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Re:	MBWA Call for Proposals	
Abstract	This document proposes a draft physical layer (PHY) specification for Mobile Broadband Wireless Access.	
Purpose	This document addresses an air interface for interoperable mobile broadband wireless access systems, operating in licensed bands below 3.5 GHz, optimized for IP-data transport.	
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<Proposed Draft Technology Specification for IEEE 802.20 Mobile Broadband Wireless Access Systems>

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Contents

1 Overview

1.1 Purpose

The purpose of this specification is to provide an air interface for interoperable mobile broadband wireless access systems, operating in licensed bands below 3.5 GHz, optimized for IP-data transport, with peak data rates per user in excess of 1 Mbps. This supports various vehicular mobility classes up to 250 Km/h in a MAN environment and targets spectral efficiencies, sustained user data rates and numbers of active users that are all significantly higher than achieved by existing mobile systems.

1.2 Scope

The scope of this document is to develop a physical layer (PHY) specification for Mobile Broadband Wireless Access that is optimized for the transport of IP based services.

1.3 Abbreviation

AMC	Adaptive Modulation & Coding
BCH	Broadcast Channel
CBPT	Coded Bit Per Tone
BCS	Bundle of Chunk Space
CCFPCH	Common Control Format Physical Channel
CCPCH	Common Control Physical Channel
CGN	Cell Group Number
CN	Cell Number
CP	Cyclic Prefix
CQMCH	Channel Quality Measurement Channel
CQMPID	Channel Quality Measure Preamble Identifier

CQMPrRS	Channel Quality Measure Preamble Resource Space
CQMRS	Channel Quality Measurement Resource Space
CQMRSS	Channel Quality Measurement Resource Sub-space
CRC	Cyclic Redundancy Check
CS	Chunk Space
DL	Downlink
DN-DSDPCH	Distributed & Nonspreading Type Downlink Shared Data Physical Channel
DSB	Distributed Spreading Block
DSCPCHID	Downlink State Control Physical Channel Identifier
DS-DSDPCH	Distributed & Spreading Type Downlink Shared Data Physical Channel
DSDCH	Downlink Shared Data Physical Channel
DTP	Downlink Traffic Packet
DPICH	Downlink Pilot Channel
FACH	Forward Access Channel
FEC	Forward Error Correction
FN	Frame Number
GF	Galois Field
H-ARQ	Hybrid Automatic Repeat Request
LDPC	Low Density Parity Check
LN-DSDPCH	Localized & Nonspreading Type Downlink Shared Data Physical Channel
LSB	Localized Spreading Block
LS-DSDPCH	Localized & Spreading Type Downlink Shared Data Physical Channel
OFDM	Orthogonal Frequency Division Multiplexing
PCH	Paging Channel
PFCH	Path-loss Feedback Channel

PRSS	Pilot Resource Subspace
RACH	Random Access Channel
RI	Resource Index
RIS	Resource Index Set
SAT	Single Antenna Transmission
SCH	State Control Channel
SCPCH	Shared Control Physical Channel
SFBC	Spatial Frequency Block Code
SPDCH	Shared Physical Data Channel
SPEX	Spatial Expansion
S-PUSRC	Successive Interference Cancellation Based Per User and Stream Rate Control
STBC	Spatial Time Block Code
STCH	Shared Traffic Channel
UACH	Uplink ACK Channel
UFCH	Uplink Feedback Channel
UL	Uplink
UNTRS	Uplink Non-Traffic Resource Space
UNTRSS	Uplink Non-Traffic Resource SubSpace
UTP	Uplink Traffic Packet
UTRS	Uplink Traffic Resource Space

2 Downlink

2.1 Physical Channels and Frame Structure

2.1.1 Transport Channel

Transport channels include Broadcast Channel (BCH), Forward Access Channel (FACH), Paging Channel (PCH), State Control Channel (SCH) and Shared Traffic Channel (STCH).

2.1.1.1 BCH

BCH is a transport channel used for broadcasting the information of system and cell.

2.1.1.2 FACH

FACH is a downlink transport channel.

2.1.1.3 PCH

PCH is a downlink transport channel and transmits over the entire cell.

2.1.1.4 SCH

SCH is an uplink or downlink transport channel and transmits the information for controlling the state of the UE.

2.1.1.5 STCH

STCH is an uplink or downlink transport channel and is shared by one or more UEs.

2.1.2 Resource partition for channelization

This subsection describes how resource space is allocated in the downlink frame structure. The length of a frame is T_{frame} and a frame consists of 20 DTPs (Downlink Traffic Packet) , each of which has T_{DTP}=0.5 ms. The downlink frame structure is illustrated in Figure 2-1.

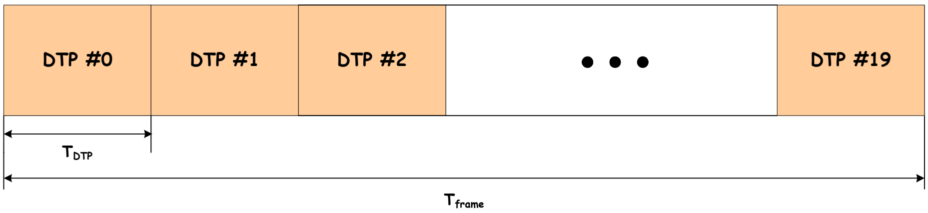

Figure 2-1 Downlink Frame Structure

In the Figure 2-1, T_{frame} is 10.0 ms. The length of an OFDM symbol is 0.5/7 ms. OFDM parameters for each channel bandwidth are defined in Table 2-1.

Table 2-1 OFDM parameters for the respective channel bandwidths

Transmission BW	5 MHz	10 MHz	15 MHz	20 MHz
Sub-frame duration	0.5 ms			
Sub-carrier spacing	15 kHz			
Sampling frequency	7.68 MHz (2 × 3.84 MHz)	15.36 MHz (4 × 3.84 MHz)	23.04 MHz (6 × 3.84 MHz)	30.72 MHz (8 × 3.84 MHz)
FFT size	512	1024	1536	2048
Number of occupied sub-carriers	301	601	901	1201
Number of OFDM symbols per sub frame	7			
CP length (μs/samples)	(4.69/36) × 3, (4.82/37) × 4	(4.75/73) × 6, (4.82/74) × 1	(4.73/109) × 2, (4.77/110) × 5	(4.75/146) × 5, (4.79/147) ×2

There are 20 DTPs in a downlink frame. A DTP consists of 7 OFDM symbols. The numbers of time-frequency bins (resources) are 2100, 4200, 6300, and 8400 in the channel bandwidths 5MHz, 10MHz, 15MHz, and 20MHz, respectively. DTP resource index sets for each channel bandwidth are defined in the Table 2-2. A DTP consists of 11 resource spaces and each resource space can be divided into several resource subspaces.

Table 2-2 DTP resource index sets for each channel bandwidth

Transmission BW	DTP resource index set
5MHz	$R_{\mathrm{DTP}} = \{r \mid 0 \le r < 2100\}$
10MHz	$R_{\mathrm{DTP}} = \{r \mid 0 \le r < 4200\}$
15MHz	$R_{\mathrm{DTP}} = \{r \mid 0 \le r < 6300\}$
20MHz	$R_{\mathrm{DTP}} = \{r \mid 0 \le r < 8400\}$

Each DTP has 11 resource spaces, RS_0~RS_{10}. Before defining RS_0~RS_{10}, it is necessary to define chunk and bundle of chunks. Logical resource space structure of DTP is illustrated in Figure 2-2.

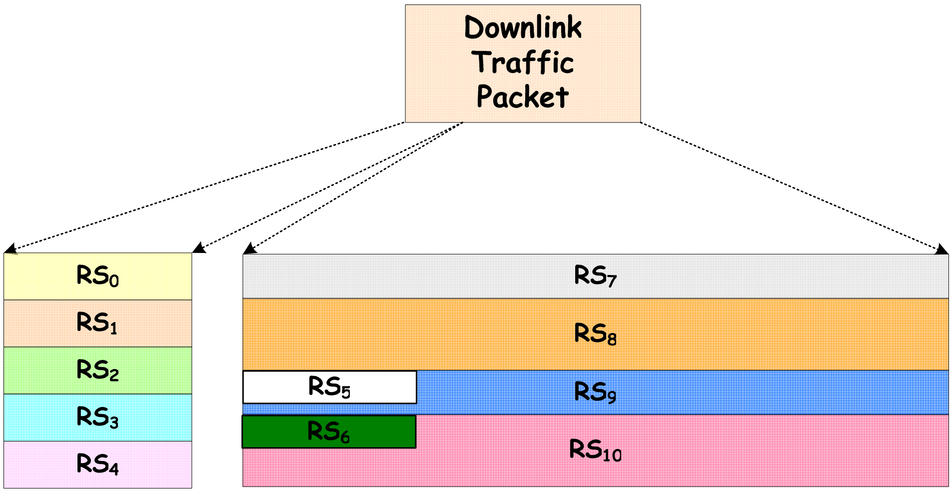

Figure 2-2 Logical resource space structure of DTP

2.1.2.1 Downlink Chunk Space

A DTP has 20, 40, 60, and 80 chunk spaces (CS) for the channel bandwidths 5MHz, 10MHz, 15MHz, and 20MHz, respectively. CS is a set of resources, and is defined in Table 2-3.

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Table 2-3 CS resource index set for each channel bandwidth

Transmission BW	CS resource index set
5MHz	$R_{\mathrm{CS_k}} = \{r \mid r \in \bigcup_{i=0}^{14} X_{300,15k+i}, 300 \le r < 2100\}$
10MHz	$R_{\mathrm{CS_k}} = \{r \mid r \in \bigcup_{i=0}^{14} X_{600,15k+i}, 600 \le r < 4200\}$
15MHz	$R_{\mathrm{CS_k}} = \{r \mid r \in \bigcup_{i=0}^{14} X_{900,15k+i}, 900 \le r < 6300\}$
20MHz	$R_{\mathrm{CS_k}} = \{r \mid r \in \bigcup_{i=0}^{14} X_{1200,15k+i}, 1200 \le r < 8400\}$

$X_{n,m} = \{k \mid m = k \left(\bmod n\right), \quad k \text{ are nonnegative integers.}\}$.

2.1.2.2 Bundle of Chunk Space

Bundle of Chunk Space (BCS) consists of several CS's. BCS is defined in Table 2-4 to Table 2-7. For example, BCS$_7$ for channel bandwidth 10MHz is defined as follows;

$$BCS_7 = CS_4 \cup CS_{17} \cup CS_{30}$$

Table 2-4 BCSs for channel bandwidth 5MHz

Bundle of chunk space	Index of CS
BCS$_0$	1, 7, 13
BCS$_1$	3, 9, 15
BCS$_2$	5, 11, 17
BCS$_3$	2, 8, 14
BCS$_4$	4, 10, 16
BCS$_5$	6, 12, 18
BCS$_6$	0, 19

Table 2-5 BCSs for channel bandwidth 10MHz

Bundle of chunk space	Index of CS
BCS$_0$	0, 13, 26
BCS$_1$	6, 19, 32
BCS$_2$	3, 16, 29
BCS$_3$	9, 22, 35
BCS$_4$	12, 25, 38
BCS$_5$	1, 14, 27
BCS$_6$	7, 20, 33

BCS$_7$	4, 17, 30
BCS$_8$	10, 23, 36
BCS$_9$	2, 15, 28
BCS$_{10}$	8, 21, 34
BCS$_{11}$	5, 18, 31
BCS$_{12}$	11, 24, 37
BCS$_{13}$	39

Table 2-6 BCSs for channel bandwidth 15MHz

Bundle of chunk space	Index of CS
BCS$_0$	0, 20, 40
BCS$_1$	10, 30, 50
BCS$_2$	5, 25, 45
BCS$_3$	15, 35, 55
BCS$_4$	1, 21, 41
BCS$_5$	11, 31, 51
BCS$_6$	6, 26, 46
BCS$_7$	16, 36, 56
BCS$_8$	2, 22, 42
BCS$_9$	12, 32, 52
BCS$_{10}$	7, 27, 47
BCS$_{11}$	17, 37, 57
BCS$_{12}$	3, 23, 43
BCS$_{13}$	13, 33, 53
BCS$_{14}$	8, 28, 48
BCS$_{15}$	18, 38, 58
BCS$_{16}$	4, 24, 44
BCS$_{17}$	14, 34, 54
BCS$_{18}$	9, 29, 49
BCS$_{19}$	19, 39, 59

Table 2-7 BCSs for channel bandwidth 20MHz

Bundle of chunk space	Index of CS
BCS$_0$	1, 27, 53
BCS$_1$	14, 40, 66
BCS$_2$	7, 33, 59
BCS$_3$	20, 46, 72
BCS$_4$	2, 28, 54
BCS$_5$	15, 41, 67
BCS$_6$	8, 34, 60
BCS$_7$	21, 47, 73
BCS$_8$	3, 29, 55

BCS_9	16, 42, 68
BCS_{10}	9, 35, 61
BCS_{11}	22, 48, 74
BCS_{12}	4, 30, 56
BCS_{13}	17, 43, 69
BCS_{14}	10, 36, 62
BCS_{15}	23, 49, 75
BCS_{16}	5, 31, 57
BCS_{17}	18, 44, 70
BCS_{18}	11, 37, 63
BCS_{19}	24, 50, 76
BCS_{20}	6, 32, 58
BCS_{21}	19, 45, 71
BCS_{22}	12, 38, 64
BCS_{23}	25, 51, 77
BCS_{24}	13, 39, 65
BCS_{25}	26, 52, 78
BCS_{26}	0, 79

2.1.2.3 Downlink Resource Space

Resource spaces, RS_0~RS_4, are defined in Table 2-8 to Table 2-12.

