PRUs in a frame	192	

- **Feedback Channel's Overhead**

	Samsung	#919 (Motorola)	#927 (LGE)	#937 (Intel)	#1071 (Nortel)	16e's
# of FBCHs per PRU	3	4	6	3	3	1.5
# of ACKCHs per PRU	18	12	18	18	24	3
Required PRUs	14	16	11	14	13	50
Overhead Ratio	7.3%	8.3%	5.7%	7.3%	6.8%	26.0%

- Proposed FBCHs and ACKCHs can share one PRU
- Overhead of all cases are small enough (only except 16e's feedback channels)

Summary

- **Tile Structure for UL Feedback Channel (2X6)**
  - Suitable for fast FBCH, enhanced FBCH, and HARQ feedback
- **Semi-orthogonal sequence**
  - Best performance for small number of bits at low SNR
- **Multiplexing of multiple feedback Channels**
  - CDM is not suitable for fast FBCH but for UL ACKCH
- **How to support MIMO feedback**
  - Link Adaptation from basic fast FBCH to enhanced FBCH

Feedback CH	Resource	Key Features / Issues	Comment
UL basic FBCH	3 FMTs	- Semi-orthogonal sequences - 6bits information	Non-coherent
UL enhanced FBCH	3 FMTs	- Coherent Detection - Switched from UL basic FBCH	
UL ACKCH	3 FMTs	- CDM for 6 users	

Text Proposal for UL Control Channel (i)

Insert the following text into Physical Layer Clause (i.e. Chapter 11 in [3]):

------------------------------------ Text Start --------------------------------

11.9.2.1 UL Fast Feedback Channel

11.9.2.1.1 Multiplexing with other control channels and data channels

The UL fast feedback channel carries one or more types of fast feedback information. ~~The use of TDM/FDM or CDM to multiplex fast feedback channels from one or more users is FFS.~~ The UL fast feedback channel is multiplexed in FDM manner among multiple users.

11.9.2.1.2 PHY structure

The transmission format of the fast feedback channel can be adaptive. The transmission format depends on feedback information type.

------------------------------------ Text End --------------------------------

Text Proposal for UL Control Channel (ii)

Insert the following text into Physical Layer Clause (i.e. Chapter 11 in [3]):

---------------------------------- Text Start ---------------------------------

11.9.2.1 UL Fast Feedback Channel

11.9.2.1.2 PHY structure

~~The structure of the resource blocks, pilots and resource mapping for the UL fast feedback channel are TBD.~~

A fast feedback channel occupies 3 UL feedback mini-tiles (UL FMTs), which are chosen from different UL DRUs for frequency diversity. Each UL FMT is defined as 2 contiguous subcarriers by 6 OFDM symbols.

Twelve tones on each FMT are BPSK modulated using semi-orthogonal sequence in Table X.

[add the table in appendix 2 of this contribution]

---------------------------------- Text End ----------------------------------

Text Proposal for UL Control Channel (iii)

Insert the following text into Physical Layer Clause (i.e. Chapter 11 in [3]):

------------------------------------ Text Start ------------------------------------

11.9.2.2 UL HARQ Feedback Channel

11.9.2.1.2 PHY structure

~~The structure of the resource blocks, pilots and resource mapping for the UL fast feedback channel are TBD.~~

UL HARQ feedback channel consists 3 UL feedback mini-tiles (UL FMTs), which are chosen from different UL DRUs for frequency diversity. Each UL FMT is defined as 2 contiguous subcarriers by 6 OFDM symbols.

Six UL HARQ feedback channels are multiplexed onto the same UL FMTs using orthogonal spreading sequences. The sequences for orthogonal spreading are FFS.

