WiBro 물리 계층과
성능개선을 위한 다중안테나 기술

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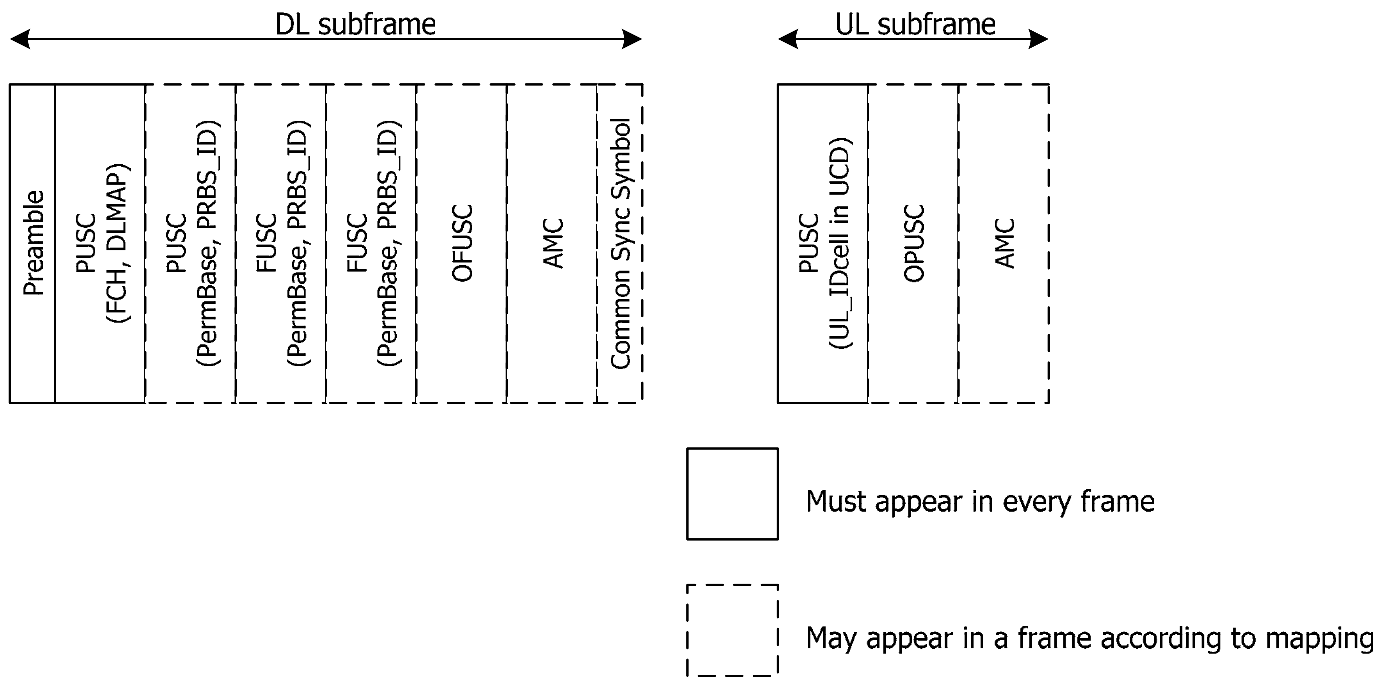
물리계층 계관

- Cellular based portable Internet system
  - Frequency reuse factor 1 이상
- OFDMA system
- TDD system
- Advanced FEC
  - CTC
- H-ARQ
- High order modulation
- Smart ANT support
  - Range Extension
  - SDMA
- STC/MIMO support
  - Open loop (STC, Spatial multiplexing)
  - Closed loop (ANT grouping/selection, Precoding)

시스템 파라미터

Parameter	Value
System Bandwidth	10 MHz
Sampling frequency	10 MHz
Number of used tones (OFUSC)	864 out of 1,024
Number of data tones (OFUSC)	768
Number of pilot tones (OFUSC)	96
Tone spacing	9.765625 kHz
Signal bandwidth	8.447 MHz
Cyclic prefix	1/8
Basic OFDMA symbol time	102.4 μs
Cyclic prefix time	12.8 μs
OFDMA symbol time	115.2 μs
TDD frame length	5 ms
Number of symbols in a frame	42
TTG+RTG	161.6 μs

❑ 프레임 구조



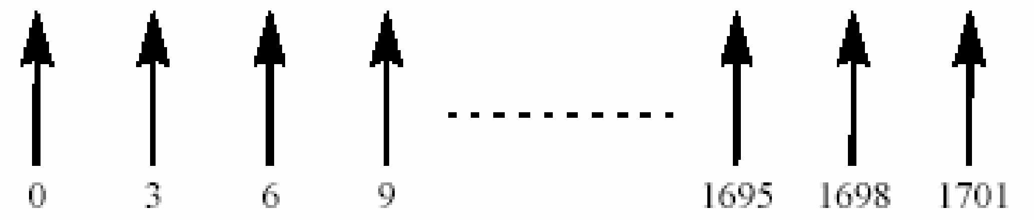
DL / UL Zone switch IE

- DL: symbol offset, length, permutation, PermBase, PRBS_ID, STC type, AMC type

- UL: symbol offset, length, permutation, UL_IDcell, AMC type

❑ 프리앰블

- 3 preamble sets
  - N+3*K



❑ Common synch symbol

- 모든 기지국에서 동일한 위치에 동일한 신호열을 사용

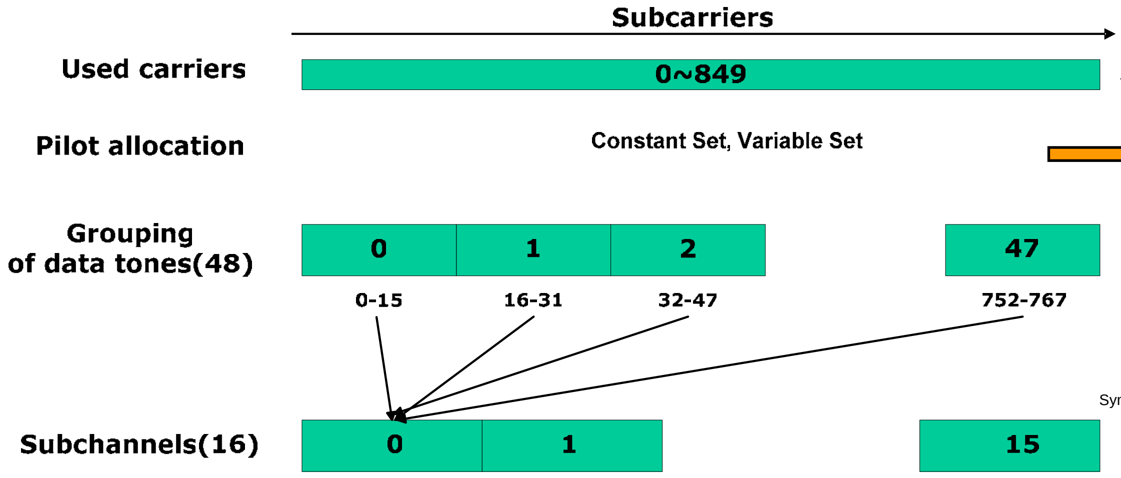
부채널구조 및 특징

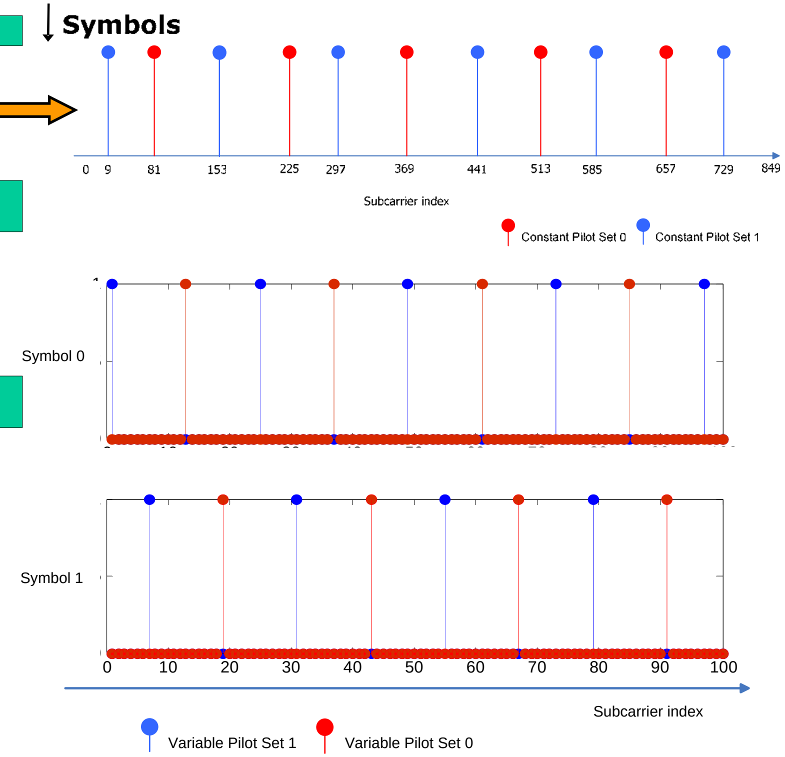
	Freq. Diversity gain	Selection Gain in scheduling	Pilot overhead	AAS 적용 용이성 (DL/UL Symmetry)
DL PUSC	Good	Good	1/8	No symmetry
DL FUSC	Good	Good	~1/11	No symmetry
DL OFUSC	Good	Good	~1/9	No symmetry
UL PUSC	Good	Good	¼	Symmetry with TUSC
UL OPUSC	Good	Good	1/9	Symmetry with TUSC
DL/UL Band AMC	Good in H-ARQ MAP Bad in normal MAP	Better	1/9	Symmetry & Better for beamforming