Table 2-8 RS_0 resource index for each channel bandwidth

Transmission BW	Resource index set of RS_0
5MHz	$R_{\mathrm{RS}_0} = \{r \mid r \in X_{4,0}, 0 \le r < 300\}$
10MHz	$R_{\mathrm{RS}_0} = \{r \mid r \in X_{4,0}, 0 \le r < 600\}$
15MHz	$R_{\mathrm{RS}_0} = \{r \mid r \in X_{4,0}, 0 \le r < 900\}$
20MHz	$R_{\mathrm{RS}_0} = \{r \mid r \in X_{4,0}, 0 \le r < 1200\}$

Table 2-9 RS_1 resource index for each channel bandwidth

Transmission BW	Resource index set of RS_1
5MHz	$R_{\mathrm{RS}_1} = \{r \mid r \in X_{4,1}, 0 \le r < 300\}$
10MHz	$R_{\mathrm{RS}_1} = \{r \mid r \in X_{4,1}, 0 \le r < 600\}$
15MHz	$R_{\mathrm{RS}_1} = \{r \mid r \in X_{4,1}, 0 \le r < 900\}$
20MHz	$R_{\mathrm{RS}_1} = \{r \mid r \in X_{4,1}, 0 \le r < 1200\}$

Table 2-10 RS$_2$ resource index for each channel bandwidth

Transmission BW	Resource index set of RS$_2$
5MHz	$R_{\mathrm{RS}_2} = \{r \mid r \in X_{32,2} \cup X_{32,3}, 0 \le r < 300\}$
10MHz	$R_{\mathrm{RS}_2} = \{r \mid r \in X_{64,2} \cup X_{64,3}, 0 \le r < 600\}$
15MHz	$R_{\mathrm{RS}_2} = \{r \mid r \in X_{96,2} \cup X_{96,3}, 0 \le r < 900\}$
20MHz	$R_{\mathrm{RS}_2} = \{r \mid r \in X_{128,2} \cup X_{128,3}, 0 \le r < 1200\}$

Table 2-11 RS$_3$ resource index for each channel bandwidth

Transmission BW	Resource index set of RS$_3$
5MHz	$R_{\mathrm{RS}_3} = \{r \mid r \in X_{8,2} \cup X_{8,3}, r \notin R_{\mathrm{RS}_2}, 0 \le r < 300\}$
10MHz	$R_{\mathrm{RS}_3} = \{r \mid r \in X_{8,2} \cup X_{8,3}, r \notin R_{\mathrm{RS}_2}, 0 \le r < 600\}$
15MHz	$R_{\mathrm{RS}_3} = \{r \mid r \in X_{8,2} \cup X_{8,3}, r \notin R_{\mathrm{RS}_2}, 0 \le r < 900\}$
20MHz	$R_{\mathrm{RS}_3} = \{r \mid r \in X_{8,2} \cup X_{8,3}, r \notin R_{\mathrm{RS}_2}, 0 \le r < 1200\}$

Table 2-12 RS$_4$ resource index for each channel bandwidth

Transmission BW	Resource index set of RS$_4$
5MHz	$R_{\mathrm{RS}_4} = \{r \mid 0 \le r < 300, r \notin R_{\mathrm{RS}_0} \cup R_{\mathrm{RS}_1} \cup R_{\mathrm{RS}_2} \cup R_{\mathrm{RS}_3}\}$
10MHz	$R_{\mathrm{RS}_4} = \{r \mid 0 \le r < 600, r \notin R_{\mathrm{RS}_0} \cup R_{\mathrm{RS}_1} \cup R_{\mathrm{RS}_2} \cup R_{\mathrm{RS}_3}\}$
15MHz	$R_{\mathrm{RS}_4} = \{r \mid 0 \le r < 900, r \notin R_{\mathrm{RS}_0} \cup R_{\mathrm{RS}_1} \cup R_{\mathrm{RS}_2} \cup R_{\mathrm{RS}_3}\}$
20MHz	$R_{\mathrm{RS}_4} = \{r \mid 0 \le r < 1200, r \notin R_{\mathrm{RS}_0} \cup R_{\mathrm{RS}_1} \cup R_{\mathrm{RS}_2} \cup R_{\mathrm{RS}_3}\}$

The sizes of RS$_0$ ~RS$_4$ are fixed, however those of RS$_5$ ~RS$_{10}$ can vary according to the ratio of high mobility users and the geographical distribution of users. Parameters, DRS$_7$ (Dimension of RS$_7$), DRS$_8$ (Dimension of RS$_8$), DRS$_9$ (Dimension of RS$_9$), and DRS$_{10}$ (Dimension of RS$_{10}$) represent the sizes of RS$_7$ ~RS$_{10}$, and these system parameters are transmitted through Common Control Physical Channel (CCPCH). Resource index sets of RS$_7$ ~RS$_{10}$ are defined in the following way.

$$R_{RS_7} = \bigcup_{i=0}^{DRS_7-1} BCS_i$$

$$R_{RS_8} = \bigcup_{i=DRS_7}^{DRS_7+DRS_8-1} BCS_i$$

$$R_{RS_9} = \bigcup_{i=DRS_7+DRS_8}^{DRS_7+DRS_8+DRS_9-1} BCS_i$$

Resource index sets for RS_{10} are shown in Table 2-13.

Table 2-13 RS_{10} resource index for each channel bandwidth

Transmission BW	Resource index sets of RS_{10}
5MHz	$R_{RS_9} = \bigcup_{i=DRS_7+DRS_8+DRS_9}^{6} BCS_i$
10MHz	$R_{RS_9} = \bigcup_{i=DRS_7+DRS_8+DRS_9}^{13} BCS_i$
15MHz	$R_{RS_9} = \bigcup_{i=DRS_7+DRS_8+DRS_9}^{19} BCS_i$
20MHz	$R_{RS_9} = \bigcup_{i=DRS_7+DRS_8+DRS_9}^{26} BCS_i$

Resource index sets of RS_5~RS_6 are defined in Table 2-14 and Table 2-15.

Table 2-14 RS_5 resource index for each channel bandwidth

Transmission BW	Resource index set of RS_5
5MHz	$R_{\mathrm{RS}_5} = \{r \mid r \in X_{4,0} \cap \left(R_{RS_9} \cup R_{RS_{10}}\right), 300 \le r < 600\}$
10MHz	$R_{\mathrm{RS}_5} = \{r \mid r \in X_{4,0} \cap \left(R_{RS_9} \cup R_{RS_{10}}\right), 600 \le r < 1200\}$
15MHz	$R_{\mathrm{RS}_5} = \{r \mid r \in X_{4,0} \cap \left(R_{RS_9} \cup R_{RS_{10}}\right), 900 \le r < 1800\}$
20MHz	$R_{\mathrm{RS}_5} = \{r \mid r \in X_{4,0} \cap \left(R_{RS_9} \cup R_{RS_{10}}\right), 1200 \le r < 2400\}$

Table 2-15 RS_6 resource index for each channel bandwidth

Transmission BW	Resource index set of RS_6
5MHz	$R_{\mathrm{RS}_6} = \{r \mid r \in X_{4,1} \cap \left(R_{RS_9} \cup R_{RS_{10}}\right), 300 \le r < 600\}$
10MHz	$R_{\mathrm{RS}_6} = \{r \mid r \in X_{4,1} \cap \left(R_{RS_9} \cup R_{RS_{10}}\right), 600 \le r < 1200\}$
15MHz	$R_{\mathrm{RS}_6} = \{r \mid r \in X_{4,1} \cap \left(R_{RS_9} \cup R_{RS_{10}}\right), 900 \le r < 1800\}$
20MHz	$R_{\mathrm{RS}_6} = \{r \mid r \in X_{4,1} \cap \left(R_{RS_9} \cup R_{RS_{10}}\right), 1200 \le r < 2400\}$

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All resource spaces for 10MHz channel bandwidth are illustrated in Figure 2-3.

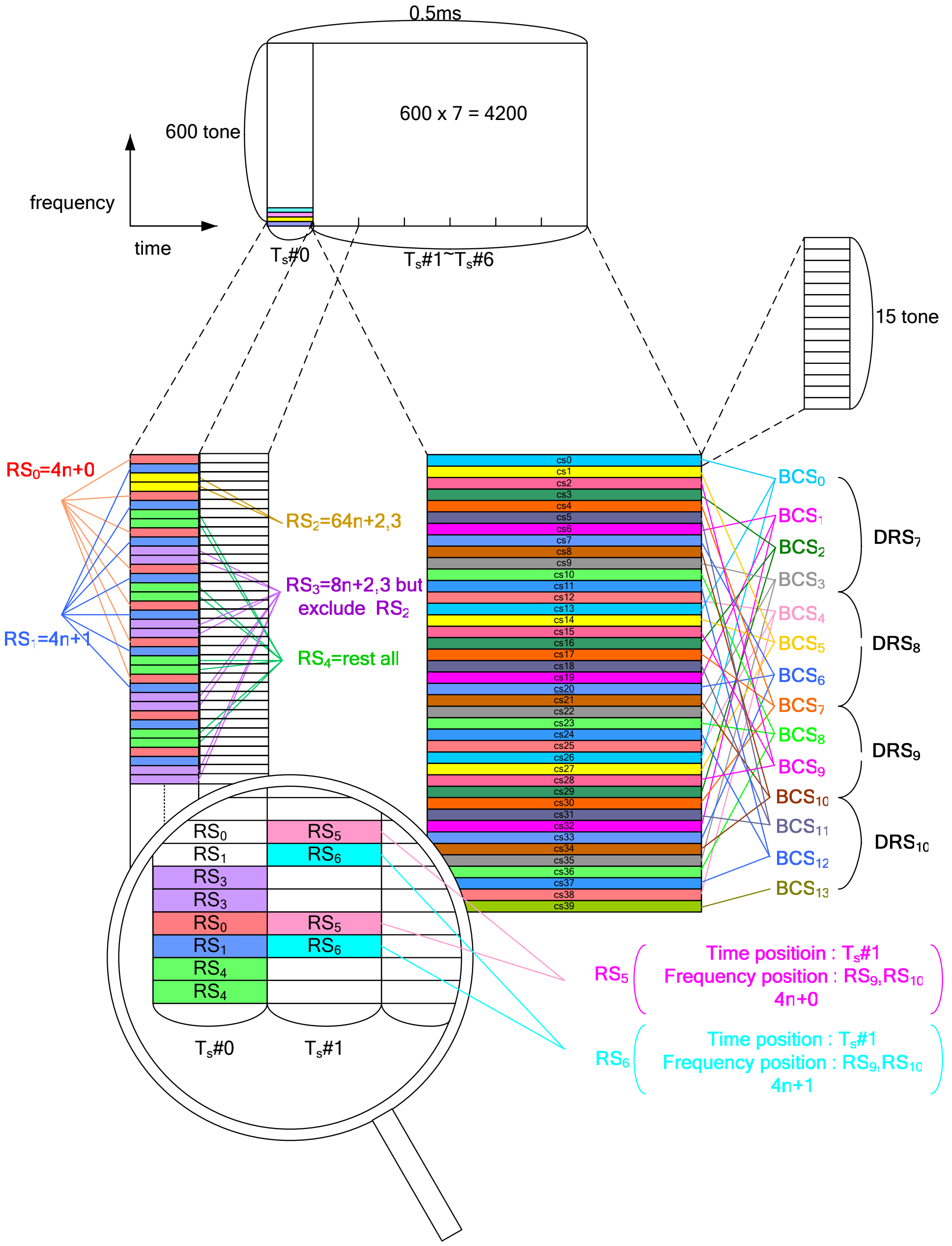

Figure 2-3 Resource space partition of channel bandwidth 10MHz

2.1.2.4 Downlink Resource Subspace

While RS_0~RS_6 are made up of a single resource subspace, RS_7~RS_{10} are divided into several resource subspaces.

In the case of RS_7, its size parameter is given by DRS_7 and it is divided into $3*DRS_7$ resource subspaces. To define resource subspaces of RS_7, it is necessary to define distributed spreading block (DSB). Let the *j*th distributed spreading block of BCS_k be $DSB_{k,j}$.

$$DSB_{\mathrm{k,j}} = \{r^{BCS_k}_{45*\lfloor j/15 \rfloor + j \bmod 15}, r^{BCS_k}_{45*\lfloor j/15 \rfloor + 15 + j \bmod 15}, r^{BCS_k}_{45*\lfloor j/15 \rfloor + 30 + j \bmod 15}\},$$

where $r_m^{BCS_k}$ represents the *m*th resource of BCS_k.

Let the *n*th resource subspace of RS_7 be $RSS_{7,n}$,

$$RSS_{7,\mathrm{n}} = \left\{ r \,\middle|\, r \in \bigcup_{l=0}^{29} DSB^{RS_7}_{\lfloor n/3 \rfloor + \lfloor l/10 \rfloor, 3*l + n \bmod 3} \right\},$$

where $DSB_{i,j}^{RS_7}$ is the *j*th DSB of the *i*th BCS in RS_7.

In the case of RS_8, its size parameter is given by DRS_8 and it is divided into $3*DRS_8$ resource subspaces. Let the *n*th resource subspace of RS_8 be $RSS_{8,n}$,

$$RSS_{8,\mathrm{n}} = \left\{ r \,\middle|\, r^{RS_8}_{\lfloor l/15 \rfloor *30*3*v + (l*3*v + n + \lfloor l/15 \rfloor *v) \bmod (15*3*v)}, r^{RS_8}_{\lfloor l/15 \rfloor *30*3*v + 15*3*v + (l*3*v + n + \lfloor l/15 \rfloor *v) \bmod (15*3*v)}, 0 \le l < 45 \right\}$$

In the case of RS_9 and RS_{10}, the resource space is composed of a single chunk space, that is, if the *k*th CS of RS_{10} is $CS_k^{RS_{10}}$ then $RSS_{10,k}=CS_k^{RS_{10}}$.