------------------------------------ Text End ------------------------------------

References

- [1] IEEE 802.16m-07/002r5, “TGm System Requirements Document (SRD)”
- [2] IEEE 802.16m-08/003r4, “Draft IEEE 802.16m System Description Document”
- [3] IEEE 802.16m-08/004r2, “Project 802.16m Evaluation Methodology Document(EMD)”
- [4] IEEE C802.16m-08/919, “Details of SDD Section 11.9.2.1 Uplink Fast Feedback Channel” (Motorola)
- [5] IEEE C802.16m-08/1071, “Proposed SDD Text for UL Control” (Nortel)
- [6] IEEE C802.16m-08/840, “UL Control Structure and Fast Feedback channel Structure” (LGE)
- [7] IEEE C802.16m-08/937, “Proposal for IEEE802.16m CQI Feedback Channel Design” (Intel)
- [8] IEEE C802.16m-08/1037, “PHY Structure for UL Fast Feedback Channel in 802.16m Systems” (MediaT다)

[Appendix 1]

How to generate Semi-Orthogonal Sequence

[Step 1] Subsequence : Hadamard sequence with length 4

$$\mathbf{u}_0 = \{+1,+1,+1,+1\},\ \mathbf{u}_1 = \{+1,+1,-1,-1\},\ \mathbf{u}_2 = \{+1,-1,+1,-1\}\ \ \mathbf{u}_3 = \{+1,-1,-1,+1\}$$

[Step 2] Combination of Subsequences (by Reed-Solomon)

$$\left\{\begin{array}{l}\mathbf{u}_0\mathbf{u}_0\mathbf{u}_0,\ \mathbf{u}_0\mathbf{u}_1\mathbf{u}_2,\ \mathbf{u}_0\mathbf{u}_2\mathbf{u}_3,\ \mathbf{u}_0\mathbf{u}_3\mathbf{u}_1,\ \mathbf{u}_1\mathbf{u}_2\mathbf{u}_0,\ \mathbf{u}_2\mathbf{u}_3\mathbf{u}_0,\ \mathbf{u}_3\mathbf{u}_1\mathbf{u}_0,\ \mathbf{u}_2\mathbf{u}_0\mathbf{u}_1, \\ \mathbf{u}_3\mathbf{u}_0\mathbf{u}_2,\ \mathbf{u}_1\mathbf{u}_0\mathbf{u}_3,\ \mathbf{u}_1\mathbf{u}_3\mathbf{u}_2,\ \mathbf{u}_2\mathbf{u}_1\mathbf{u}_3,\ \mathbf{u}_3\mathbf{u}_2\mathbf{u}_1,\ \mathbf{u}_1\mathbf{u}_1\mathbf{u}_1,\ \mathbf{u}_2\mathbf{u}_2\mathbf{u}_2,\ \mathbf{u}_3\mathbf{u}_3\mathbf{u}_3\end{array}\right\}$$

[Step 3] Phase-difference vector : Extension to Bi-orthogonal sets

$$\mathbf{u}_0\mathbf{u}_0\mathbf{u}_0 \Rightarrow \begin{cases} +\mathbf{u}_0,+\mathbf{u}_0,+\mathbf{u}_0 \\ +\mathbf{u}_0,-\mathbf{u}_0,+\mathbf{u}_0 \\ +\mathbf{u}_0,+\mathbf{u}_0,-\mathbf{u}_0 \\ +\mathbf{u}_0,-\mathbf{u}_0,-\mathbf{u}_0 \end{cases},\quad \mathbf{u}_0\mathbf{u}_1\mathbf{u}_2 \Rightarrow \begin{cases} +\mathbf{u}_0,+\mathbf{u}_1,+\mathbf{u}_2 \\ +\mathbf{u}_0,-\mathbf{u}_1,+\mathbf{u}_2 \\ +\mathbf{u}_0,+\mathbf{u}_1,-\mathbf{u}_2 \\ +\mathbf{u}_0,-\mathbf{u}_1,-\mathbf{u}_2 \end{cases},\quad \cdots$$

Total Number of CWs : 4(step1)X4(step2)X4(step3) = 64 (6bits)

[Appendix 2]

Amount of MIMO Feedback Information

- **Assumptions on Information Contents**
  - DL transmission scheme : LLRU CL-MIMO
  - Absolute CQI: 5 bits, Differential CQI: 2bits
  - The number of reported subbands : 3

				SU-SCW	SU-MCW (2layer)	MU
Contents	Long period	Subband indication		12	12	12
		Subband CQI	Type	abs	abs + diff	abs
			Bit	5	5 + 3	5
		rank		2	2	x
		Total bits		33	42	27
	Short period	Subband CQI	Type	diff	diff	diff
			Bit	2	2 x 2	2
		PMI		2~4	2~4	2~3
		Total bits		12~18	18~24	12~15