부채널구조 및 특징

❑ DL FUSC

- ◆ Slot = 1 symbol
- ◆ Construction: 1024기반

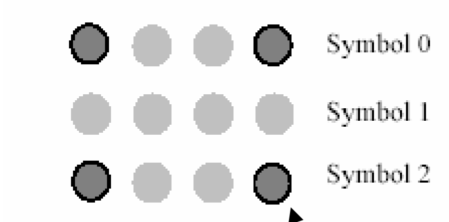


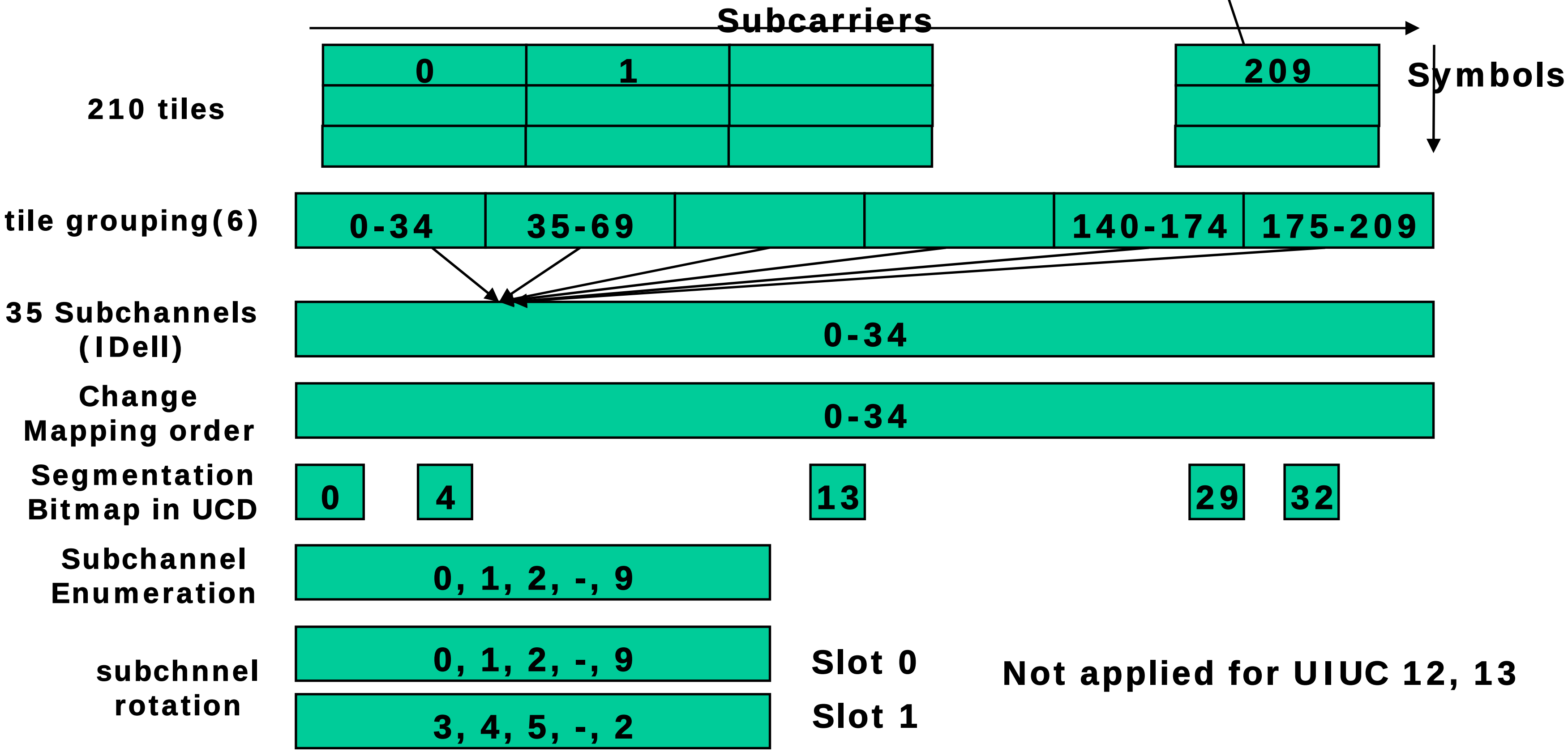


Pilot allocation

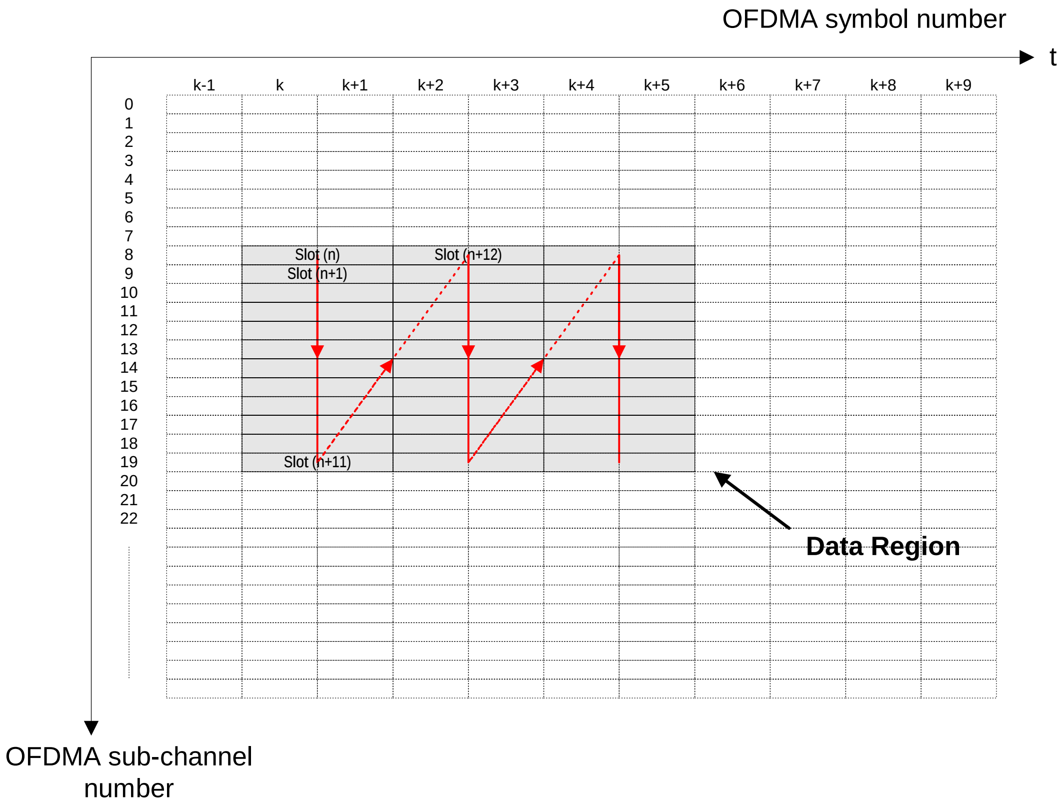
❑ UL PUSC

- Slot = 3 symbols
- Construction: 1024기반





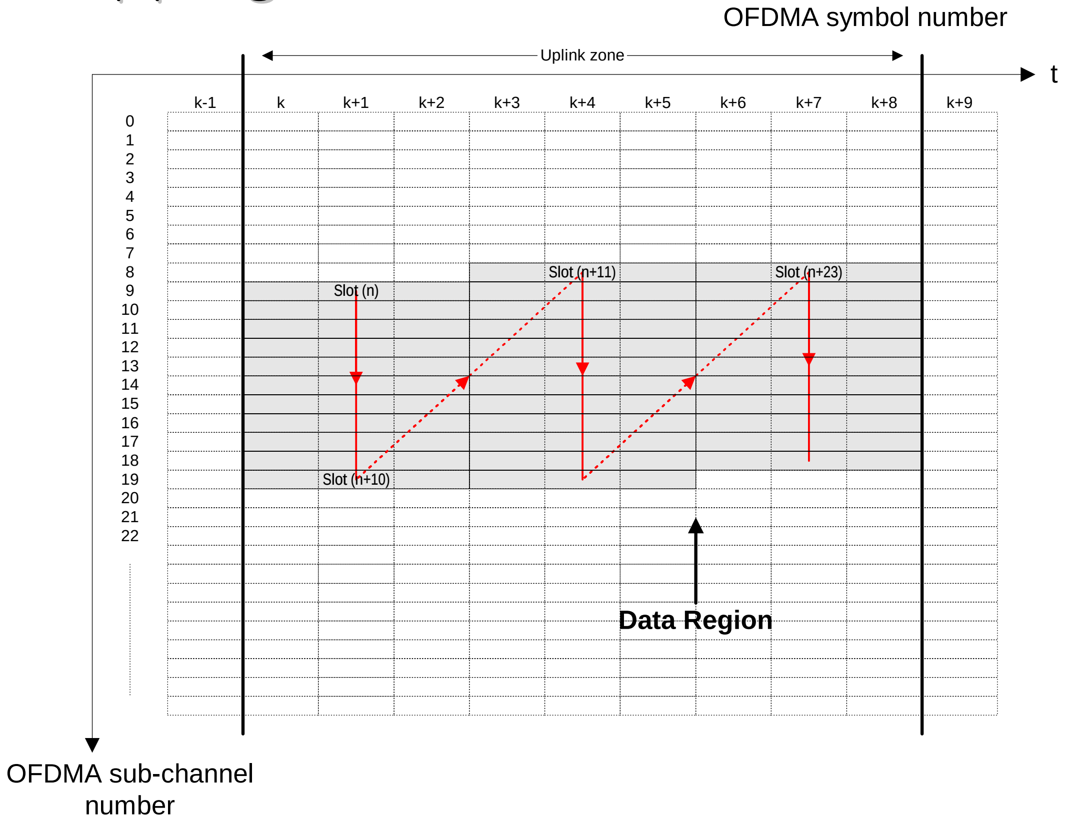
❑ DL data mapping



- **Each slot shall span one or more subchannels in the subchannel axis and two one or more OFDMA symbols in the time axis.**
- **Continue the mapping such that the OFDMA symbol subchannel index is increased.**

데이터 Mapping

❑ UL data mapping



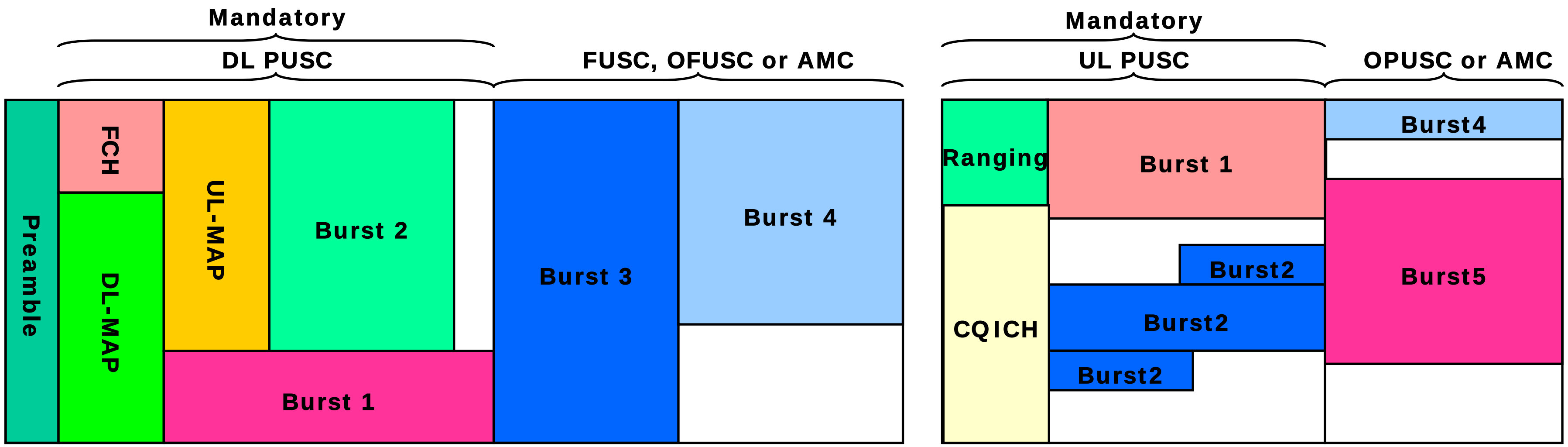
The UL mapping consists of two steps.