In the case of RS_{10}, there is a localized spreading block (LSB) defined below. If the *j*th LSB of $RSS_{10,k}$ is $LSB_{k,j}$,

$$LSB_{\mathrm{k,j}} = \{r^{RSS_{10,k}}_{3*j}, r^{RSS_{10,k}}_{3*j+1}, r^{RSS_{10,k}}_{3*j+2}\},$$

where $r_m^{RSS_{10,k}}$ is the *m*th resource of $RSS_{10,k}$.

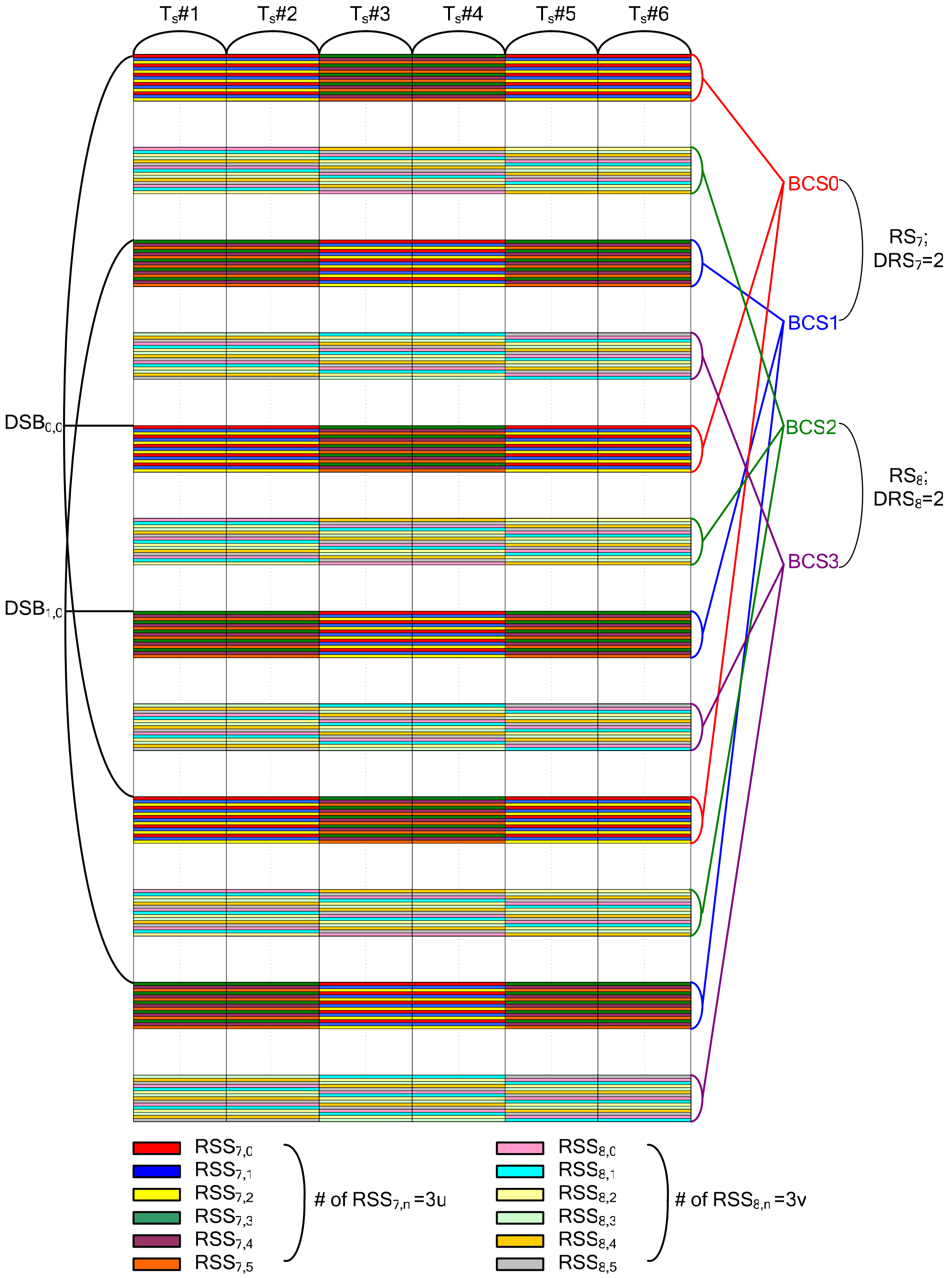

Figure 2-4 RSS$_{7,n}$ and RSS $_{8,n}$ when DRS$_7$ =2 and DRS$_8$=2

2.1.3 Downlink Physical Channel

2.1.3.1 DPICH (Downlink Pilot Channel)

There are 4 transmit antennas at the BS and the pilot channels for transmit antennas uses resource spaces RS_0, RS_1, RS_2, and RS_3 respectively. That is, the pilot channel for antenna i uses RS_i.

DPICH is the downlink physical channel which transmits a predefined symbol sequence in DTP. The location of pilot symbols for the transmit antennas in each DTP is illustrated in Figure 2-5.

There are 4 DPICHs ($DPICH_i$, i=0, 1, 2, 3) in a DTP. The pilot symbols for transmit antennas 0, 1, 2 and 3 are transmitted in $DPICH_0$, $DPICH_1$, $DPICH_2$, and $DPICH_3$ respectively. DPICH0 and DPICH1 are common pilot channels that are always located in DTP, but whether to use $DPICH_2$ and $DPICH_3$ depends on the UE. $DPICH_0$ and $DPICH_1$ are used for estimating the channels of antennas 0 and 1, and also used for searching for the cell group. However, $DPICH_2$ and $DPICH_3$ are used only for estimating the channels of antennas 2 and 3.

$DPICH_0$ consists of $N_p = \lfloor 600/N_{ps} \rfloor = 150$ symbols. N_{ps} (=4) represents the spacing of pilot symbols in the frequency domain.

$DP_{0,k}(m)$ is a pilot symbol in single frame.

$$DP_{0,k}(m) : 0 \le k \le N_p - 1, \quad m = 0,\ 1,\ \cdots,\ N_{sub} - 1$$

N_{sub} represents the number of DTPs in a single frame and m denotes the DTP index.

$DP_{0,k}(m)$ is given by the product of two sequences as shown below.

$$DP_{0,k}(m) = d_k^{(l)} s_k^{(i)} a_k^{(g)}(m), \quad 0 \le k \le N_p - 1,$$

where l, i, and g represent the sector number, cell number, and cell group number, respectively. The sector-specific code $\{d_k^{(l)}\}_{n=0}^{N_p-1}$ is given by

$$d_k^{(l)} = \exp\left(j \frac{2\pi l \cdot (k \bmod 3)}{3} \right), \quad l = 0,1,2\,.$$

The cell-scrambling code $\{s_n^{(i)}\}_{n=0}^{N_p-1}$ is the same for all the subframes.

The cell group-specific code $\{a_n^{(g)}(m)\}_{n=0}^{N_p-1}$, m = 0, 1, …, N_{sub}-1, is different for different subframe number m. The code $a_n^{(g)}(m)$ is made by the differential form of $\{b_n^{(g)}(m)\}_{n=0}^{N_p-2}$.

$$a_0^{(g)}(m) = 1 \;,\quad a_n^{(g)}(m) = b_0^{(g)}(m) b_1^{(g)}(m) \cdots b_{n-1}^{(g)}(m) \quad,\quad n = 1, 2, \cdots, N_p - 1$$

Equivalently, it can be written as follows.

$$a_0^{(g)}(m) = 1 \;,\quad a_n^{(g)}(m) = a_{n-1}^{(g)}(m) b_{n-1}^{(g)}(m)$$

Also, $\{b_n^{(g)}(m)\}_{n=0}^{N_p-2}$, $m = 1, 2, \cdots, N_{sub} - 2$, is made from $\{b_n^{(g)}(0)\}_{n=0}^{N_p-2}$ and $\{c_n^{(g)}(m)\}_{n=0}^{N_p-2}$.

$$b_n^{(g)}(m) = c_n^{(g)}(m-1) b_n^{(g)}(m-1) \quad,\quad m = 1,\ 2, \cdots,\ N_{sub} - 2\,,$$

where $b_n^{(g)}(0) = [\mathbf{W}^{(256)}]_{n+75,g+18}$, $n = 0, 1, \cdots, N_p - 2$, and $[\mathbf{W}^{(256)}]_{n,k}$ is the (n,k)th element of the 256×256 Hadamard matrix.

The code $\{c_n^{(g)}(m)\}_{n=0}^{N_p-2}$ is given as follows.

$$c_n^{(g)}(m) = [\mathbf{W}^{(256)}]_{n+75, f(g,m)+1} \quad,\quad n = 0, 1, \cdots, 148\,,\ m = 0, 1, \cdots, N_{sub} - 2\,,$$

where $f(g,m)$ is the sequence constructed by using the (15,3)-Reed Solomon code and whose value is given at Table 2-16.

DPICH$_1$ is the physical channel transmitting the pilot symbols for the transmit antenna 1 and the sequence of the pilot symbols in DPICH$_1$ is the same sequence as in DPICH$_0$.

DPICH$_2$ and DPICH$_3$ are the physical channel transmitting the pilots for the transmit antennas 2 and 3, respectively. The m-sequence is used as the pilot sequence for DPICH$_2$ and DPICH$_3$.

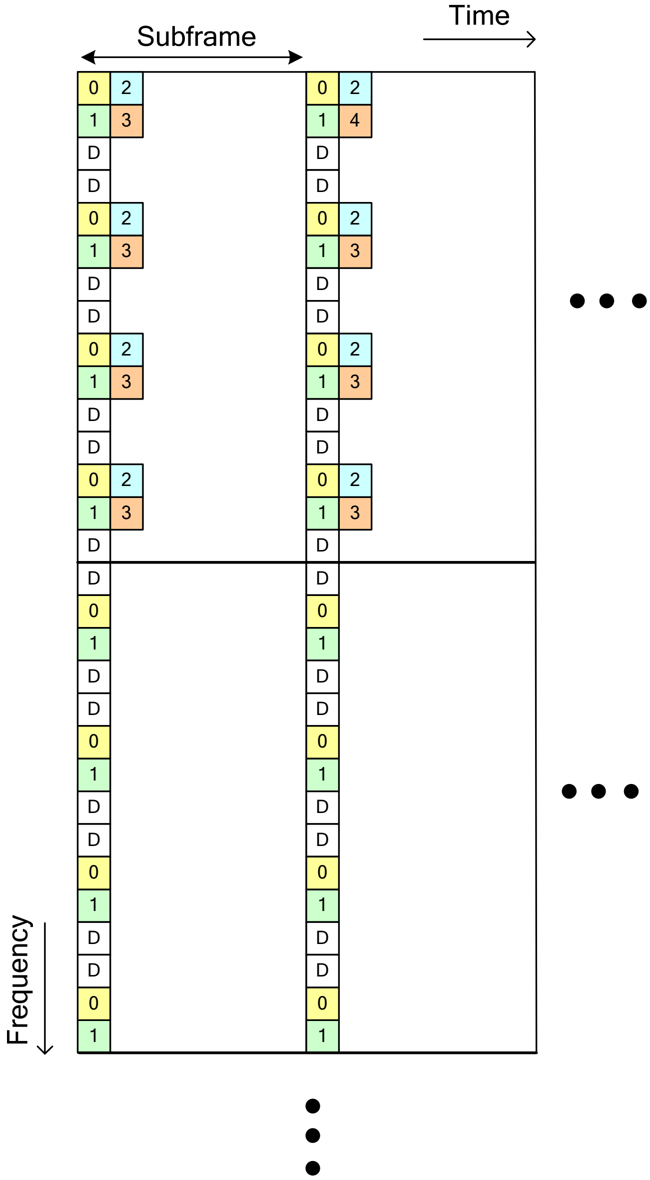

Figure 2-5 DPICH structure

Table 2-16 *f(g,m)*

m g	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
0	1	10	2	14	11	6	5	6	11	14	2	10	1	0	0	1	10	2	14
1	1	2	9	3	10	12	10	3	9	2	1	4	6	6	4	1	2	9	3
2	1	9	7	7	9	1	8	12	15	5	4	5	15	12	8	1	9	7	7
3	1	1	12	10	8	11	7	9	13	9	7	11	8	10	12	1	1	12	10
4	3	12	12	3	0	1	9	15	8	10	8	15	9	1	0	3	12	12	3
5	3	4	7	14	1	11	6	10	10	6	11	1	14	7	4	3	4	7	14
6	3	15	9	10	2	6	4	5	12	1	14	0	7	13	8	3	15	9	10
7	3	7	2	7	3	12	11	0	14	13	13	14	0	11	12	3	7	2	7
8	5	6	13	7	14	8	14	7	13	6	5	0	2	2	0	5	6	13	7
9	5	14	6	10	15	2	1	2	15	10	6	14	5	4	4	5	14	6	10
10	5	5	8	14	12	15	3	13	9	13	3	15	12	14	8	5	5	8	14
11	5	13	3	3	13	5	12	8	11	1	0	1	11	8	12	5	13	3	3
12	7	0	3	10	5	15	2	14	14	2	15	5	10	3	0	7	0	3	10
13	7	8	8	7	4	5	13	11	12	14	12	11	13	5	4	7	8	8	7
14	7	3	6	3	7	8	15	4	10	9	9	10	4	15	8	7	3	6	3
15	7	11	13	14	6	2	0	1	8	5	10	4	3	9	12	7	11	13	14
16	9	1	15	15	1	9	0	4	7	13	12	13	7	4	0	9	1	15	15
17	9	9	4	2	0	3	15	1	5	1	15	3	0	2	4	9	9	4	2
18	9	2	10	6	3	14	13	14	3	6	10	2	9	8	8	9	2	10	6
19	9	10	1	11	2	4	2	11	1	10	9	12	14	14	12	9	10	1	11
20	11	7	1	2	10	14	12	13	4	9	6	8	15	5	0	11	7	1	2
21	11	15	10	15	11	4	3	8	6	5	5	6	8	3	4	11	15	10	15
22	11	4	4	11	8	9	1	7	0	2	0	7	1	9	8	11	4	4	11
23	11	12	15	6	9	3	14	2	2	14	3	9	6	15	12	11	12	15	6
24	13	13	0	6	4	7	11	5	1	5	11	7	4	6	0	13	13	0	6
25	13	5	11	11	5	13	4	0	3	9	8	9	3	0	4	13	5	11	11
26	13	14	5	15	6	0	6	15	5	14	13	8	10	10	8	13	14	5	15
27	13	6	14	2	7	10	9	10	7	2	14	6	13	12	12	13	6	14	2
28	15	11	14	11	15	0	7	12	2	1	1	2	12	7	0	15	11	14	11
29	15	3	5	6	14	10	8	9	0	13	2	12	11	1	4	15	3	5	6
30	15	8	11	2	13	7	10	6	6	10	7	13	2	11	8	15	8	11	2
31	15	0	0	15	12	13	5	3	4	6	4	3	5	13	12	15	0	0	15
32	2	15	11	12	12	11	15	2	0	8	13	4	13	8	0	2	15	11	12
33	2	7	0	1	13	1	0	7	2	4	14	10	10	14	4	2	7	0	1
34	2	12	14	5	14	12	2	8	4	3	11	11	3	4	8	2	12	14	5
35	2	4	5	8	15	6	13	13	6	15	8	5	4	2	12	2	4	5	8
36	0	9	5	1	7	12	3	11	3	12	7	1	5	9	0	0	9	5	1
37	0	1	14	12	6	6	12	14	1	0	4	15	2	15	4	0	1	14	12
38	0	10	0	8	5	11	14	1	7	7	1	14	11	5	8	0	10	0	8
39	0	2	11	5	4	1	1	4	5	11	2	0	12	3	12	0	2	11	5
40	6	3	4	5	9	5	4	3	6	0	10	14	14	10	0	6	3	4	5
41	6	11	15	8	8	15	11	6	4	12	9	0	9	12	4	6	11	15	8

42	6	0	1	12	11	2	9	9	2	11	12	1	0	6	8	6	0	1	12
43	6	8	10	1	10	8	6	12	0	7	15	15	7	0	12	6	8	10	1
44	4	5	10	8	2	2	8	10	5	4	0	11	6	11	0	4	5	10	8
45	4	13	1	5	3	8	7	15	7	8	3	5	1	13	4	4	13	1	5
46	4	6	15	1	0	5	5	0	1	15	6	4	8	7	8	4	6	15	1
47	4	14	4	12	1	15	10	5	3	3	5	10	15	1	12	4	14	4	12
48	10	4	6	13	6	4	10	0	12	11	3	3	11	12	0	10	4	6	13
49	10	12	13	0	7	14	5	5	14	7	0	13	12	10	4	10	12	13	0
50	10	7	3	4	4	3	7	10	8	0	5	12	5	0	8	10	7	3	4
51	10	15	8	9	5	9	8	15	10	12	6	2	2	6	12	10	15	8	9
52	8	2	8	0	13	3	6	9	15	15	9	6	3	13	0	8	2	8	0
53	8	10	3	13	12	9	9	12	13	3	10	8	4	11	4	8	10	3	13
54	8	1	13	9	15	4	11	3	11	4	15	9	13	1	8	8	1	13	9
55	8	9	6	4	14	14	4	6	9	8	12	7	10	7	12	8	9	6	4
56	14	8	9	4	3	10	1	1	10	3	4	9	8	14	0	14	8	9	4
57	14	0	2	9	2	0	14	4	8	15	7	7	15	8	4	14	0	2	9
58	14	11	12	13	1	13	12	11	14	8	2	6	6	2	8	14	11	12	13
59	14	3	7	0	0	7	3	14	12	4	1	8	1	4	12	14	3	7	0
60	12	14	7	9	8	13	13	8	9	7	14	12	0	15	0	12	14	7	9
61	12	6	12	4	9	7	2	13	11	11	13	2	7	9	4	12	6	12	4
62	12	13	2	0	10	10	0	2	13	12	8	3	14	3	8	12	13	2	0
63	12	5	9	13	11	0	15	7	15	0	11	13	9	5	12	12	5	9	13

2.1.3.2 CCFPCH (Control Channel Format Physical Channel)

CCFPCH is the downlink physical channel to inform which resource subspaces in RS_7 are used for SCPCH (Shared Control Physical Channel). CCFPCH uses resource space RS_2.

2.1.3.3 CCPCH (Common Control Physical Channel)

CCPCH is the downlink physical channel which transmits BCH, FACH, PCH, and SCH transport channels at a fixed rate in DTP. CCPCH uses resource space RS_3.

2.1.3.4 SCPCH (Shared Control Physical Channel)

SCPCH is the downlink physical channel which transmits scheduling information of up/down link data channels and ARQ information. SCPCH uses basically resource space RS_4 and additionally resource space RS_7 when it is needed. CCFPCH informs which resource subspaces in RS_7 are used for SCPCH.

2.1.3.5 DSDPCH (Downlink Shared Data Physical Channel)

DSDPCH is the downlink physical channel which transmits downlink STCH transport channel at a variable rate in DTP. This channel consists of a number of DSDSCHs (Downlink Shared Data Subchannel). The number of DSDSCH to be used for a DSDPCH depends on the data size of STCH to be transmitted.

There are 4 types of DSDSCHs, which are basic units of DSDPCH. If the UE speed is high distributed type DSDSCH is used, and if the UE speed is low localized type DSDSCH is used. If inter-cell interference is large, spreading type DSDSCH is used, and if inter-cell interference is small, nonspreading type DSDSCH is used.

2.1.3.5.1 Distributed & Spreading type DSDSCH (DS-DSDSCH)

DS-DSDSCH is used for the UE with high speed mobility and large inter-cell interference. This channel is also used for SCPCH. Resource space RS_7 is used. This channel uses a number of scattered subcarriers, which results in frequency diversity. To reduce inter-cell interference, spreading with spreading factor 3 is used. A DSB is made up of 3 resources and one symbol is spread using these 3 resources of a DSB. A DS-DSDSCH uses one resource subspace of RS_7. Two transmit antennas are used.

2.1.3.5.2 Distributed & Nonspreading type DSDSCH (DN-DSDSCH)

DN-DSDSCH is used for the UE with high speed mobility and small inter-cell interference. Resource space RS_8 is used. This channel uses a number of scattered subcarriers, which results in frequency diversity. Spreading is not used A DN-DSDSCH uses one resource subspace of RS_8. Two transmit antennas are used.

2.1.3.5.3 Localized & Nonspreading type DSDSCH (LN-DSDSCH)

LN-DSDSCH is used for the UE with low speed mobility and small inter-cell interference. Resource space RS_9 is used. This channel uses a number of adjacent subcarrier (chunk), and frequency domain scheduling increases the system throughput by multiuser diversity. Spreading is not used. An LN-DSDSCH uses one resource subspace of RS_9. Four transmit antennas are used. There are 4 LN-DSDSCHs which use the same subcarriers. Since each stream uses an LN-DSDSCH, 4 data streams can be transmitted over a resource subspace. If the number of CS allocated for RS_9 is $3*DRS_9$, the number of LN-DSDSCH is $4*3*DRS_9$.

2.1.3.5.4 Localized & Spreading type DSDSCH (LS-DSDSCH)

LS-DSDSCH is used for the UE with low speed mobility and large inter-cell interference. Resource space RS_{10} is used. This channel uses a number of adjacent subcarrier (chunk), and frequency domain scheduling increases the system throughput by multiuser diversity. To reduce inter-cell interference, spreading with spreading factor 3 is used. An LSB is made up of 3 resources and one symbol is spread using these 3 resources of an LSB. An LS-DSDSCH uses one resource subspace of RS_{10}. Four transmit antennas are used. As is in LN-DSDSCH, there are 4 LS-DSDSCHs which use the same subcarriers. Since each stream uses an LS-DSDSCH, 4 data streams can be transmitted over a resource subspace. In case of bandwidth 10MHz, if the number of CS allocated for RS_{10} is DRS_{10}, the number of LS-DSDSCH is $4*3*DRS_{10}$.

서식 있음: 표준

서식 있음: 제목 2,H2,heading 2

서식 있음: 글머리 기호 및 번호 매기기

2.2 Modulation and Mapping

2.2.1 Overview

서식 있음: 표준

The downlink transmission scheme is based on the conventional OFDMA. Figure 2-6 illustrates the downlink modulation scheme. First, the packets to be transmitted are generated from the channel mapping and coding. The physical channels consist of DPICH, CCFPCH, CCPCH, SCPCH and DSDPCH. The DSDPCH consists of DS-DSDSCH, DN-DSDSCH, LN-DSDSCH and LS-DSDSCH. The block of channel coding mapping and coding in Figure 2-6 is explained in Section 4 and the generation procedure of the DPICH symbol stream is described in Section 2.1. The bit streams from channel mapping and coding block are converted to the symbol streams by the symbol mapping. The symbol streams of DS-DSDSCH and LS-DSDSCH are spread by multiplying the sector-specific spreading code. Then, the output signal of the spreading block is multiplied by the channel gain and mapped to a frequency-time resource. In this step, the symbols from the different channels can be mapped to the same frequency-time resource. In this case, the symbols mapped to the same frequency-time resource are added. After frequency-time mapping, the signal is multiplied by the cell-specific scrambling code and OFDM-modulated by performing the IFFT and inserting the cyclic prefix. Finally, the OFDM-modulated signals are pulse-shaped by windowing.

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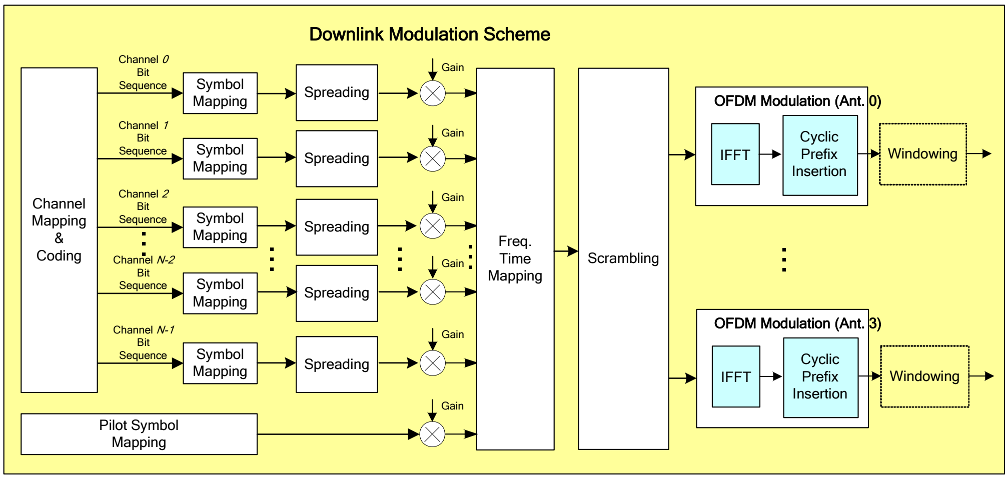

Figure 2-6 Downlink modulation scheme

2.2.2 Symbol Mapping

The bit streams from channel mapping and coding, $\{b_{m,n}\}_{n=0}^{n=Z_m-1}$, are mapped into the symbol streams $\{\mathbf{s}_{m,k}\}_{k=0}^{k=Z'_m-1}$ where Z_m and Z'_m are the lengths of the bit stream and symbol stream, respectively. The k^{th} symbol vector of the m^{th} channel, $\mathbf{s}_{m,k} = \left[s_{m,k,0} \ \cdots \ s_{m,k,N_{\text{TxAnt}}-1} \right]^T$ is the complex vector of size $N_{TxAnt} \times 1$, where N_{TxAnt} is the number of transmit antennas. The i^{th} element $s_{m,k,i}$ of $\mathbf{s}_{m,k}$ to be transmitted by the i^{th} antenna is determined by the modulation schemes (QPSK, 16QAM and 64QAM) and the transmit diversity schemes (SAT, SFBC, STBC and S-PUSRC).

The complex symbol $s_{m,k,i}$ is given by

$$s_{m,k,i} = (I_{i,out}^{m,k} + jQ_{i,out}^{m,k}) \times K_{MOD} \times \frac{1}{\sqrt{N_{TxAnt}}},$$

where $I_{i,out}^{m,k}$ and $Q_{i,out}^{m,k}$ are real and imaginary parts of the complex modulation symbol, respectively, and K_{MOD} is the normalization factor. The normalization factor K_{MOD} is given by Table 2-17.

서식 있음: 글자 위치 내림: 3 pt

서식 있음: 글자 위치 내림: 3 pt

서식 있음: 글자 위치 내림: 6 pt

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서식 있음: 글자 위치 내림: 7 pt

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Table 2-17 K_{MOD} for each modulation scheme

Modulation	K_{MOD}
QPSK	1/√2
16QAM	1/√10
64QAM	1/√42

2.2.2.1 SAT

Figure 2-7 illustrates the symbol mapping and

Table 2-18 shows the N_{CBPT} (Number of Coded Bit Per Tone) for each modulation scheme. The bit stream of the m^{th} channel, $\{b_{m,n}\}_{n=0}^{n=Z_m-1}$ is serial-to-parallel converted to N_{CBPT} bits, and then mapped to a complex symbol according to the modulation scheme.