A. Step 1 – Allocate OFDMA slots to bursts

B. Step 2 – Map OFDMA slots within the UL allocation.

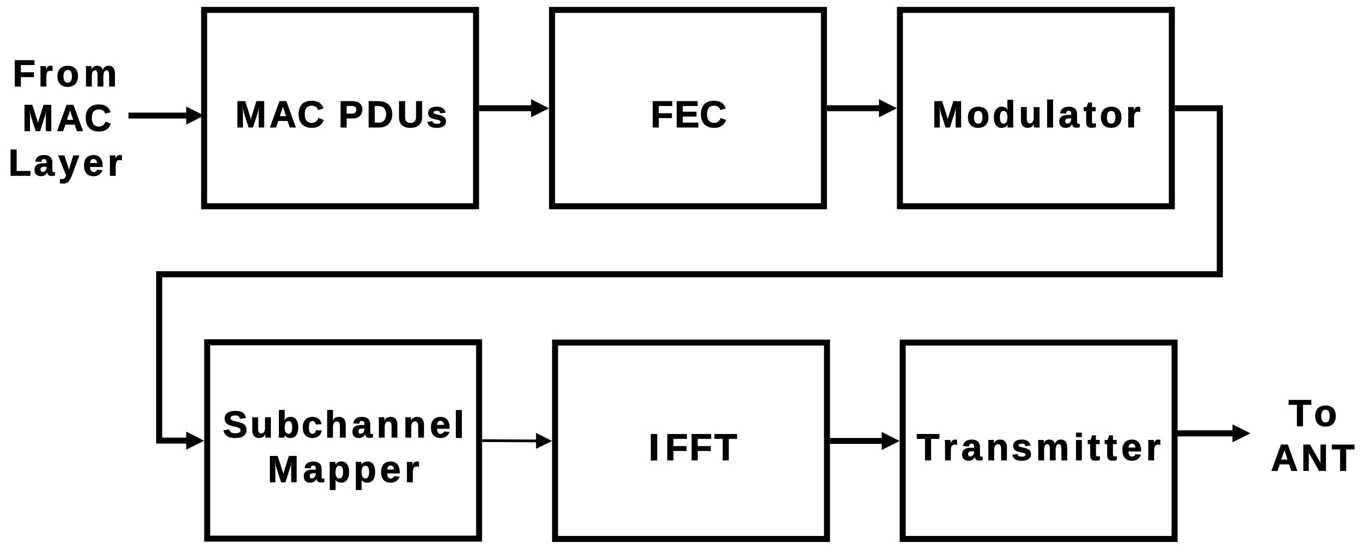
데이터 Mapping

❑ 논리적 프레임 구조



- FCH: 24 bits, 첫번째 PUSC zone 할당정보, MAP 할당정보
- MAP: Burst allocation 정보
- Data bursts: Data or control traffic from/to MAC later

❑ Tx Signal Flow



오류정정부호

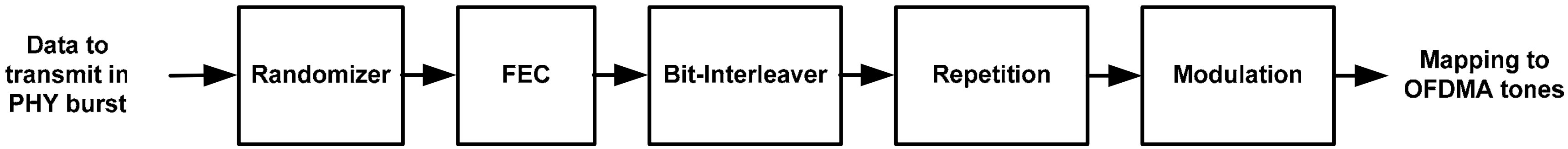
❑ 제공되는 오류정정 부호의 종류

- ◆ Convolution Code (CC)
- ◆ Block Turbo Code (BTC)
- ◆ Convolutional Turbo Code (CTC)
- ◆ Low Density Parity Check code (LDPC)

❑ Coding rate

- ◆ R = 1/12 ~ 5/6
- ◆ R = ¼ 이상은 Repetition coding을 사용한다.

❑ 오류정정부호 signal path



오류정정부호

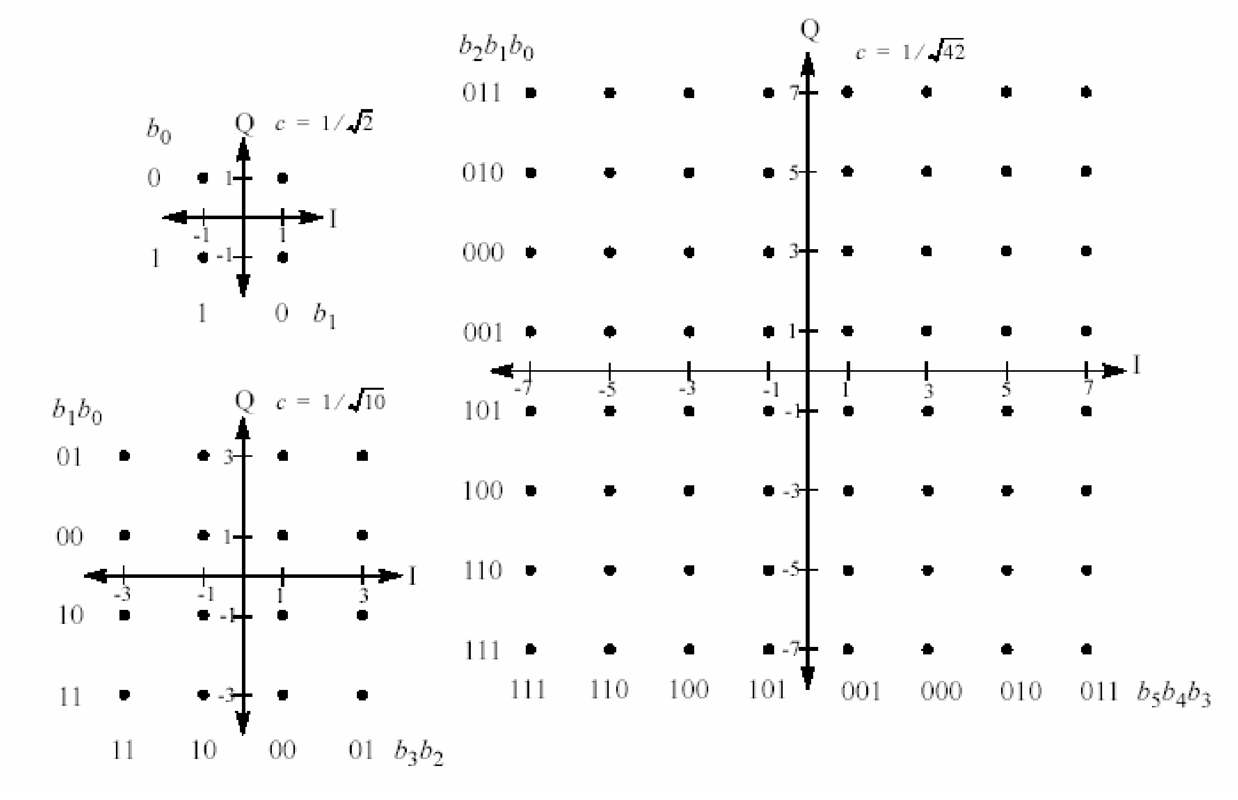
❑ H-ARQ 지원

- Link adaptation mismatch 보상
  - CINR estimation error
  - CINR feedback latency
- Incremental Redundancy Type
  - CTC로만 지원 가능
- Chase combining type
  - 모든 오류정정 부호(CC, BTC, CTC, LDPC)에 대하여 가능
- 단말 당 최대 16개의 H-ARQ 채널 지원
- ACK/NACK feedback
  - Dedicated PHY layer ACK/NACK feedback channel

변조

❑ Data Modulation

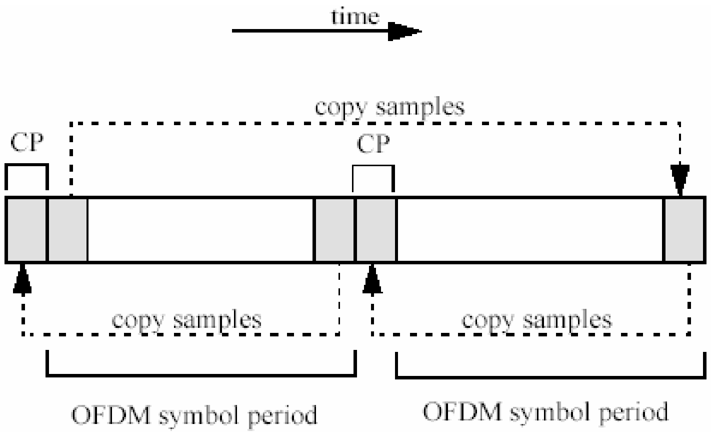
- UL: QPSK, 16QAM
- DL: QPSK, 16QAM, 64QAM



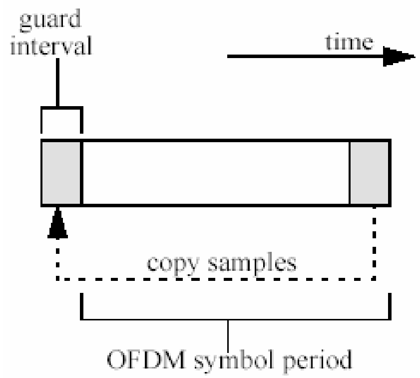
QPSK, 16QAM, 64QAM constellation

❑ Ranging

- Ranging based on CDMA code
- Initial ranging & HO ranging
  - Adjust time, freq. and power offset of MSS entering network
- Periodic ranging
  - Adjust time, freq. and power offset
- BW REQ ranging
  - BW request



Initial Ranging



Periodic or BW Req. Ranging

제어채널

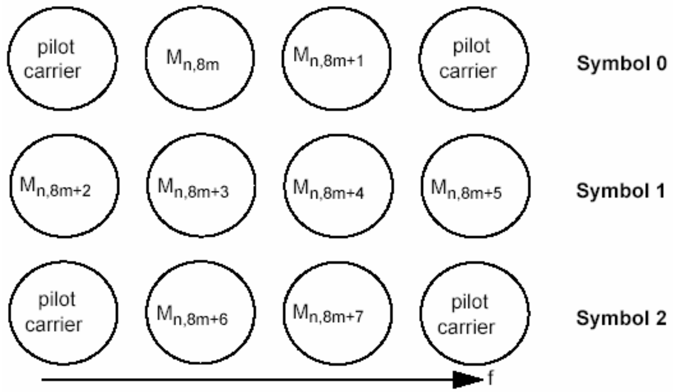
❑ CQICH

- ◆ CQI channel: 32 different SNR levels
  - ➢ 6 tiles (8 subcarriers X 6 tiles)
    - QPSK modulation
    - a data payload of 6 bits.

6 bits payload -> vector indices per Tile Tile(0), Tile(1), … Tile(5)
0b101001 -> 6,4,0,3,5,2

Vector index	$M_{n,8m}, M_{n,8m+1}, \ldots M_{n,8m+7}$
0	P0, P1, P2, P3, P0, P1, P2, P3
1	P0, P3, P2, P1, P0, P3, P2, P1
2	P0, P0, P1, P1, P2, P2, P3, P3
3	P0, P0, P3, P3, P2, P2, P1, P1
4	P0, P0, P0, P0, P0, P0, P0, P0
5	P0, P2, P0, P2, P0, P2, P0, P2
6	P0, P2, P0, P2, P2, P0, P2, P0
7	P0, P2, P2, P0, P2, P0, P0, P2

Orthogonal Modulation Index in Fast-feedback channel



Subcarrier mapping of Fast-feedback modulation symbols for PUSC

제어채널

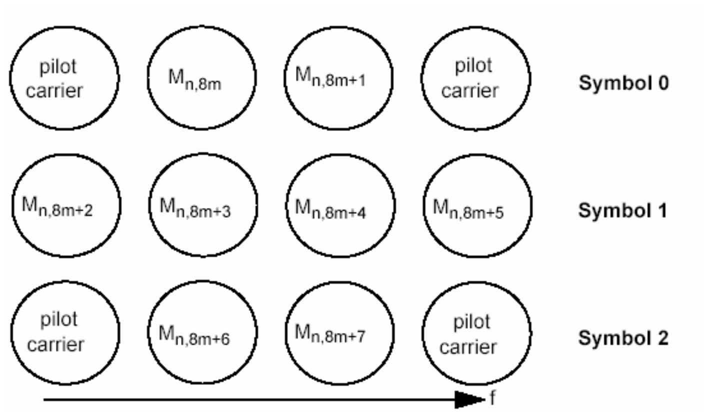
❑ ACKCH

- ◆ Feedback for DL Hybrid ARQ
- ◆ 1 bit(ACK/NACK) is encoded into a length 3 codeword
  - ➢ 3 tiles (8 subcarriers X 3 tiles)
    - ▪ QPSK modulation

ACK 1bit symbol -> vector indices per Tile Tile(0), Tile(1), Tile(2)
0 -> 0,0,0; 1 -> 4,7,2

Vector index	$M_{n,8m}, M_{n,8m+1}, \ldots, M_{n,8m+7}$
0	P0, P1, P2, P3, P0, P1, P2, P3
1	P0, P3, P2, P1, P0, P3, P2, P1
2	P0, P0, P1, P1, P2, P2, P3, P3
3	P0, P0, P3, P3, P2, P2, P1, P1
4	P0, P0, P0, P0, P0, P0, P0, P0
5	P0, P2, P0, P2, P0, P2, P0, P2
6	P0, P2, P0, P2, P2, P0, P2, P0
7	P0, P2, P2, P0, P2, P0, P0, P2