서식 있음: 맞춤법 및 문법 검사 안 함

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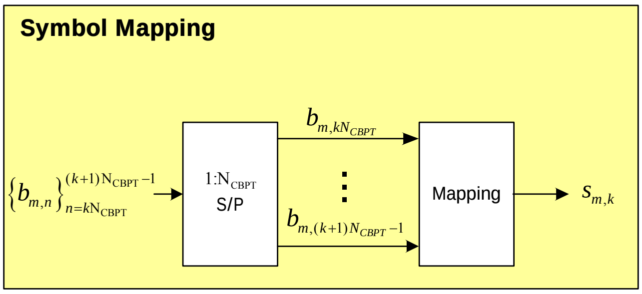

Figure 2-7 Symbol mapping

Table 2-18 N_{CBPT} and modulation scheme

N_{CBPT}	Modulation Option	Antenna Scheme	N_{TxAnt}
2	QPSK	SAT	1
2	QPSK	SFBC	2
4	QPSK	SPEX	2
4	16-QAM	SAT	1
4	16-QAM	SFBC	2
6	64-QAM	SAT	1
6	64-QAM	SFBC	2

8	16-QAM	SPEX	2
2	QPSK	S-PUSRC	4
4	16-QAM	S-PUSRC	4
6	64-QAM	S-PUSRC	4

The mapping method of each modulation scheme is shown in Table 2-19 to Table 2-21.

Table 2-19 QPSK-SAT modulation

$b_{m,k\times N_{CBPT}}$	$I_{0,out}^{m,k}$	$b_{m,k\times N_{CBPT}+1}$	$Q_{0,out}^{m,k}$
0	1	0	1
1	-1	1	-1

Table 2-20 16QAM-SAT modulation

$b_{m,k\times N_{CBPT}}, b_{m,k\times N_{CBPT}+2}$	$I_{0,out}^{m,k}$	$b_{m,k\times N_{CBPT}+1}, b_{m,k\times N_{CBPT}+3}$	$Q_{0,out}^{m,k}$
00	1	00	1
01	3	01	3
10	-1	10	-1
11	-3	11	-3

Table 2-21 64QAM-SAT modulation method

$b_{m,k\times N_{CBPT}}, b_{m,k\times N_{CBPT}+2}, b_{m,k\times N_{CBPT}+4}$	$I_{0,out}^{m,k}$	$b_{m,k\times N_{CBPT}+1}, b_{m,k\times N_{CBPT}+3}, b_{m,k\times N_{CBPT}+5}$	$Q_{0,out}^{m,k}$
001	1	001	1
000	3	000	3
010	5	010	5
011	7	011	7
101	-1	101	-1
100	-3	100	-3
110	-5	110	-5
111	-7	111	-7

2.2.2.2 SFBC or STBC

The procedures of SFBC and STBC are the same. Figure 2-8 shows the symbol mapping of SFBC (or STBC). The bit stream of the m^{th} channel $\{b_{m,n}\}_{n=0}^{n=Z_m-1}$ is serial-to-parallel converted to $2\times N_{CBPT}$ bits, and then mapped to the complex symbol for SFBC (or STBC).

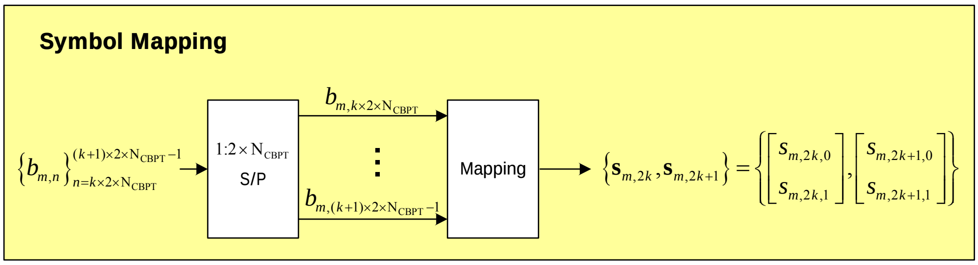

Figure 2-8 SFBC or STBC symbol mapping

The mapping method for each modulation scheme is shown in Table 2-22 to Table 2-24.

Table 2-22 QPSK-SFBC/STBC modulation

$b_{m,k\times2\times N_{CBPT}}$	$I^{m,2\times k}_{0,out}$	$I^{m,2\times k+1}_{1,out}$	$b_{m,k\times2\times N_{CBPT}+1}$	$Q^{m,2\times k}_{1,out}$	$Q^{m,2\times k+1}_{0,out}$
0	1	1	0	1	-1
1	-1	-1	1	-1	1
$b_{m,k\times2\times N_{CBPT}+2}$	$I^{m,2\times k}_{1,out}$	$I^{m,2\times k+1}_{0,out}$	$b_{m,k\times2\times N_{CBPT}+3}$	$Q^{m,2\times k}_{0,out}$	$Q^{m,2\times k+1}_{1,out}$
0	1	-1	0	1	1
1	-1	1	1	-1	-1

Table 2-23 16QAM-SFBC/STBC modulation

$b_{m,k\times2\times N_{CBPT}}, b_{k\times2\times N_{CBPT}+2}$	$I^{m,2\times k}_{0,out}$	$b_{m,k\times2\times N_{CBPT}+1}, b_{m,k\times2\times N_{CBPT}+3}$	$Q^{m,2\times k}_{0,out}$
00	1	00	1
01	3	01	3
10	-1	10	-1
11	-3	11	-3

$b_{m,k\times2\times N_{CBPT}+4}, b_{m,k\times2\times N_{CBPT}+6}$	$I_{1,out}^{m,2\times k}$	$b_{m,k\times2\times N_{CBPT}+5}, b_{m,k\times2\times N_{CBPT}+7}$	$Q_{1,out}^{m,2\times k}$
00	1	00	1
01	3	01	3
10	-1	10	-1
11	-3	11	-3
$b_{m,k\times2\times N_{CBPT}}, b_{m,k\times2\times N_{CBPT}+2}$	$I_{1,out}^{m,2\times k+1}$	$b_{m,k\times2\times N_{CBPT}+1}, b_{m,k\times2\times N_{CBPT}+3}$	$Q_{1,out}^{m,2\times k+1}$
00	1	00	-1
01	3	01	-3
10	-1	10	1
11	-3	11	3
$b_{m,k\times2\times N_{CBPT}+4}, b_{m,k\times2\times N_{CBPT}+6}$	$I_{0,out}^{m,2\times k+1}$	$b_{m,k\times2\times N_{CBPT}+5}, b_{m,k\times2\times N_{CBPT}+7}$	$Q_{0,out}^{m,2\times k+1}$
00	-1	00	1
01	-3	01	3
10	1	10	-1
11	3	11	-3

Table 2-24 64QAM-SFBC/STBC modulation

$b_{m,k\times2\times N_{CBPT}}, b_{m,k\times2\times N_{CBPT}+2}, b_{m,k\times2\times N_{CBPT}+4}$	$I_{0,out}^{m,2\times k}$	$b_{m,k\times2\times N_{CBPT}+1}, b_{m,k\times2\times N_{CBPT}+3}, b_{m,k\times2\times N_{CBPT}+5}$	$Q_{0,out}^{m,2\times k}$
001	1	001	1
000	3	000	3
010	5	010	5
011	7	011	7
101	-1	101	-1
100	-3	100	-3
110	-5	110	-5
111	-7	111	-7
$b_{m,k\times2\times N_{CBPT}+6}, b_{m,k\times2\times N_{CBPT}+8}, b_{m,k\times2\times N_{CBPT}+10}$	$I_{1,out}^{m,2\times k}$	$b_{m,k\times2\times N_{CBPT}+7}, b_{m,k\times2\times N_{CBPT}+9}, b_{m,k\times2\times N_{CBPT}+11}$	$Q_{1,out}^{m,2\times k}$
001	1	001	1
000	3	000	3
010	5	010	5
011	7	011	7
101	-1	101	-1
100	-3	100	-3
110	-5	110	-5
111	-7	111	-7

$b_{m,k\times2\times N_{CBPT}}$, $b_{m,k\times2\times N_{CBPT}+2}$, $b_{m,k\times2\times N_{CBPT}+4}$	$I_{1,out}^{m,2\times k+1}$	$b_{m,k\times2\times N_{CBPT}+1}$, $b_{m,k\times2\times N_{CBPT}+3}$, $b_{k\times2\times N_{CBPT}+5}$	$Q_{1,out}^{m,2\times k+1}$
001	1	001	-1
000	3	000	-3
010	5	010	-5
011	7	011	-7
101	-1	101	1
100	-3	100	3
110	-5	110	5
111	-7	111	7
$b_{m,k\times2\times N_{CBPT}+6}$, $b_{m,k\times2\times N_{CBPT}+8}$, $b_{m,k\times2\times N_{CBPT}+10}$	$I_{0,out}^{m,2\times k+1}$	$b_{m,k\times2\times N_{CBPT}+7}$, $b_{m,k\times2\times N_{CBPT}+9}$, $b_{m,k\times2\times N_{CBPT}+11}$	$Q_{0,out}^{m,2\times k+1}$
001	-1	001	1
000	-3	000	3
010	-5	010	5
011	-7	011	7
101	1	101	-1
100	3	100	-3
110	5	110	-5
111	7	111	-7

2.2.2.3 SPEX

Figure 2-9 shows the symbol mapping of SPEX scheme. The bit stream of the m^{th} channel $\{b_{m,n}\}_{n=0}^{n=Z_m-1}$ is serial-to-parallel converted to N_{CBPT} bits, and then mapped to the complex symbol for SPEX scheme.

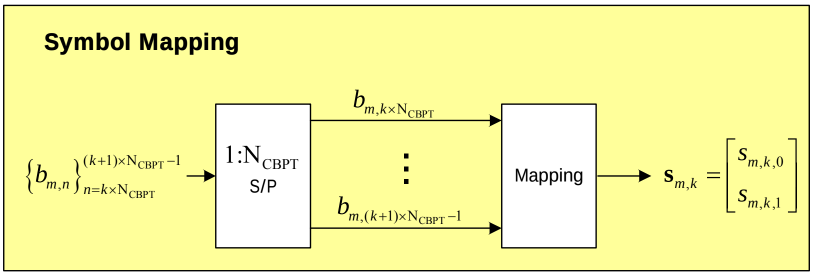

Figure 2-9 SPEX symbol mapping

The mapping method of each modulation scheme is shown in Table 2-25 and Table 2-26

Table 2-25 QPSK-SPEX modulation

$b_{m,k\times N_{CBPT}}$	$I^{m,k}_{0,out}$	$b_{m,k\times N_{CBPT}+1}$	$Q^{m,k}_{0,out}$
0	1	0	1
1	-1	1	-1
$b_{m,k\times N_{CBPT}+2}$	$I^{m,k}_{1,out}$	$b_{m,k\times N_{CBPT}+3}$	$Q^{m,k}_{1,out}$
0	1	0	1
1	-1	1	-1

Table 2-26 16QAM-SPEX modulation

$b_{m,k\times N_{CBPT}}, b_{m,k\times N_{CBPT}+2}$	$I^{m,k}_{0,out}$	$b_{m,k\times N_{CBPT}+1}, b_{m,k\times N_{CBPT}+3}$	$Q^{m,k}_{0,out}$
00	1	00	1
01	3	01	3
10	-1	10	-1
11	-3	11	-3
$b_{m,k\times N_{CBPT}+4}, b_{m,k\times N_{CBPT}+6}$	$I^{m,k}_{1,out}$	$b_{m,k\times N_{CBPT}+5}, b_{m,k\times N_{CBPT}+7}$	$Q^{m,k}_{1,out}$
00	1	00	1
01	3	01	3
10	-1	10	-1
11	-3	11	-3

2.2.2.4 S-PUSRC

Figure 2-10 shows the symbol mapping of S-PUSRC scheme. The bit stream of the m^{th} channel $\left\{b_{m,n}\right\}_{n=0}^{n=Z_m-1}$ is serial-to-parallel converted to N_{CBPT} bits, and then mapped to the complex symbol for S-PUSRC scheme.

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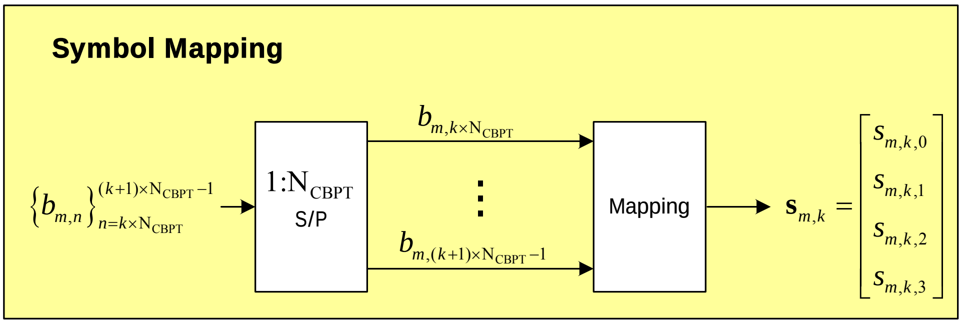

Figure 2-10 S-PUSRC symbol mapping

The symbol mapping is composed of two steps. The result of the first step is given by

$$\bar{s}_{m,k} = \bar{I}_{0,out}^{m,k} + j\bar{Q}_{0,out}^{m,k},$$

and Table 2-27 to Table 2-29 show the mapping method for each modulation scheme.

Table 2-27 QPSK-S-PUSRC symbol mapping

$b_{k\times N_{CBPT}}$	$\bar{I}_{0,out}^{m,k}$	$b_{k\times N_{CBPT}+1}$	$\bar{Q}_{0,out}^{m,k}$
0	1	0	1
1	-1	1	-1

Table 2-28 16QAM-S-PUSRC symbol mapping

$b_{k\times N_{CBPT}}, b_{k\times N_{CBPT}+2}$	$\bar{I}_{0,out}^{m,k}$	$b_{k\times N_{CBPT}+1}, b_{k\times N_{CBPT}+3}$	$\bar{Q}_{0,out}^{m,k}$
00	1	00	1
01	3	01	3
10	-1	10	-1
11	-3	11	-3

Table 2-29 64QAM-S-PUSRC symbol mapping

$b_{k\times N_{CBPT}}, b_{k\times N_{CBPT}+2}, b_{k\times N_{CBPT}+4}$	$\bar{I}_{0,out}^{m,k}$	$b_{k\times N_{CBPT}+1}, b_{k\times N_{CBPT}+3}, b_{k\times N_{CBPT}+5}$	$\bar{Q}_{0,out}^{m,k}$
001	1	001	1
000	3	000	3
010	5	010	5
011	7	011	7

101	-1	101	-1
100	-3	100	-3
110	-5	110	-5
111	-7	111	-7

In the second step, the symbol vector $\mathbf{s}_{m,k} = [s_{m,k,0}, s_{m,k,1}, s_{m,k,2}, s_{m,k,3}]$ is obtained by multiplying $\bar{s}_{m,k}$ by the precoding vector $\mathbf{u}_m = [\ u_0^m, u_1^m, u_2^m, u_3^m\ ]$ and the normalization factor as follows.

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$$s_{m,k,i} = (I_{i,out}^{m,k} + jQ_{i,out}^{m,k}) \times K_{MOD} \times \frac{1}{\sqrt{N_{TxAnt}}}$$

where

$$I_{i,out}^{m,k} = \bar{I}_{i,out}^{m,k} \times \mathrm{Re}[u_i^m] - \bar{Q}_{i,out}^{m,k} \times \mathrm{Im}[u_i^m]\ ,\ Q_{i,out}^{m,k} = \bar{I}_{i,out}^{m,k} \times \mathrm{Im}[u_i^m] + \bar{Q}_{i,out}^{m,k} \times \mathrm{Re}[u_i^m]\ .$$

2.2.3 Spreading

The spreading is applied to DS-DSDSCH and LS-DSDSCH. Figure 2-11 illustrates the spreading method. The input symbol is spread by multiplying the sector-specific spreading code $\{\ c_0^{(j)},\ c_1^{(j)},\ c_2^{(j)}\ \}$. After spreading, the symbol is given by

$$\tilde{\mathbf{s}}_{m,3k+l} = c_l^{(j)} \mathbf{s}_{m,k}\quad ,\quad l = 0,1,\cdots,2\ .$$

The spreading codes $\{\ c_0^{(j)},\ c_1^{(j)}, c_2^{(j)}\ \}$ and $\{\ c_0^{(j')},\ c_1^{(j')}, c_2^{(j')}\ \}$ of sectors j and j' in the same cell are designed to be orthogonal. The spreading codes for the three-sector systems are $\{\ 1,\ 1, 1\ \}\quad ,\quad \{\ 1,\ e^{j2/3\pi}, e^{-j2/3\pi}\ \}$ and $\{\ 1,\ e^{-j2/3\pi}, e^{j2/3\pi}\ \}$.

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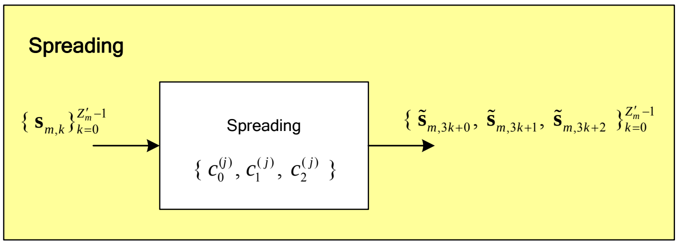

Figure 2-11 Spreading

2.2.4 Frequency-Time mapping

The spread signal vector $\{\tilde{\mathbf{s}}_{m,3k}, \tilde{\mathbf{s}}_{m,3k+1}, \tilde{\mathbf{s}}_{m,3k+2}\}_{k=0}^{Z'_m-1}$ for the spreading-type channels (DS-DSDSCH and LS-DSDSCH) and the non-spread signal $\{\tilde{\mathbf{s}}_{m,k}\}_{k=0}^{Z'_m-1}$ for the non-spreading type channels (DN-DSDSCH and LN-DSDSCH) are multiplied by channel gain G_m. The spread symbol for DS-DSDSCH is mapped to a Distributed Spreading Block (DSB). The spread symbol for LS-DSDSCH is mapped to a Localized Spreading Block (LSB). The non-spread symbol for DN-DSDSCH and LN-DSDSCH is mapped to a frequency-time bin.

The symbol associated with resource index r is mapped to OFDM symbol time t and subcarrier f in the DTP as follows.

$$t = \lfloor r / N \rfloor,$$

$$f = r \bmod N$$

where N is the number of the used subcarriers (e.g. N = 600 for 10 MHz bandwidth). In this step, the symbols from the different channels can be mapped to the same frequency-time resource. In this case, symbols mapped to the same frequency-time resource are added.

2.2.5 Scrambling

Figure 2-11 illustrates the scrambling method. The frequency-time mapped signal is multiplied by the cell-specific scrambling code. The M-PSK modulated pseudo random sequence is used for the cell-specific scrambling code.

2.2.6 OFDM Modulation

The frequency domain structure of an OFDM symbol is described in Figure 2-12. The DC subcarrier is not used and $N_{sc,D}$ subcarriers are located in both sides of DC subcarrier with spacing Δf. $N_{sc,D}$ is FFT size. $N_{sc,D}/2$ subcarriers are in each side.

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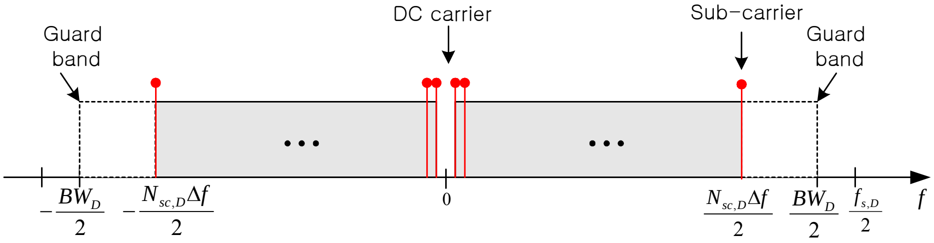

Figure 2-12 The frequency domain structure of OFDM symbol in downlink

The baseband signal of n^{th} OFDM symbol to be transmitted by antenna i is as follows:

$$S_{n,D}^{i}(t)=\sum_{q=-N_{SC,D}/2}^{N_{SC,D}/2}U_{q,i}(n)\Psi_{q,n}(t),$$

where q is the index of subcarriers, n the index of OFDM symbol, $U_{q,i}(n)$ the n^{th} OFDM complex symbol of q^{th} subcarrier to be transmitted by antenna i and

$$\Psi_{q,n}(t)=\begin{cases}\exp\left(j2\pi k\Delta f\left(t-T_g-nT_{sym}\right)\right), & nT_{sym}\le t\le (n+1)T_{sym}\\ 0, & \text{otherwise}\end{cases}.$$

The method of constructing OFDM symbol with CP is illustrated in Figure 2-13. The signal with CP, denoted by $\tilde{S}_{n,D}^{i}(t)$, is as follows:

$$\tilde{S}_{n,D}^{i}(t)=\begin{cases}S_{n,D}^{i}\left(t+T_d-T_g\right), & nT_{sym}\le t\le nT_{sym}+T_g\\ S_{n,D}^{i}\left(t-T_g\right), & nT_{sym}+T_g\le t\le (n+1)T_{sym}\\ 0, & \text{otherwise}\end{cases}.$$

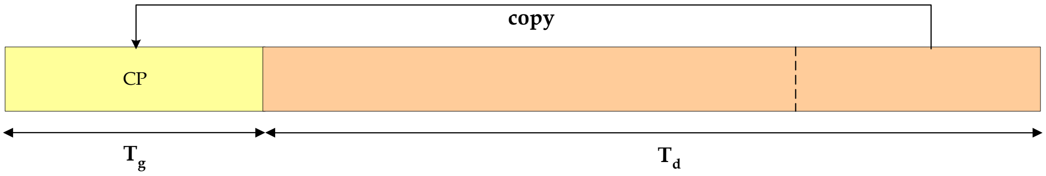

Figure 2-13 OFDM symbol with CP

2.2.7 Windowing

To minimize the leakage of OFDM signals to other bands, windowing is used in the time domain. The baseband signal with windowing, denoted by $\hat{S}^{i}_{n,D}(t)$ is as follows:

i) when the rectangular window is used ,

$$\hat{S}^{i}_{n,D}(t) = \tilde{S}^{i}_{n,D}(t)$$

ii) when the raised cosine window is used ,

$$\hat{S}^{i}_{n,D}(t) = \begin{cases} w(t+\alpha T_{sym}/2)\tilde{S}^{i}_{n,D}(t+T_d-\alpha T_{sym}/2), & -\alpha T_{sym}/2 \le t \le 0 \\ w(t+\alpha T_{sym}/2)\tilde{S}^{i}_{n,D}(t), & 0 \le t \le T_{sym} \\ w(t+\alpha T_{sym}/2)\tilde{S}^{i}_{n,D}(t-T_{sym}+T_g), & T_{sym} \le t \le (1+\alpha/2)T_{sym} \\ 0, & \text{otherwise} \end{cases}$$

where

$$w(t) = \begin{cases} 0.5+0.5\cos(\pi + t\pi/(\alpha T_{sym})), & 0 \le t \le \alpha T_{sym} \\ 1, & \alpha T_{sym} \le t \le T_{sym} \\ 0.5+0.5\cos((t-T_{sym})\pi/(\alpha T_{sym})), & T_{sym} \le t \le (1+\alpha)T_{sym} \\ 0, & \text{otherwise} \end{cases}.$$

Here, α is a roll-off factor which can be optimized within $\alpha < T_g/T_{sym}$ to minimize the leakage of OFDM signals. Finally, the transmission baseband signal of antenna i , denoted by $S^{i}_{D}(t)$ is

$$S^{i}_{D}(t) = \sum_{n=-\infty}^{\infty} \hat{S}^{i}_{n,D}(t).$$

3 Uplink

3.1 Physical Channels and Frame Structure

3.1.1 Transport Channels

Transport channels include State Control Channel (SCH), Random Access Channel (RACH), and Shared Traffic Channel (STCH).

3.1.1.1 SCH

SCH is an uplink or downlink transport channel and transmits information for controlling the state of UE.

3.1.1.2 RACH

RACH is an uplink transport channel and is transmitted over the whole cell.

3.1.1.3 STCH

STCH is an uplink or downlink transport channel and is shared by one or more UEs.

3.1.2 Resource partition for channelization

The length of a frame is T_{frame} and a frame consists of 20 UTPs (uplink Traffic Packet) , each of which has T_{DTP}=0.5 ms. The uplink frame structure is illustrated in Figure 3-1

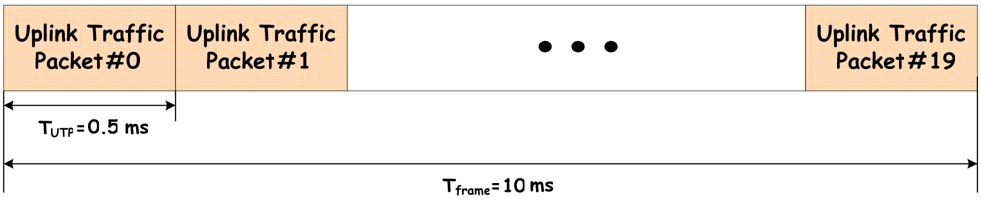

Figure 3-1 Uplink frame structure

T_{frame}=10ms and T_{UTP}=0.5ms.

A frame consists of 20 UTP and 8 OFDM symbols form a UTP. The number of resources which can be used in UTP and resource index set are defined in Table 3-1. This resource is divided into 3 resource spaces and each space can be further divided into subspaces.

Table 3-1 Number of resources and resource index set

BW	Used Subcarrier(K)	Resource Index Set
5	300	$R_{\mathrm{UTP}} = \{r \mid 0 \le r < 2400\}$
10	600	$R_{\mathrm{UTP}} = \{r \mid 0 \le r < 4800\}$
15	900	$R_{\mathrm{UTP}} = \{r \mid 0 \le r < 7200\}$
20	1200	$R_{\mathrm{UTP}} = \{r \mid 0 \le r < 9600\}$

A half of the resource spaces are used in the case of the 1st and the 6th OFDM symbols since their symbol duration is a half of the usual OFDM symbol time.

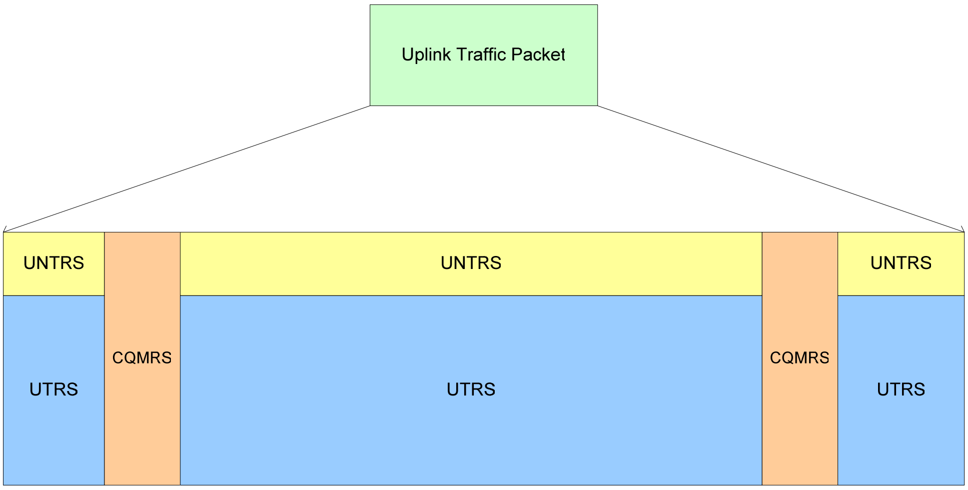

Figure 3-2 Resource space structure of UTP

3.1.2.1 Channel Quality Measurement Resource Space

The resource index set for CQMRS, R_{CQMRS} is defined as

$$R_{\mathrm{CQMRS}} = \{r \mid \left\lfloor \frac{r}{K} \right\rfloor = 1,6\}\,.$$

CQMRS is divided into CQMRSS (Channel Quality Measurement Resource Sub-space) and PRSS (Pilot Resource Sub-space) which are used for channel quality measurement and channel estimation at the receiver, respectively.