Orthogonal Modulation Index in UL ACK channel

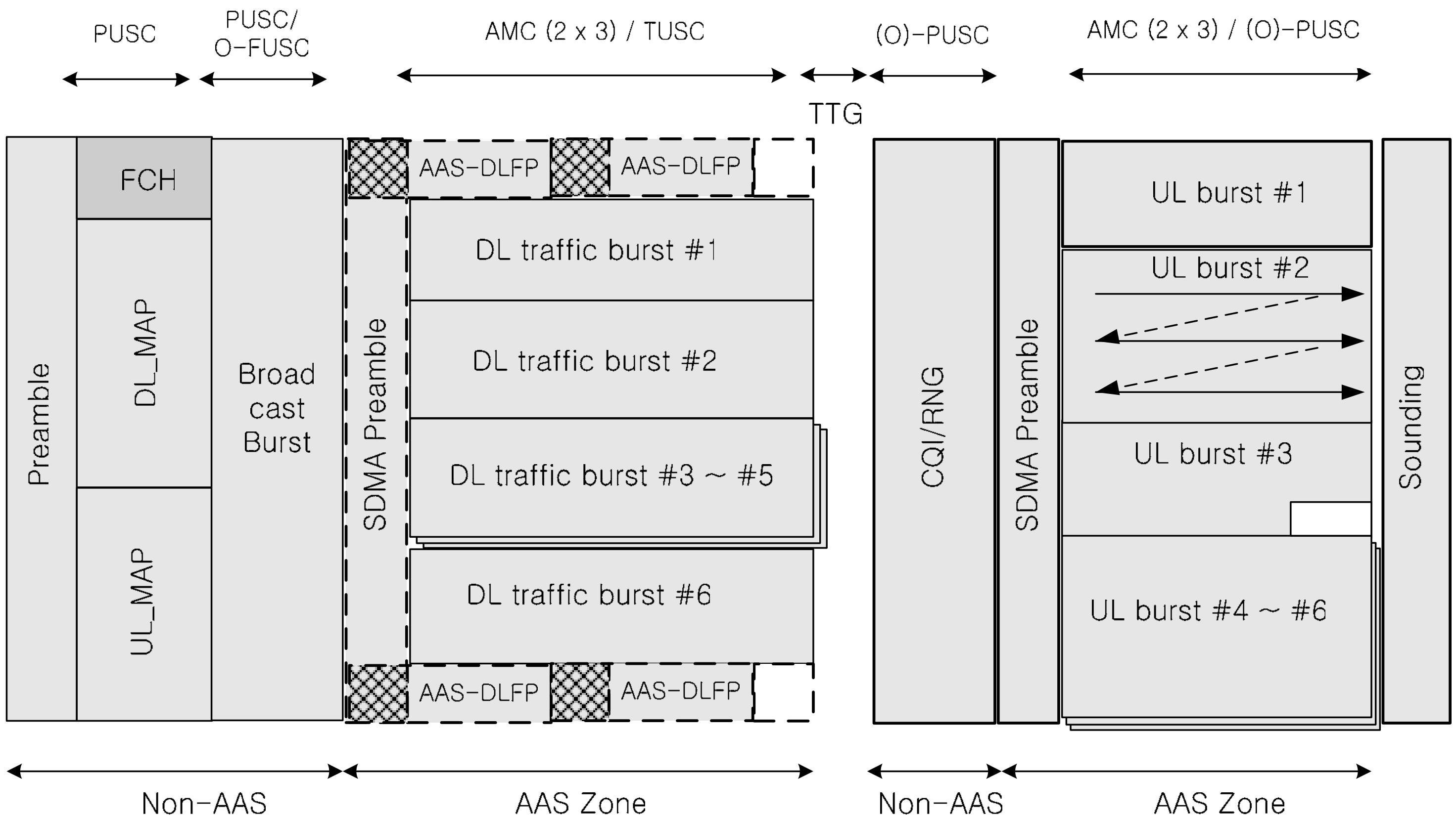


Subcarrier mapping of UL-ACK modulation symbols for PUSC

AAS (Adaptive Antenna System)

❑ Dedicated AAS zones for DL/UL

- ◆ DL/UL frame의 일부 심벌을 AAS zone으로 사용
- ◆ Non-AAS 영역과 시간적으로 분리됨



AAS (Adaptive Antenna System)

❑ AAS features

- DLFP (Down Link Frame Prefix)
  - FCH, MAP없이 AAS allocation 정보 획득
- UL AAS preamble
  - Spatial signature 획득
  - DL/UL symmetric traffic일 경우 DL에 적용 가능
- DL AAS preamble
  - DL Beam 구분
- UL Channel Sounding
  - DL/UL asymmetric traffic일 경우 DL용 spatial signature 획득
- Private MAP
  - Allocation 정보를 traffic과 동일한 Beam으로 전송
  - MAP overhead 감소
- SDMA allocation IE
  - SDMA allocation을 효율적으로 하여 MAP overhead를 줄임

AAS (Adaptive Antenna System)

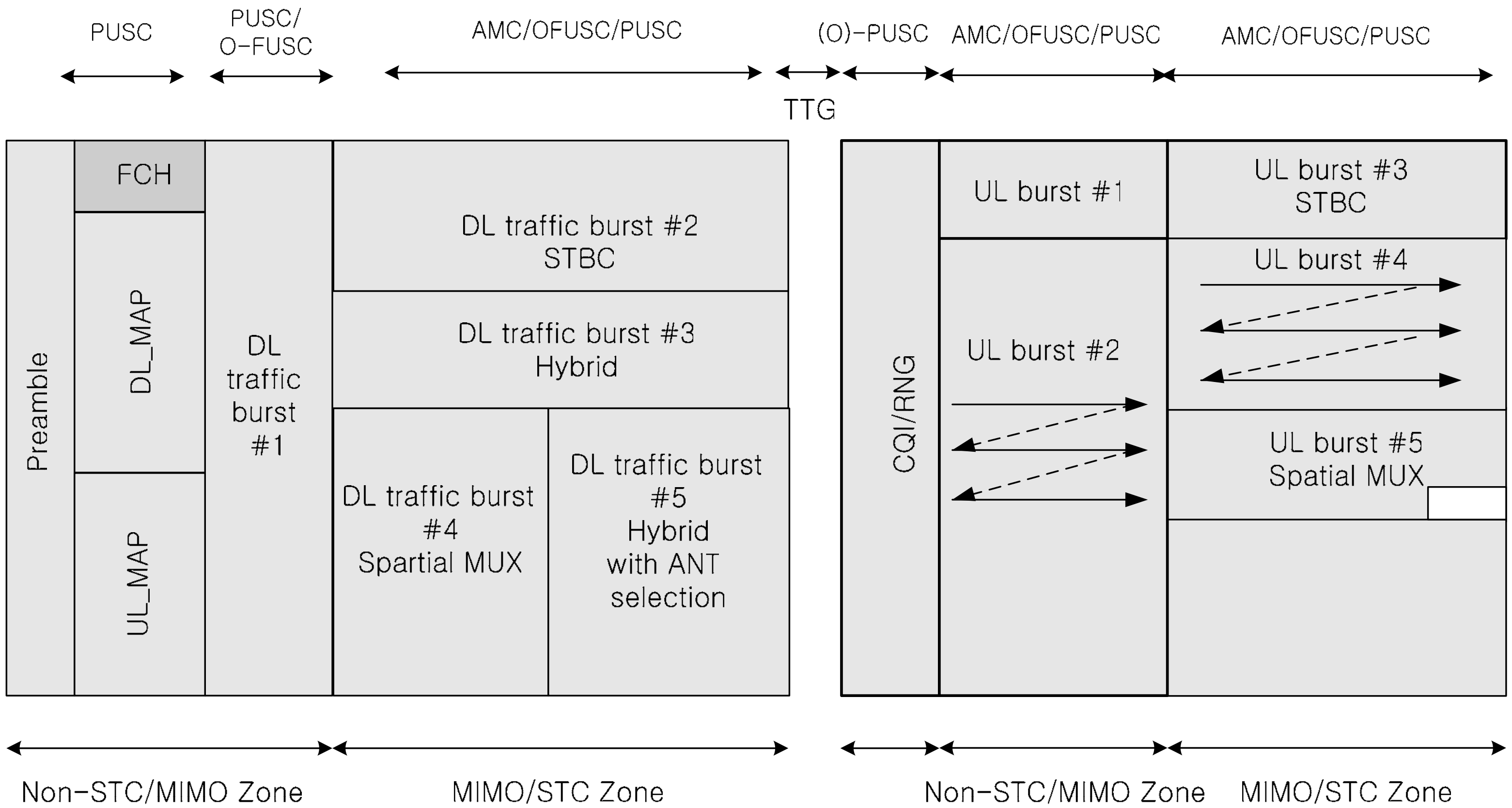
❑ AAS 운용

- ◆ Coverage Extension
  - ➢ MAP coverage 밖의 MSS에 대하여 적용
  - ➢ DLFP를 이용하여 MSS가 Network entry를 수행하도록 함
- ◆ Adaptive Beam forming
  - ➢ UL AAS preamble, Channel sounding을 이용하여 spatial signature 확보
- ◆ SDMA (Spatial Division Multiple Access)
  - ➢ UL AAS preamble, Channel sounding을 이용하여 spatial signature 확보
  - ➢ DL AAS preamble을 사용하여 SDMA beam을 구별

STC/MIMO

❑ Dedicated MIMO/STC zones for DL/UL

- DL/UL frame의 일부 심벌을 MIMO/STC zone으로 사용
- Non-STC/MIMO 영역과 시간적으로 분리됨



STC/MIMO

❑ 지원 방식

- ◆ Open loop STC/MIMO
  - ➢ CINR외 별도 궤환 정보를 필요로 하지 않는다.
  - ➢ Transmit diversity
    - ▪ Alamouti code 등: 높은 diversity order
  - ➢ Spatial Muxing
    - ▪ Blast 방식: 높은 전송효율
  - ➢ Hybrid 방식
- ◆ Closed loop MIMO (Feedback is required)
  - ➢ CINR외 별도의 궤환정보를 필요로 한다.
  - ➢ Antenna grouping
    - ▪ TD, Hybrid 방식에서 spatial channel 상태에 따라 Tx ant pair 선택을 변경
  - ➢ Antenna selection
    - ▪ SM에 대하여 전송 ANT 선택
  - ➢ Codebook based precoding

Contents

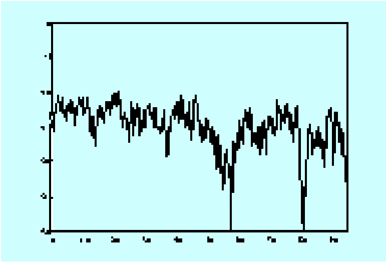
Ⅰ	WiBro 물리계층
Ⅱ	성능 개선을 위한 다중안테나 기술 - Theoretical Background - WiBro AAS Technology - WiBro MIMO Technology

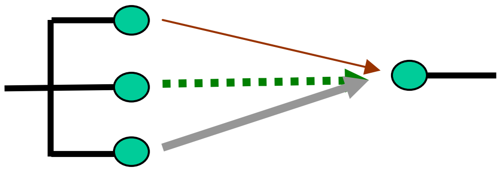
Theoretical Backgrounds

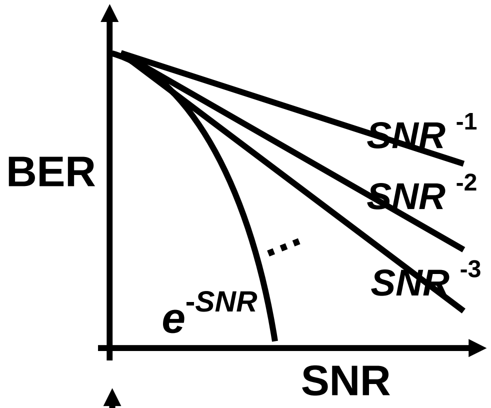
- Antenna Technology
- Channel Capacity

Multiple Antenna Technology

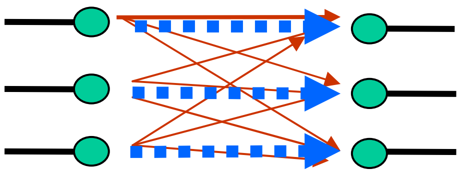
- ***Space Diversity:*** **Link Reliability**