Table 3-2 Resource index set of CQMRS

N_{TxAnt}	SubSpace	Resource Index Set
1	CQMRSS	$\{r \mid K \le r < K + \frac{8}{15}K, r \in \bigcup_{q=0,2,4} X_{8,q}\}$ $\bigcup\{r \mid 6K \le r < 6K + \frac{8}{15}K, r \in \bigcup_{q=3,5,7} X_{8,q}\}$
	PRSS_0	$\{r \mid K \le r < K + \frac{8}{15}K, r \in \bigcup_{q=6} X_{8,q}\}$ $\bigcup\{r \mid 6K \le r < 6K + \frac{8}{15}K, r \in \bigcup_{q=1} X_{8,q}\}$
	PRSS_1	$\{r \mid k + \frac{8}{15}K \le r < 2K, r \bmod 2 = 0\}$ $\bigcup\{r \mid 6K + \frac{8}{15}K \le r < 7K, r \bmod 2 = 1\}$
2	CQMRSS	$\{r \mid K \le r < K + \frac{8}{15}K, r \in \bigcup_{q=0,4} X_{8,q}\}$ $\bigcup\{r \mid 6K \le r < 6K + \frac{8}{15}K, r \in \bigcup_{q=3,5} X_{8,q}\}$
	PRSS_0	$\{r \mid K \le r < K + \frac{8}{15}K, r \in \bigcup_{q=2,6} X_{8,q}\}$ $\bigcup\{r \mid 6K \le r < 6K + \frac{8}{15}K, r \in \bigcup_{q=1,7} X_{8,q}\}$
	PRSS_1	$\{r \mid K + \frac{8}{15}K \le r < 2K, r \bmod 2 = 0\}$ $\bigcup\{r \mid 6K + \frac{8}{15}K \le r < 7K, r \bmod 2 = 1\}$

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3.1.2.2 Uplink Non-Traffic Resource Space

The resource index set for UNTRS, R_{UNTRS} is a subset of the remaining set after removing R_{CQMRS} from the resource space for UTP.

$$R_{\text{UNTRS}} \subset \{r \mid \frac{8}{15}K \le r < K\} \bigcup \{r \mid 2K \le r < 6K, r \text{ modK} \ge \frac{8}{15}K\} \bigcup \{r \mid 7K + \frac{8}{15}K \le r < 8K\}$$

There are 5 subspaces, UNTRS$_0$ ~ UNTRS$_4$ in UNTRS and the resource index set for each subspace is shown in Table 3-3.

Table 3-3 Resource index set for UNTRS

SubSpace	Resource Index Set
UNTRSS$_0$	$\{r \mid r \in R_{UNTRS}, r \in \bigcup_{\substack{m=3 \\ q=0,\cdots,\frac{K}{150}-1}} X_{\frac{7}{150}K, \frac{K}{150}m+q}\}$
UNTRSS$_1$	$\{r \mid r \in R_{UNTRS}, r \in \bigcup_{\substack{m=4,5,11 \\ q=0,\cdots,\frac{K}{150}-1}} X_{\frac{7}{75}K, \frac{K}{150}m+q}\}$
UNTRSS$_2$	$\{r \mid r \in R_{UNTRS}, r \in \bigcup_{\substack{m=6,12 \\ q=0,\cdots,\frac{K}{150}-1}} X_{\frac{7}{75}K, \frac{K}{150}m+q}\}$
UNTRSS$_3$	$\{r \mid r \in R_{UNTRS}, r \in \bigcup_{\substack{m=13,41,69 \\ q=0,\cdots,\frac{K}{150}-1}} X_{\frac{7}{15}K, \frac{K}{150}m+q}\}$
UNTRSS$_4$	$\{r \mid r \in R_{UNTRS}, r \in \bigcup_{\substack{m=27,55 \\ q=0,\cdots,\frac{K}{150}-1}} X_{\frac{7}{15}K, \frac{K}{150}m+q}\}$

3.1.2.3 Uplink Traffic Resource Space

The resource index set for UTRS, R_{UTRS} is a subset of the remaining set after removing R_{CQMRS} and R_{UNTRS} from the resource space for UTP .

$$R_{\text{UTRS}} \subset \{r \mid 0 \le r < K\} \bigcup \{r \mid 2K \le r < 6K\} \bigcup \{r \mid 7K \le r < 8K\}$$

$$R_{\text{UTRS}} \bigcap (R_{\text{UNTRS}} \bigcup R_{CQMRS}) = \varnothing$$

UTRS is further divided into two subspaces: one is for localized channels and the other for distributed channels.

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For localized channels,

$$\{r \mid r \notin R_{CQMRS}, \left(r \bmod \mathrm{K}\right) < \frac{8}{15}K, \left\lfloor \frac{r \bmod \mathrm{K}}{80} \right\rfloor = q, q = 0,1,\cdots,\frac{8}{15\times 80}K-1\}.$$

For distributed channels,

$$\{r \mid r \notin R_{CQMRS}, \left(r \bmod \mathrm{K}\right) \geq \frac{8}{15}K, r \in \bigcup_{\substack{m=0,1,2 \\ q=0,\cdots,\frac{K}{150}-1}} X_{\frac{7}{150}K, \frac{K}{150}m+q}\}$$

3.1.3 Uplink Resource Index Set Division

Each space or sub-space is divided into several resource index subsets.

3.1.3.1 Channel Quality Measurement Resource Space

When the number of transmit antenna is 1, a CQMRS consists of $6\times\frac{K}{150}$ resource index subsets, RIS_i^{CQMRS}, where $0 \leq i < 6\times\frac{K}{150}$. When the number of transmit antenna is 2, a CQMRS consists of $4\times\frac{K}{150}$ resource index subsets, RIS_i^{CQMRS}, where $0 \leq i < 4\times\frac{K}{150}$.

3.1.3.2 Uplink Non-Traffic Resource SubSpace 0

A UNTRSS$_0$ consists of $\frac{K}{150}$ resource index subsets, $RIS_i^{\mathrm{UNTRSS}_0}$, where $0 \leq i < \frac{K}{150}$.

3.1.3.3 Uplink Non-Traffic Resource SubSpace 1

A UNTRSS$_1$ consists of $3\times\frac{K}{150}$ resource index subsets, $RIS_i^{\mathrm{UNTRSS}_1}$, where $0 \leq i < 3\times\frac{K}{150}$.

3.1.3.4 Uplink Non-Traffic Resource SubSpace 2

A UNTRSS$_2$ consists of $2\times\frac{K}{150}$ resource index subsets, $RIS_i^{\mathrm{UNTRSS}_2}$, where $0\le i<2\times\frac{K}{150}$.

3.1.3.5 Uplink Non-Traffic Resource SubSpace 3

A UNTRSS$_3$ consists of $\frac{K}{150}$ resource index subsets, $RIS_i^{\mathrm{UNTRSS}_3}$, where $0\le i<\frac{K}{150}$.

3.1.3.6 Uplink Non-Traffic Resource SubSpace 4

A UNTRSS$_4$ consists of $\frac{K}{150}$ resource index subsets, $RIS_i^{\mathrm{UNTRSS}_4}$, where $0\le i<\frac{K}{150}$.

3.1.3.7 Uplink Traffic Resource Subspace

A UTRSS consists of $13\times\frac{K}{150}$ resource index subsets, RIS_i^{UTRSS}, where $0\le i<13\times\frac{K}{150}$.

3.1.4 Uplink Physical Channel

3.1.4.1 CQMCH (Channel Quality Measurement Channel)

CQMCH is an uplink physical channel that transmits a specific sequence for uplink channel quality measurement. A UTP consists of at most $6\times\frac{K}{150}$ CQMCH(CQMCH$_0$~CQMCH$_{6K/150}$), and a CQMCH consists of 10 symbols $\{CQMCH_k, 0\le k<10\}$ and is mapped to RIS_i^{CQMRS}. CQMCH$_k$ is defined as

$$CQMCH_k = A\times(1-2\times C_{s,m}^{l}),$$

where $C_{s,m}^{l}$ is a sequence generated by the degree-l m-sequence generator with initial value s.

3.1.4.2 PFCH (Path-loss Feedback Channel)

PFCH is an uplink physical channel which transmits path-loss information for interference coordination (or management) at a fixed rate. In a UTP, there are $\frac{K}{150}$ PFCHs(PFCH$_0$~PFCH$_{K/150}$). A PFCH$_\mathrm{i}$ consists of 60 symbols and is mapped to $RIS_i^{\mathrm{UNTRSS}_0}$. PFCH uses QPSK modulation.

3.1.4.3 UFCH (Uplink Feedback Channel)

UFCH is an uplink physical channel which transmits downlink CQI at a fixed rate. In a UTP, there are $3\times\frac{K}{150}$ UFCHs(UFCH$_0$~UFCH$_{3K/150}$). A UFCH$_\mathrm{i}$ consists of 30 symbol and is mapped to $RIS_i^{\mathrm{UNTRSS}_1}$. UFCH uses QPSK modulation.

3.1.4.4 SCPCH (State Control Physical Channel)

SCPCH is an uplink physical channel used for SCH transport channel and transmits at a fixed rate. In a UTP, there are $2\times\frac{K}{150}$ SCPCH(SCPCH$_0$~SCPCH$_{2K/150}$). A SCPCH$_\mathrm{i}$ consists of 30 symbol and is mapped to $RIS_i^{\mathrm{UNTRSS}_2}$. SCPCH uses QPSK modulation.

3.1.4.5 UACH (Uplink ACK Channel)

UACH is an uplink physical channel which transmits ACK for downlink DSDPCH at a fixed rate. In a UTP, there are at most $\frac{K}{150}$ UACH(UACH$_0$~UACH$_{K/150}$). A UACH$_\mathrm{i}$ consists of 18 symbols and is mapped to $RIS_i^{\mathrm{UNTRSS}_3}$. UACH uses QPSK modulation.

3.1.4.6 RACH (Random Access Channel)

RACH is an uplink physical channel for random access. In a UTP, there are $\frac{K}{150}$ RACH(RACH$_0$~RACH$_{K/150}$). A RACH$_\mathrm{i}$ consists of 12 symbols and is mapped to $RIS_i^{\mathrm{UNTRSS}_4}$.

3.1.4.7 SPDCH (Shared Physical Data Channel)

SPDCH is an uplink physical channel used for uplink STCH transport channel, RACH transport channel, and uplink SCH channel at a variable rate. In a UTP, there are at most $13\times\frac{K}{150}$ SPDCH(SPDCH$_0$~SPDCH$_{13K/150}$). A SPDCH$_i$ consists of 480 symbols in maximum and is mapped to RIS_i^{UNTRSS}. SPDCH uses QPSK, 16QAM, and 64QAM (optional) modulation.

3.1.4.8 Summary

Table 3-4 summarizes the maximum number of uplink physical channels and the number of resources used in each uplink physical channel.

Table 3-4 Maximal number of channels and resources of UTP

Channel	Max. number of channels per packet	Number of resources per channel	Remark
CQMCH	6K/150	60	
PFCH	K/150	60	
UFCH	3K/150	30	
SCPCH	2K/150	30	
UACH	K/150	18	
RACH	K/150	12	
SPDCH	10K/150 3K/150	48 60	

3.2 Modulation and Mapping

3.2.1 Overview

The uplink transmission scheme is based on DFT-spread OFDM. One or two transmit antennas are used at the UE (N_{TxAnt} = 1, 2).

The DFT-spread OFDM is illustrated in Figure 3-3. First, a packet (bit stream) which is transmitted by each physical channel is generated through channel mapping and coding. The physical channels are uplink SCPCH, UFCH, PFCH, UACH and uplink SPDCH. The procedure of bit stream generation is explained in Section 4. The procedure of CQM symbol generation is described in Section 3.1.

The bit stream generated from channel mapping and coding is converted to the symbol stream through symbol mapping. The symbol is multiplied by channel gain and is mapped to a frequency-time bin. After the mapped symbols are scrambled, DFT Spread OFDM operation is carried out. The DFT-spread OFDM operation consists of DFT, symbol to subcarrier mapping, IFFT and cyclic prefix insertion. The windowing can be employed to suppress out-of-band emission.

When handoff occurs, the UE should communicate with more than one BS. This requires as many uplink modulation procedures as the number of simultaneously accessible BSs. The procedure of dotted blocks in Figure 3-3 is used for the UE to communicate with new BS, when handoff occurs. When there is no handoff, the dotted blocks are not used. Section 3.2.2 to 3.2.6 describe the uplink modulation procedure for one BS. When the UE communicates with multiple BSs simultaneously, this procedure is carried out for each BS, and then all the baseband signals are added.