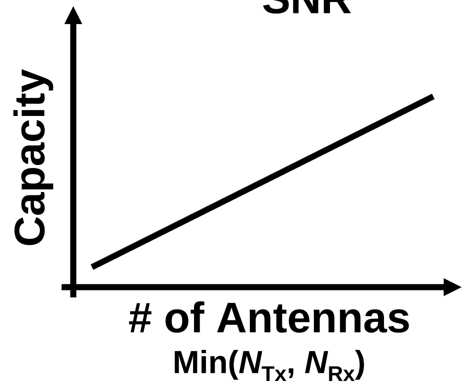




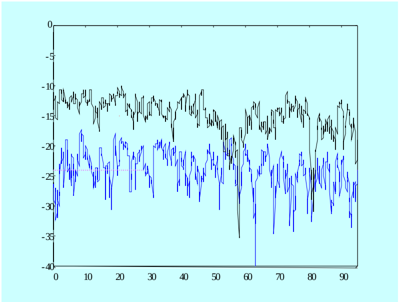


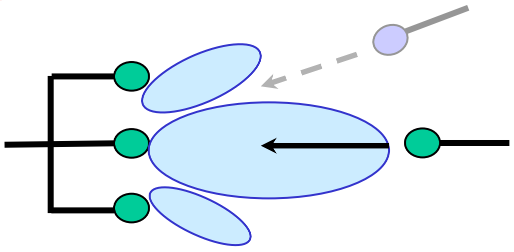
- ***Spatial Multiplexing:*** **Data Rate**

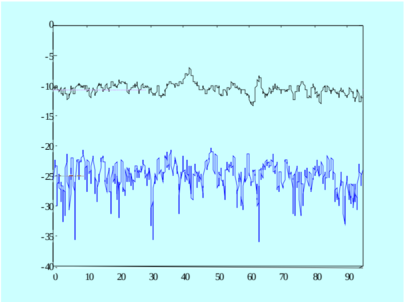




- ***Beamforming:*** **SINR, SDMA**



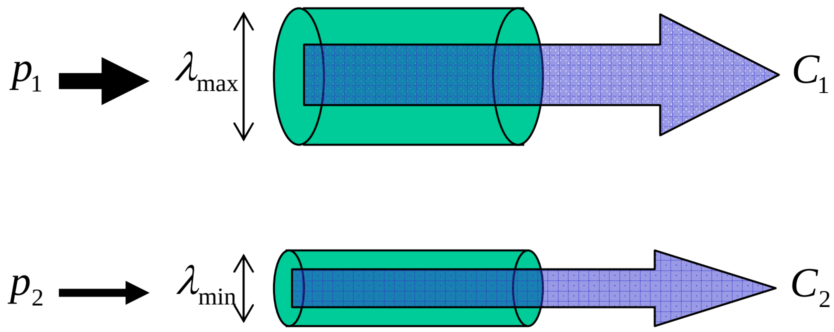




Transmission Scheme

$$H = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} = [\mathrm{h}_1 \quad \mathrm{h}_2]$$

λ_i : eigen – value of HH^*



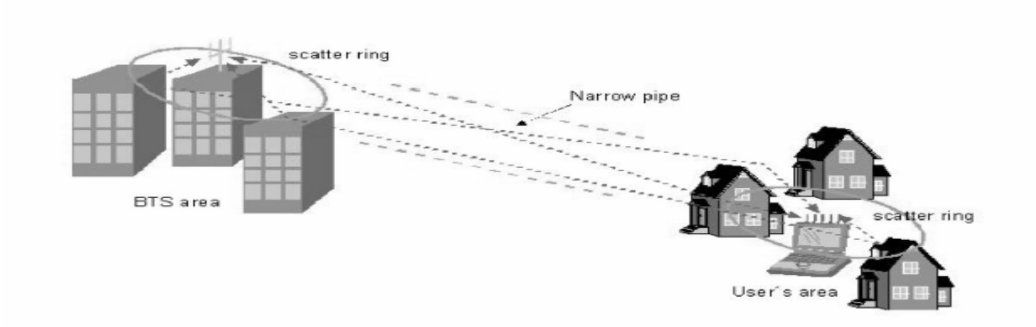
방식	용량	전력할당
WF-CL-MIMO/ WF-SVD-MIMO	$C = \sum_i \log_2(\lambda_i \mu)^+$	$\sum_i (\mu - \frac{1}{\lambda_i})^+ = \rho$
EP-SVD-MIMO	$C = \sum_i \log_2(1+\rho/2 \cdot \lambda_i)$	$p_i = \rho/2$
BF-MRC	$C = \log_2(1+\rho \cdot \lambda_{max})$	$p_{max} = \rho$
STC-MRC	$C = \log_2(1+\rho/2 \cdot (\lambda_{max} + \lambda_{min}))$	$p_i = \rho/2$

Channel Model

- **Channel Model**: $\mathbf{H}_k = \mathbf{C}_{Rx,k}^{1/2}\mathbf{G}_k \mathbf{C}_{Tx,k}^{1/2}$

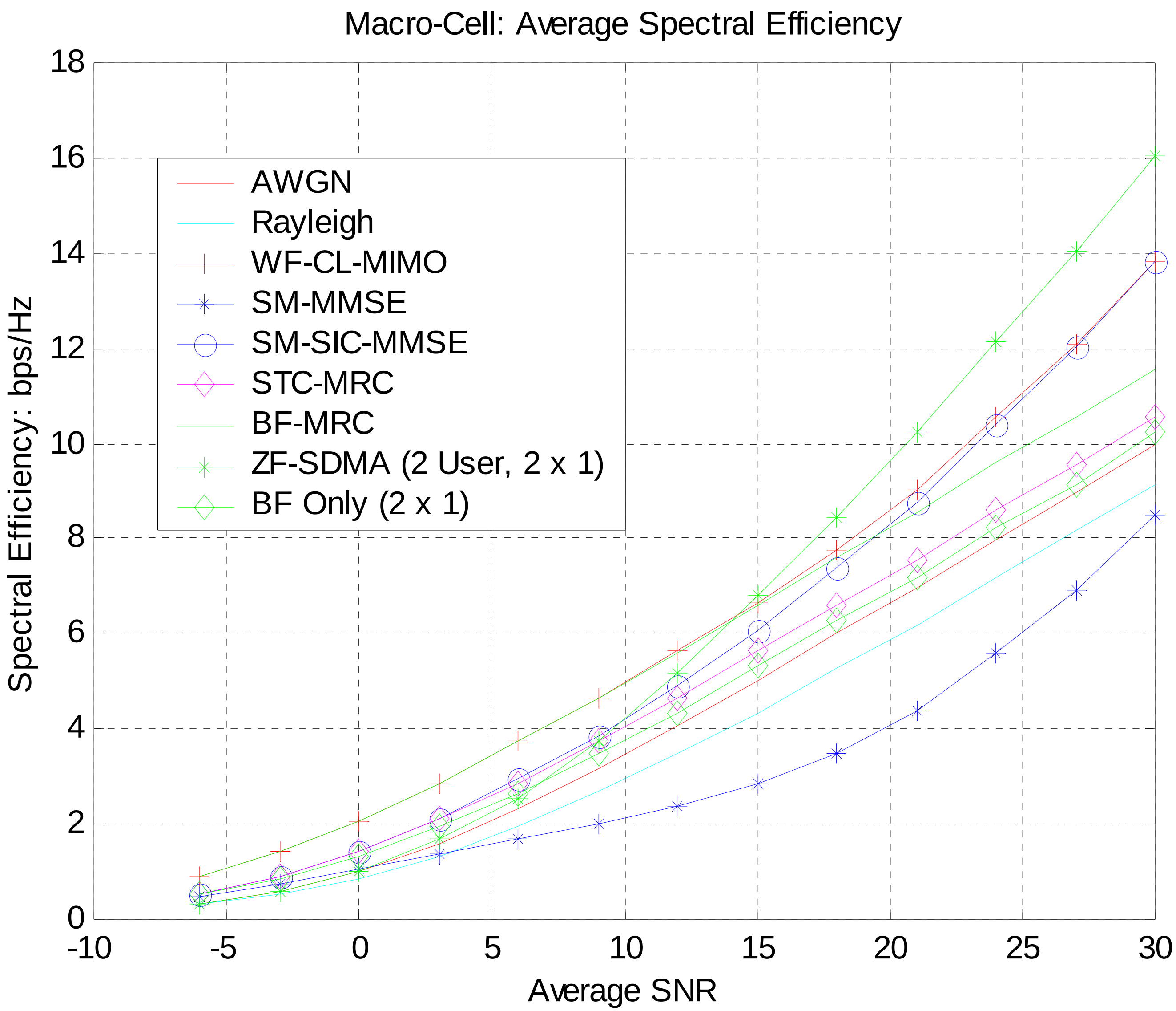
  where $\mathbf{G}_k$ has i.i.d zero-mean unit variance complex Gaussian RV's as elements for user k and

$$\mathbf{C}_{Tx,k} = \begin{bmatrix} 1 & \rho_{Tx,k} \\ \rho_{Tx,k}^* & 1 \end{bmatrix} \qquad \mathbf{C}_{Rx,k} = \begin{bmatrix} 1 & \rho_{Rx,k} \\ \rho_{Rx,k}^* & 1 \end{bmatrix}$$



- ✓ $\lambda/2$ antenna spacing
- ✓ $\rho_{Tx} = 0.97e^{i0.34\pi}$ (Macro Cell), $0.76e^{i0.17\pi}$ (Micro Cell), -0.3 (Pico Cell)
  ρ_{Rx} = -0.3 (Rich Scattering)

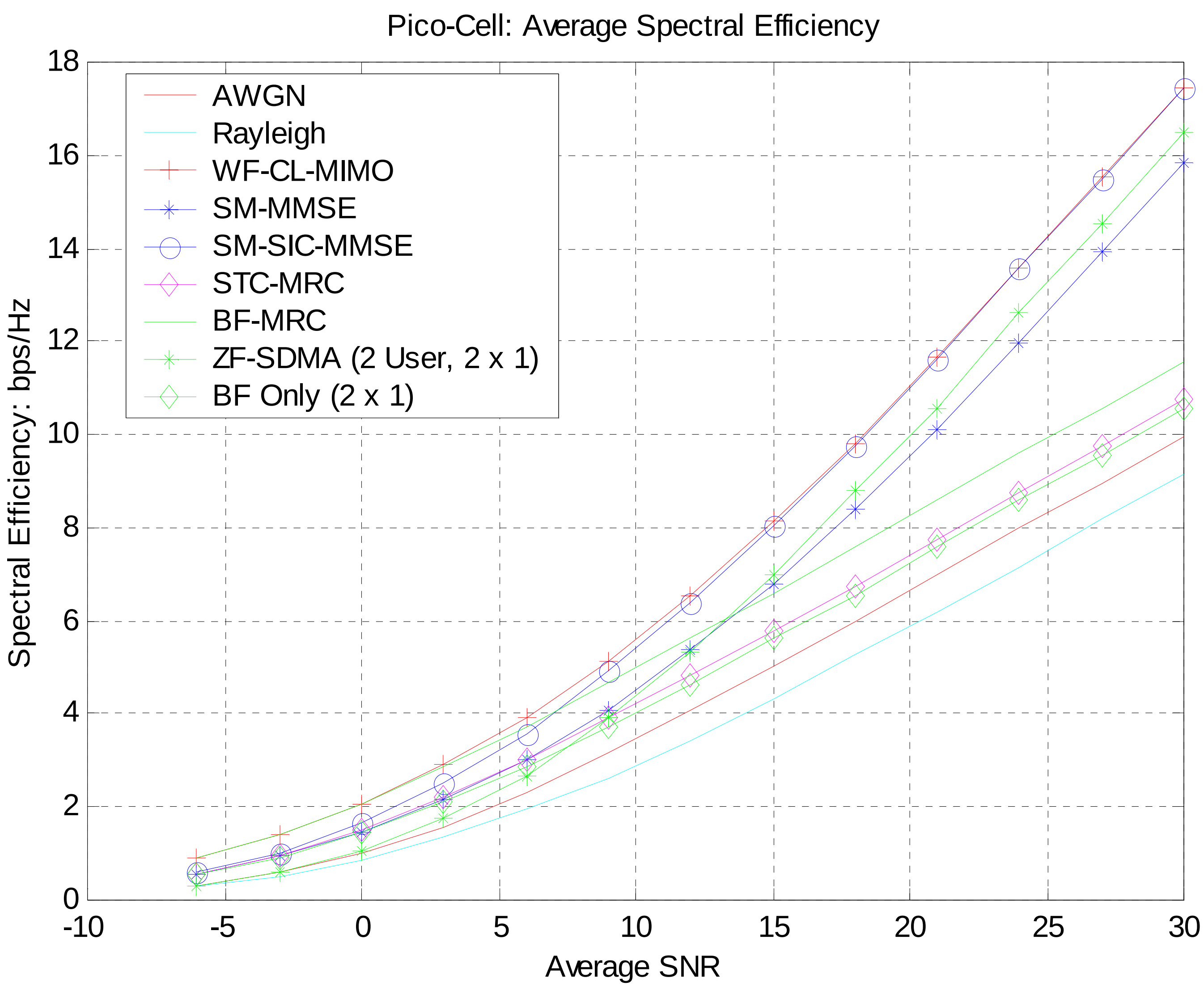
Shannon Capacity



$$H = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} = [\mathrm{h}_1 \quad \mathrm{h}_2]$$

Take the vectors for ZF-SDMA & BF-Only in 2x1 topology

Shannon Capacity



MIMO vs. AAS

Technology Comparison

Category	AAS	MIMO
Pilot Preamble	Per Beam	Per Antenna
Channel State Information	Necessary (Closed-Loop)	Necessary or Not (Closed or Open Loop)
RF Calibration	Adaptive BF (Yes) Pre-defined BF (No)	Adaptive Precoding (Yes) Codebook Precoding (No)
Favorable Conditions	Near LOS Macro-Cell	Rich-Scattering Pico-Cell/Indoor
General Design Approach	Coverage Enhance BS Throughput	Link Reliability (TD) SS Data Rate (SM)

WiBro AAS Technology

- AAS System Design
- Air Interface Details
- AAS System Operation
- Implementation Issues

AAS System Design

Design Requirement

- **Data Channel Coverage Extension**
  - ✓ Beam-formed Transmission of Data & Pilot Signals
  - ✓ Dedicated Pilot Processing
- **Control Coverage Extension**
  - ✓ Beam-formed Access & BW Allocation Channel
- **SDMA Scheduling**
  - ✓ Periodic Channel Sounding Signals
- **Wide-band TDD OFDMA System**
  - ✓ Band-narrow Orthogonal Signal Design in Freq. Domain

AAS System Design

Air Interface Specification

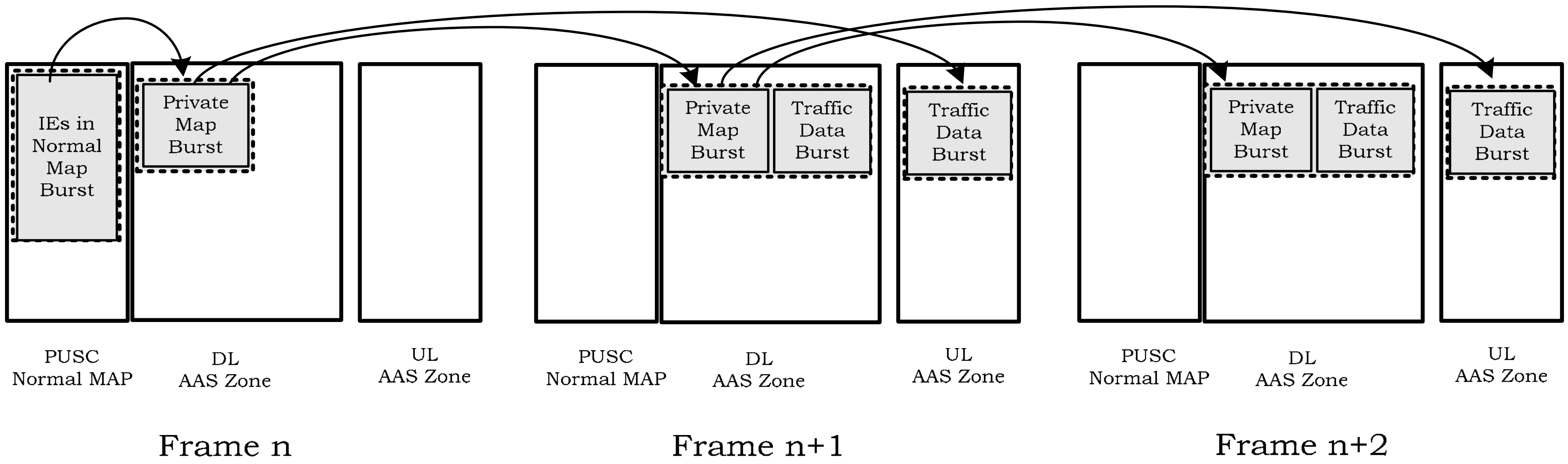
- **Downlink Design**
  - **MAP Coverage Extension**
    - AAS DLFP: Diversity Beam Scan of System & Access Information
    - AAS Private MAP: Beam-formed MAP Transmission
  - **SDMA Allocation: AAS SDMA DL IE**
  - **Dedicated Pilot: AAS Preamble, Per-Beam Pilot**
- **Uplink Design**
  - **Access Channel Coverage Extension**
    - AAS Ranging Channel Pointed by AAS DLFP
  - **SDMA Allocation: AAS SDMA UL IE**
  - **Dedicated Pilot: AAS Preamble, Per-Beam Pilot**
  - **Signature Estimation: Sounding Symbol**

MAP Signaling for AAS Mode

MAP	Pointed by	Code Rate	비 고
Normal Map	FCH	QPSK 1/2 ~1/12 (Fixed)	H-ARQ Support
Sub-Map	Sub-Map Pointer IE in DL Map	DIUC & Repetition (Variable)	H-ARQ Support
Private Map	DL IE in DL Map DL Comp IE in AAS DLFP Private Map (Chain)	DIUC & Repetition (Variable)	H-ARQ Support MAP SDMA

Air Interface Details

Private Map Chain



- Initiated from Normal Map, AAS-DLFP
- Specify DL/UL BW Allocation for Next Frame
- Concatenation of MAP and DL Data Burst
- Beam-formed/SDMA Transmission in AAS Zone

Air Interface Details

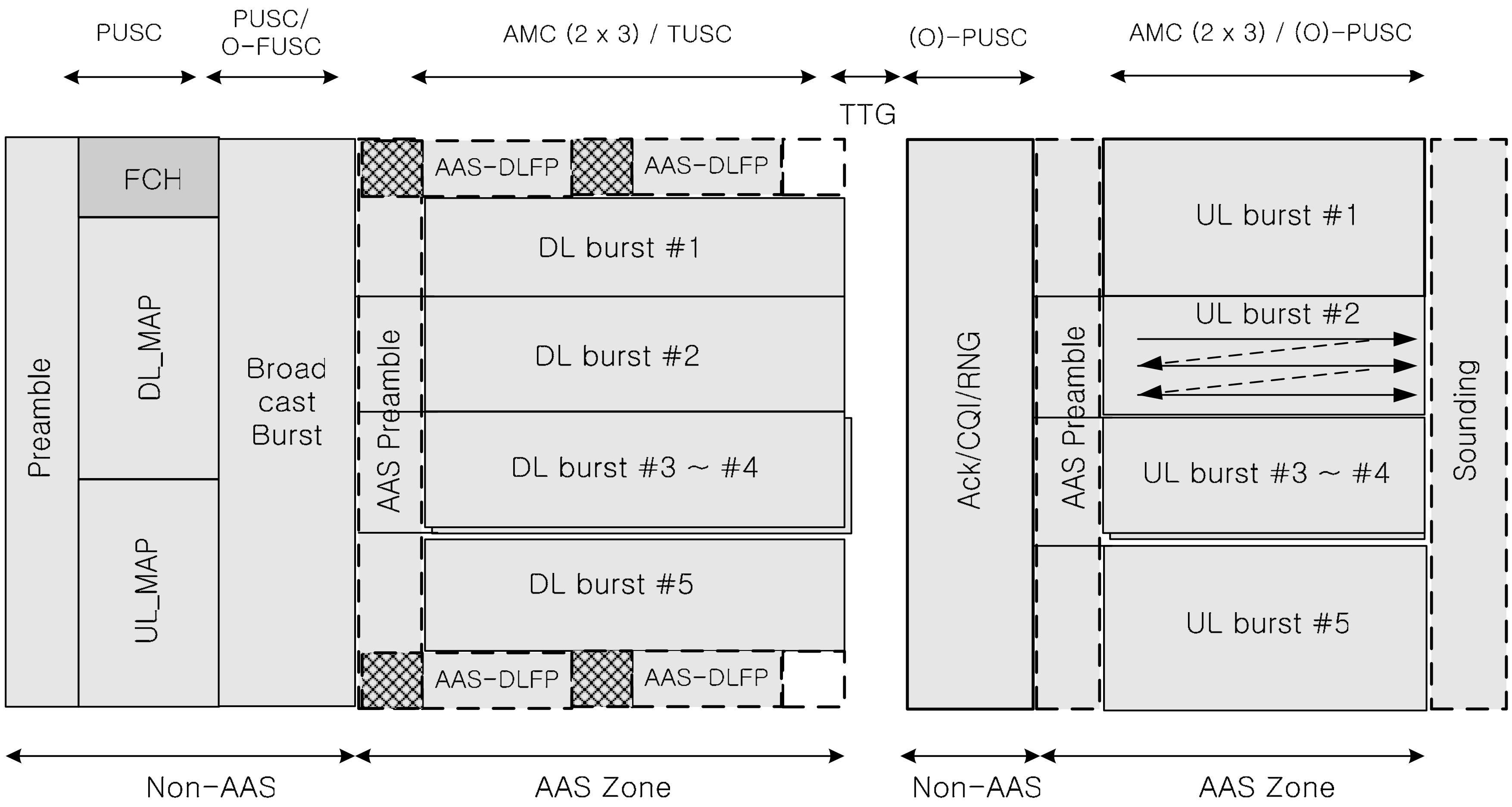
Signal Design for AAS Mode

Category	Specifications	비 고
AAS Preamble	* Combination of DL Preamble Sequence * Random Freq. Shift / Orthogonal Cyclic Shift	
Per-Beam Pilot	* Orthogonal per-Beam Pilot for Tracking * Supported in AMC Permutation Only - DL AMC (2 x 3) ↔ UL AMC (2 x 3)	
Sounding Symbol	* Allocation Unit: 2 bin vs. DL sub-channel * Orthogonality: Cyclic Shift vs. Freq. Decimation * Golay Seq. for Low PAPR (5.1 ~ 6.3 dB) * Originally Proposed for MIMO Operation	Type A/B

Possible Frame Configuration

Acronyms

Tile **U**sage of **S**ub-**C**hannel
: DL TUSC1 ↔ UL PUSC
DL TUSC2 ↔ UL O-PUSC



AAS System Operation

- **Signature Estimation**
  - TDD Channel Reciprocity
  - Band-narrow Estimation (Bin/Tile)
- **Paired Operation**
  - Symmetric DL/UL BW Allocation
  - Signature Estimation from UL Allocation
  - DL Beam-forming based on Estimated Signature
- **Scheduling Operation**
  - Maximize Multi-user Diversity
  - Monitor RF Condition & Decide BW Allocation Instants
  - Required Feedback Signals: Sounding Symbol, CQI Information

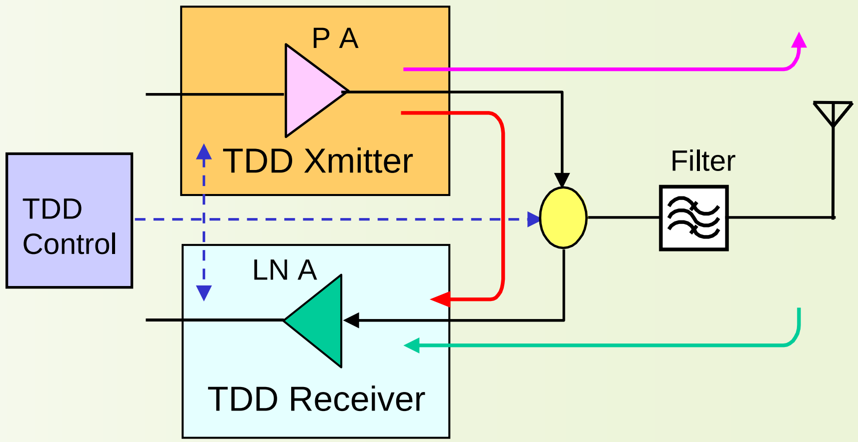
Implementation Issues

SDMA Scheduling

- Scheduling Domain: Space, Time (Frame), Frequency (Band AMC)
- Trade-Off between Complexity vs. Throughout
- Proprietary Rx./Tx. SDMA Beam-forming Algorithm

RF Path Calibration

- Proprietary Calibration Scheme
- Compensate Relative RF Path Characteristic among Antennas



WiBro MIMO Technology

- MIMO System Design
- Air Interface Details
- MIMO System Operation

MIMO System Design

Design Requirement

- **Tx. Matrix:** Up to 4 for DL and 2 for UL
- **Data Channel Reliability Enhancement**
  - ✓ Open-loop Transmit Diversity
  - ✓ Per-Antenna Pilot Signals
- **Per User Data Rate Enhancement**
  - ✓ Spatial Multiplexing of Coded Symbol (Vertical Encoding)
  - ✓ Per-spatial Mode Rate Control (Horizontal Encoding)
  - ✓ Pre-coding with Index Feed-back or Channel Sounding
- **Multi-user MIMO Scheduling**
  - ✓ Periodic Channel Sounding Signals
- **Wide-band TDD OFDMA System**
  - ✓ Band-narrow Orthogonal Signal Design in Freq. Domain

MIMO System Design

Downlink Specifications

# BS Antenna		2 Tx	3 Tx	4 Tx	Comments
Open-loop	**TD (A)**	√ (Alamouti)	√ (Beceem's)	√ (Alamouti with antenna circulation)	Spatial rate (Ns) = 1
	Hybrid (B)	√ (ETRI's)	√ (antenna circulation)	√ (double-Alamouti w/ different second pairing)	Ns = 2 Rate control possible (multi-FEC or single-FEC)
	SM (C)	√	√	√	Ns = Nt Rate control possible (multi-FEC or single-FEC)
Closed-loop	**Antenna grouping/ selection**	√ (AS)	√ (AS for rate 1,2)	√ (AG for rate 1,2) √ (AS for rate 1,2,3)	Grouping/Selection index fed back
	General Precoding	√	√	√	Codebook based precoding (or eigen beamforming)

MIMO System Design

Uplink Specifications

# SS Antenna		2 Tx	2 SS with single Tx	Comments
Open-loop	TD	√ (Alamouti)	N/A	
	SM	√	√	2 Tx: Rate control possible Collaborative SM among 2 SS with single Tx antenna

Air Interface Details

	TD (Transmit Diversity)	Hybrid (TD + SM)	SM (Spatial Multiplexing)
T/F →, Ant. ↓	**A**	**B**	**C**
2 Tx.	$A_{(Mt=2)} = \begin{bmatrix} s_1 & -s_2^* \\ s_2 & s_1^* \end{bmatrix}$ (For UL Only)	$\frac{1}{\sqrt{1+r^2}}\begin{pmatrix} S_i + jr\cdot S_{i+3} & r\cdot S_{i+1} + S_{i+2} \\ S_{i+1} - r\cdot S_{i+2} & jr\cdot S_i + S_{i+3} \end{pmatrix}, r = \frac{-1+\sqrt{5}}{2}$	$C_{(Mt=2)} = \begin{bmatrix} s_1 \\ s_2 \end{bmatrix}$ (For UL Only)
3 Tx.	$A_{(Mt=3)} = \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & 0 & 0 \\ \tilde{s}_2 & \tilde{s}_1^* & \tilde{s}_3 & -\tilde{s}_4^* \\ 0 & 0 & \tilde{s}_4 & \tilde{s}_3^* \end{bmatrix}$ (Simple ML Decoding; Constellation Rotation for Diversity)	$\begin{bmatrix} \sqrt{\frac{3}{4}} & 0 & 0 \\ 0 & \sqrt{\frac{3}{4}} & 0 \\ 0 & 0 & \sqrt{\frac{3}{2}} \end{bmatrix} \begin{bmatrix} \tilde{S}_1 & -\tilde{S}_2^* & \tilde{S}_5 & -\tilde{S}_6^* \\ \tilde{S}_2 & \tilde{S}_1^* & \tilde{S}_6 & \tilde{S}_5^* \\ \tilde{S}_7 & \tilde{S}_8^* & \tilde{S}_3 & -\tilde{S}_4^* \end{bmatrix}$ (Constellation Rotation and Circulation for Diversity)	$C_{(Mt=3)} = \begin{bmatrix} s_1 \\ s_2 \\ s_3 \end{bmatrix}$
4 Tx.	$A_{(Mt=4)} = \begin{bmatrix} s_1 & -s_2^* & 0 & 0 \\ s_2 & s_1^* & 0 & 0 \\ 0 & 0 & s_3 & -s_4^* \\ 0 & 0 & s_4 & s_3^* \end{bmatrix}$	$B_{(Mt=4)} = \begin{bmatrix} s_1 & -s_2^* & s_5 & -s_7^* \\ s_2 & s_1^* & s_6 & -s_8^* \\ s_3 & -s_4^* & s_7 & -s_5^* \\ s_4 & s_3^* & s_8 & s_6^* \end{bmatrix}$	$C_{(Mt=4)} = \begin{bmatrix} s_1 \\ s_2 \\ s_3 \\ s_4 \end{bmatrix}$

(dashed ellipse) **: For UL Only**

(dotted circle) Simple ML Decoding; Constellation Rotation for Diversity

(checkered circle) Constellation Rotation and Circulation for Diversity

Air Interface Details

TD (Transmit Diversity) — **A**

Hybrid (TD + SM) — **B**

T/F

Ant.

3 Tx.

$$A_{(Mt=3)} = \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & 0 & 0 \\ \tilde{s}_2 & \tilde{s}_1^* & \tilde{s}_3 & -\tilde{s}_4^* \\ 0 & 0 & \tilde{s}_4 & \tilde{s}_3^* \end{bmatrix}$$

$$\begin{bmatrix} \sqrt{\frac{3}{4}} & 0 & 0 \\ 0 & \sqrt{\frac{3}{4}} & 0 \\ 0 & 0 & \sqrt{\frac{3}{2}} \end{bmatrix} \begin{bmatrix} \tilde{s}_1 & -\tilde{s}_2^* & \tilde{s}_5 & -\tilde{s}_6^* \\ \tilde{s}_2 & \tilde{s}_1^* & \tilde{s}_6 & \tilde{s}_5^* \\ \tilde{s}_7 & \tilde{s}_8^* & \tilde{s}_3 & -\tilde{s}_4^* \end{bmatrix}$$

$$s_i = x_i e^{j\theta} = s_{i,I} + js_{i,Q}; \theta = \tan^{-1}(1/3)$$

x_i : QAM Constellation

$$\tilde{s}_1 = s_{1,I} + js_{3,Q}; \tilde{s}_2 = s_{2,I} + js_{4,Q}$$

$$\tilde{s}_3 = s_{3,I} + js_{1,Q}; \tilde{s}_4 = s_{4,I} + js_{2,Q}$$

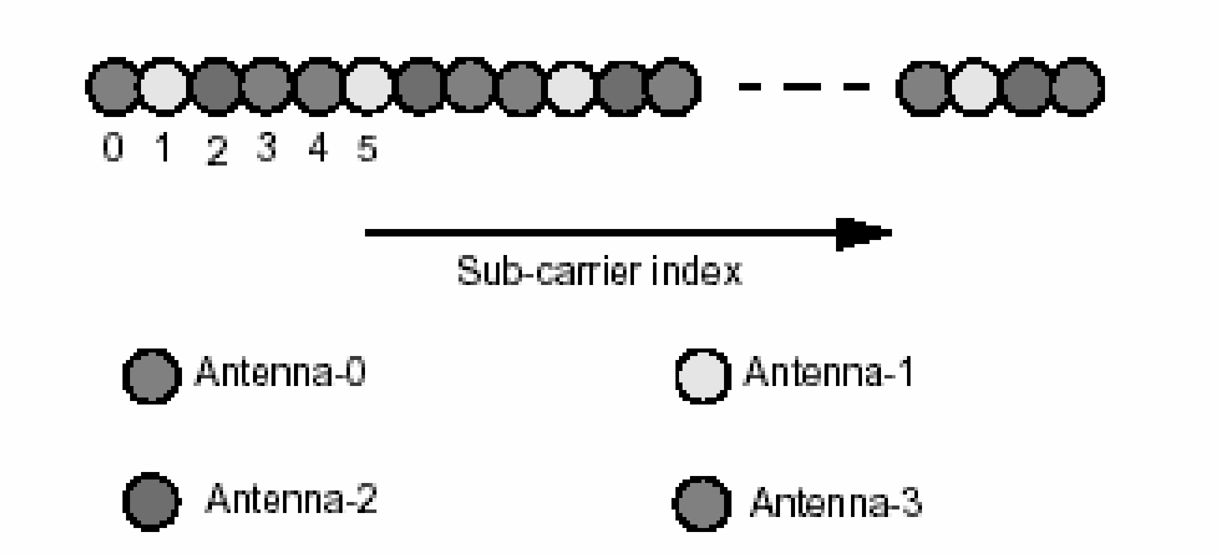
$$\tilde{s}_5 = s_{5,I} + js_{7,Q}; \tilde{s}_6 = s_{6,I} + js_{8,Q}$$

$$\tilde{s}_7 = s_{7,I} + js_{5,Q}; \tilde{s}_8 = s_{8,I} + js_{6,Q}$$

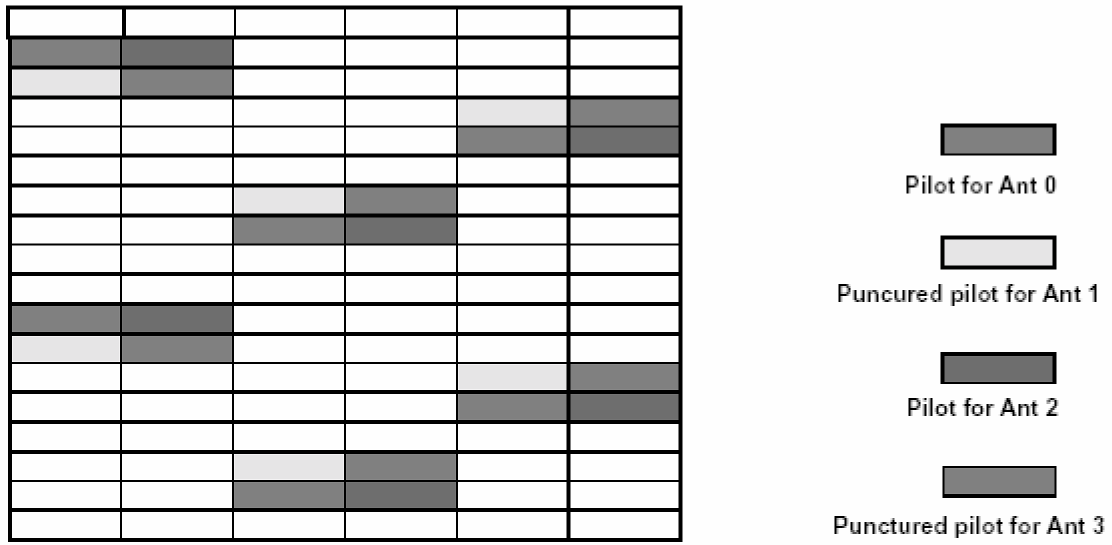
	f_1	f_2				
T_1	$\tilde{s}_1$	0	$\tilde{s}_2$	$\tilde{s}_3$	0	$\tilde{s}_4$
T_2	$-\tilde{s}_2^*$	0	$\tilde{s}_1^*$	$-\tilde{s}_4^*$	0	$\tilde{s}_3^*$
	Ant 0		**Ant 1**		**Ant 2**	

Air Interface Details

- **MIMO Mid-amble**
  - DL Channel Estimation per Antenna
  - Orthogonality by Freq. Decimation
  - Up to 4 Transmit Antenna Support
  - Optimized Sequences for PAPR Reduction

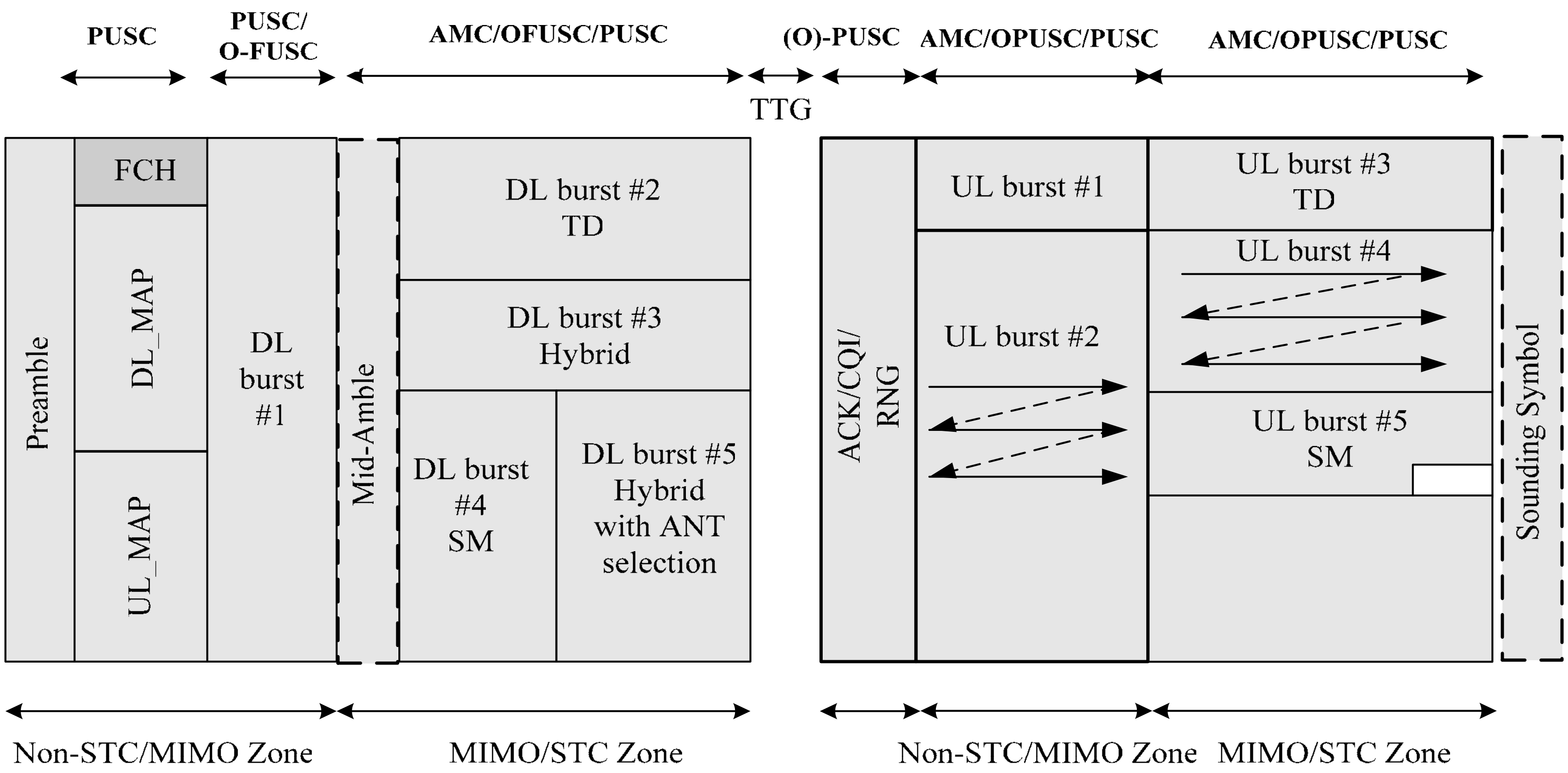


- **MIMO Pilot Pattern Example**
  - AMC and O-FUSC Permutation
  - Same Pilot Overhead as SISO Case
  - Pilot Shifting and Data Puncturing for 2/3 Tx. and 4 Tx.



4 Tx. for AMC/O-FUSC

Possible Frame Configuration



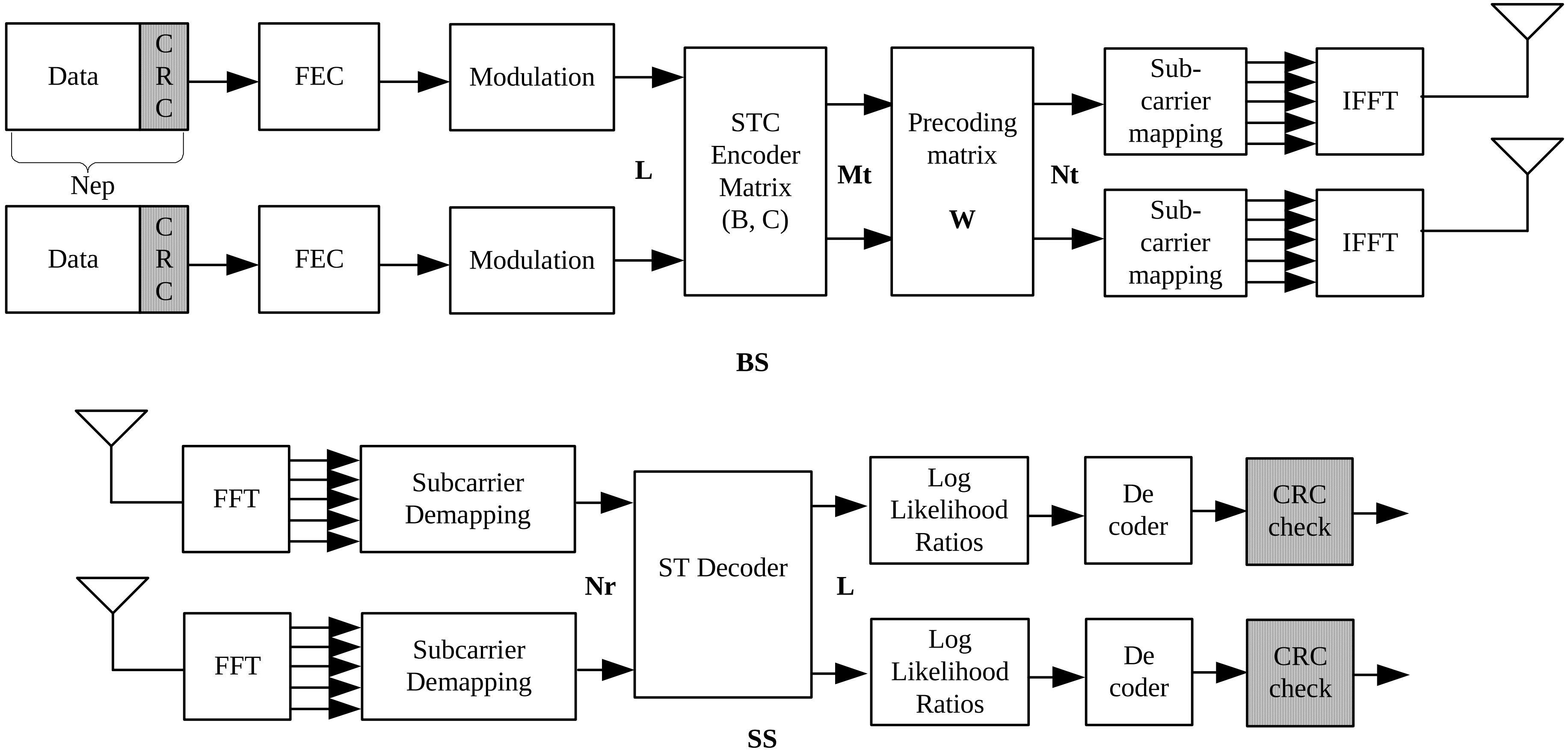
MIMO System Operation

- **Terminology**
  - Layers (L), (STC Coded) Streams (Mt), Antennas (Nt)
- **Open loop (OL)**
  - Specified by Transmission Matrix: A (TD), B (Hybrid), or C (SM)
- **Closed loop (CL)**
  - Implemented by precoding matrix ***W*** at the output of STC
  - Precoding information fed back from SS using either fast feedback channels (CQICH) or UL sounding channels

	Layer = 1 (TD or VE only)				L = 2 (HE only)			L = 3 (HE only)		L = 4 (HE only)
Ns	Mt = 1	2	3	4	Mt = 2	3	4	Mt = 3	4	Mt = 4
1	Beam-forming	A (TD)	A (TD)[1]	A (TD)[1]						
2		B (VE)	B (VE)[1]	B (VE)[1]		B (HE)[1]	B (HE)[1]			
Nt		C (VE)	C (VE)	C (VE)	C (HE)			C (HE)		C (HE)

[1)] **Applicability of the Antenna Grouping Technique.**

MIMO System Example



Layers (L) = 2, STC Coded Streams (Mt) = 2, Antennas (Nt) = 2, Nr ≥ Nt

MIMO System Operation

MIMO System Operation

- **Step 1. Capability Selection**
  - – Transmission Matrix: A,B,C for 2 ~ 4 Tx.
  - – Feedback Capability: Precoding index, AG/AS, Channel Sounding
- **Step 2. Operation Mode Selection**
  - – Operation Mode Selection within Capability
  - – Decision Factor: User Geometry (SNR), Antenna Correlation, Mobility
- **Step 3. Packet Scheduling**
  - – Maximize Multi-user Diversity
  - – Monitor RF Condition & Decide BW Allocation Instants
  - – Required Feedback Signals: CQI, AG/AS Index, Precoding Index, Channel Sounding

Implementation Issues

Mode Selection

- ❖ Open loop vs. Closed loop : Mobility
- ❖ STC vs. Multiplexing: User Geometry, Antenna Correlation
- ❖ Vertical vs. Horizontal Encoding: Decoding Capability, Feedback Info.

Terminal Complexity

- ❖ Multiple RF Path Design
- ❖ ST Decoder: MMSE, MMSE-SIC, ML Decoding
- ❖ CTC Codec: Peak Data Rate with Spatial Multiplexing

Thank You !

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