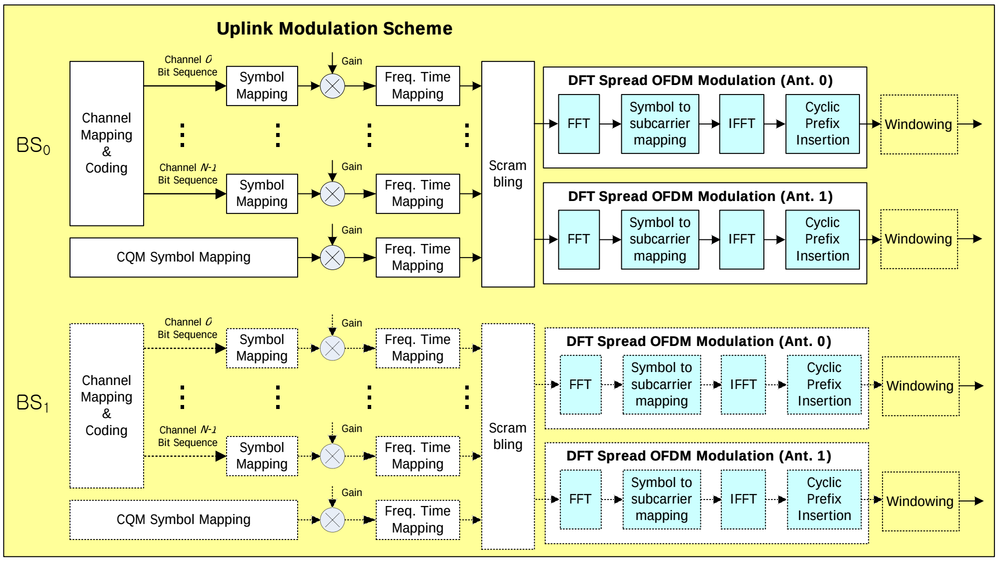

Figure 3-3 DFT-spread OFDM

3.2.2 Symbol Mapping

The bit streams from channel mapping and coding, $\{b_{m,n}\}_{n=0}^{n=Z_m-1}$, are mapped to the symbol streams $\{\mathbf{s}_{m,k}\}_{k=0}^{k=Z'_m-1}$ where Z_m and Z'_m are the lengths of the bit stream and symbol stream, respectively. The k^{th} symbol vector of the m^{th} channel, $\mathbf{s}_{m,k}=\left[s_{m,k,0} \;\cdots\; s_{m,k,N_{\mathrm{TxAnt}}-1}\right]^T$, is the complex vector of size $N_{TxAnt}\times 1$, where N_{TxAnt} is the number of transmit antennas. The i^{th} element $s_{m,k,i}$ of $\mathbf{s}_{m,k}$ to be transmitted by the i^{th} antenna is determined by the modulation schemes (QPSK and 16QAM) and the transmit diversity schemes (SAT, STBC and SPEX).

The complex symbol $s_{m,k,i}$ is given by

$$s_{m,k,i}=(I_{i,out}^{m,k}+jQ_{i,out}^{m,k})\times K_{MOD}\times\frac{1}{\sqrt{N_{TxAnt}}},$$

where $I_{i,out}^{m,k}$ and $Q_{i,out}^{m,k}$ are real and imaginary parts of the complex modulation symbol, respectively and K_{MOD} is the normalization factor. The normalization factor K_{MOD} is given by Table 3-5.

Table 3-5 K_{MOD} for each modulation scheme

Modulation	K_{MOD}
QPSK	1/√2
16QAM	1/√10

Table 3-6 shows the N_{CBPT} (Number of Coded Bit Per Tone) for each modulation option and antenna scheme.

Table 3-6 N_{CBPT} and modulation scheme

N_{CBPT}	Modulation Option	Antenna Scheme	N_{TxAnt}
2	QPSK	SAT	1
2	QPSK	STBC	2
4	QPSK	SPEX	2
4	16-QAM	SAT	1
4	16-QAM	STBC	2
8	16-QAM	SPEX	2

3.2.2.1 SAT

Figure 3-4 shows the symbol mapping. The bit stream of the m^{th} channel, $\left\{b_{m,n}\right\}_{n=0}^{n=Z_m-1}$, is serial-to-parallel converted to N_{CBPT} bits, and then mapped to a complex symbol according to the modulation scheme.

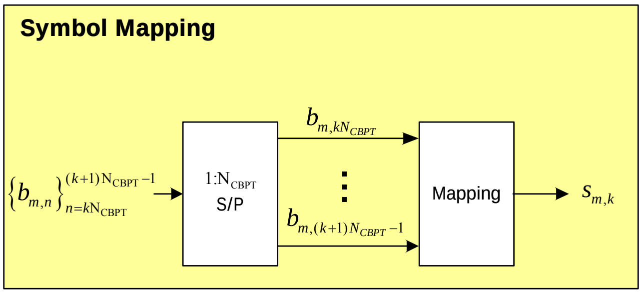

Figure 3-4 Symbol mapping

The mapping method for each modulation scheme is shown in Table 3-7 and Table 3-8

Table 3-7 QPSK-SAT modulation

$b_{m,k\times N_{CBPT}}$	$I_{0,out}^{m,k}$	$b_{m,k\times N_{CBPT}+1}$	$Q_{0,out}^{m,k}$
0	1	0	1
1	-1	1	-1

Table 3-8 16QAM-SAT modulation

$b_{m,k\times N_{CBPT}}, b_{m,k\times N_{CBPT}+2}$	$I_{0,out}^{m,k}$	$b_{m,k\times N_{CBPT}+1}, b_{m,k\times N_{CBPT}+3}$	$Q_{0,out}^{m,k}$
00	1	00	1
01	3	01	3
10	-1	10	-1
11	-3	11	-3

3.2.2.2 STBC

Figure 3-5 shows the symbol mapping for STBC. The bit stream of the m^{th} channel $\left\{b_{m,n}\right\}_{n=0}^{n=Z_m-1}$ is serial-to-parallel converted to $2\times N_{CBPT}$ bits, and then mapped to the complex symbol for STBC.

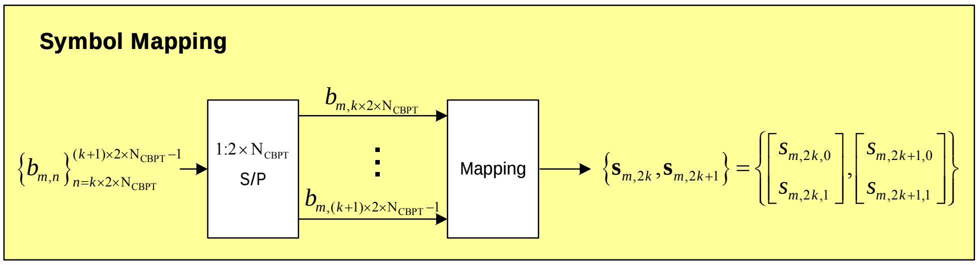

Figure 3-5 STBC symbol mapping

The mapping method for each modulation scheme is shown in Table 3-9 and Table 3-10.

Table 3-9 QPSK-STBC modulation

$b_{m,k\times2\times N_{CBPT}}$	$I_{0,out}^{m,2\times k}$	$I_{1,out}^{m,2\times k+1}$	$b_{m,k\times2\times N_{CBPT}+1}$	$Q_{1,out}^{m,2\times k}$	$Q_{0,out}^{m,2\times k+1}$
0	1	1	0	1	-1
1	-1	-1	1	-1	1
$b_{m,k\times2\times N_{CBPT}+2}$	$I_{1,out}^{m,2\times k}$	$I_{0,out}^{m,2\times k+1}$	$b_{m,k\times2\times N_{CBPT}+3}$	$Q_{0,out}^{m,2\times k}$	$Q_{1,out}^{m,2\times k+1}$
0	1	-1	0	1	1
1	-1	1	1	-1	-1

Table 3-10 16QAM- STBC modulation

$b_{m,k\times2\times N_{CBPT}},b_{k\times2\times N_{CBPT}+2}$	$I_{0,out}^{m,2\times k}$	$b_{m,k\times2\times N_{CBPT}+1},b_{m,k\times2\times N_{CBPT}+3}$	$Q_{0,out}^{m,2\times k}$
00	1	00	1
01	3	01	3
10	-1	10	-1
11	-3	11	-3
$b_{m,k\times2\times N_{CBPT}+4},b_{m,k\times2\times N_{CBPT}+6}$	$I_{1,out}^{m,2\times k}$	$b_{m,k\times2\times N_{CBPT}+5},b_{m,k\times2\times N_{CBPT}+7}$	$Q_{1,out}^{m,2\times k}$
00	1	00	1
01	3	01	3
10	-1	10	-1

11	-3	11	-3
$b_{m,k\times2\times N_{CBPT}}, b_{m,k\times2\times N_{CBPT}+2}$	$I_{1,out}^{m,2\times k+1}$	$b_{m,k\times2\times N_{CBPT}+1}, b_{m,k\times2\times N_{CBPT}+3}$	$Q_{1,out}^{m,2\times k+1}$
00	1	00	-1
01	3	01	-3
10	-1	10	1
11	-3	11	3
$b_{m,k\times2\times N_{CBPT}+4}, b_{m,k\times2\times N_{CBPT}+6}$	$I_{0,out}^{m,2\times k+1}$	$b_{m,k\times2\times N_{CBPT}+5}, b_{m,k\times2\times N_{CBPT}+7}$	$Q_{0,out}^{m,2\times k+1}$
00	-1	00	1
01	-3	01	3
10	1	10	-1
11	3	11	-3

3.2.2.3 SPEX

Figure 3-6 shows the symbol mapping for SPEX scheme. The bit stream of the m^{th} channel $\left\{b_{m,n}\right\}_{n=0}^{n=Z_m-1}$ is serial-to-parallel converted to N_{CBPT} bits, and then mapped to the complex symbol for SPEX scheme.

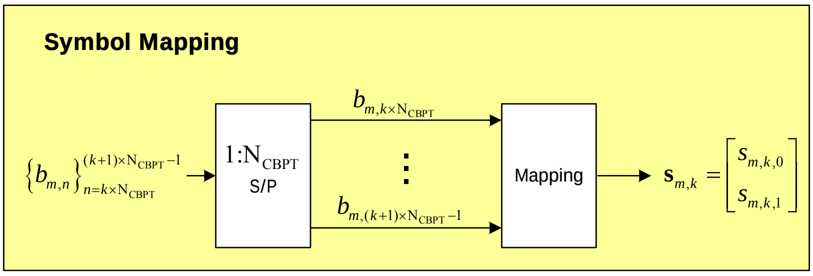

Figure 3-6 SPEX symbol mapping

The mapping method for each modulation scheme is shown in Table 3-11 and Table 3-12.

Table 3-11 QPSK-SPEX modulation

$b_{m,k\times N_{CBPT}}$	$I_{0,out}^{m,k}$	$b_{m,k\times N_{CBPT}+1}$	$Q_{0,out}^{m,k}$
0	1	0	1
1	-1	1	-1
$b_{m,k\times N_{CBPT}+2}$	$I_{1,out}^{m,k}$	$b_{m,k\times N_{CBPT}+3}$	$Q_{1,out}^{m,k}$
0	1	0	1
1	-1	1	-1

Table 3-12 16QAM-SPEX modulation

$b_{m,k\times N_{CBPT}}, b_{m,k\times N_{CBPT}+2}$	$I_{0,out}^{m,k}$	$b_{m,k\times N_{CBPT}+1}, b_{m,k\times N_{CBPT}+3}$	$Q_{0,out}^{m,k}$
00	1	00	1
01	3	01	3
10	-1	10	-1
11	-3	11	-3
$b_{m,k\times N_{CBPT}+4}, b_{m,k\times N_{CBPT}+6}$	$I_{1,out}^{m,k}$	$b_{m,k\times N_{CBPT}+5}, b_{m,k\times N_{CBPT}+7}$	$Q_{1,out}^{m,k}$
00	1	00	1
01	3	01	3
10	-1	10	-1
11	-3	11	-3

3.2.3 Frequency-Time Mapping

Symbol stream $\left\{s_{m,k}\right\}_{k=0}^{k=Z'_m-1}$ generated by symbol mapping is multiplied by channel gain G_m, so that $\left\{s'_{m,k}\right\}_{k=0}^{k=Z'_m-1}$ is produced. Each signal $s'_{m,k}$ is mapped to a frequency-time bin.

3.2.4 Scrambling

The frequency-time mapped signal, $V_q(n)$, is $V_q(n) = s'_{m,k}$, $-300 \le q \le 300, q \ne 0$, when $t_{m,k} = n, p_{m,k} = q$. The scrambled signal $U_q(n)$ is generated by multiplying $V_q(n)$ by the pseudo random scrambling codes.

3.2.5 DFT Spread OFDM Modulation

The frequency domain structure of OFDM symbol is described in Figure 3-7. The DC subcarrier is not used and $N_{sc,U}$ subcarriers are located in both sides of DC subcarrier with spacing Δf. $N_{sc,U}/2$ sub-carriers are in each side.

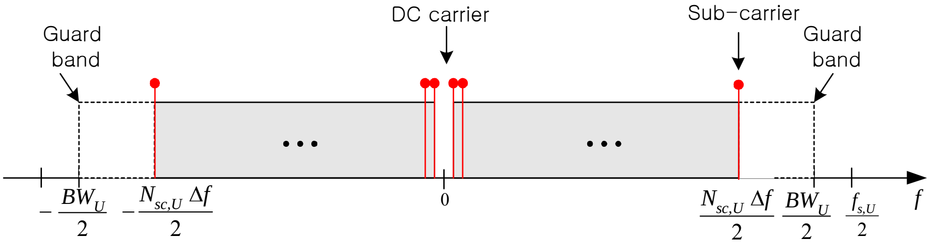

Figure 3-7 Frequency domain structure of OFDM symbol in uplink

The baseband signal of the n^{th} DFT-spread OFDM symbol to be transmitted by antenna i is as follows:

$$S_{n,U}^{i}(t)=\sum_{q=-300}^{300}U_{q,i}(n)\Psi_{q,n}(t),$$

where q is the index of subcarriers, n the index of OFDM symbols, $U_{q,i}(n)$ the n^{th} DFT spread OFDM complex symbol of the q^{th} subcarrier to be transmitted by antenna i and

$$\Psi_{q,n}(t)=\begin{cases}\exp\left(j2\pi k\Delta f\left(t-T_g-nT_{sym}\right)\right), & nT_{sym}\le t\le(n+1)T_{sym}\\ 0, & \text{otherwise}\end{cases}.$$

The method of constructing DFT-spread OFDM symbol with CP for UTP is displayed in **Figure 3-8**. The signals with CP, denoted by $\tilde{S}_{n,U}^{i}(t)$ are as follows:

$$\tilde{S}_{n,U}^{i}(t)=\begin{cases}S_{n,U}^{i}\left(t+T_d-T_g\right), & nT_{sym}\le t\le nT_{sym}+T_g\\ S_{n,U}^{i}\left(t-T_g\right), & nT_{sym}+T_g\le t\le(n+1)T_{sym}\\ 0, & \text{otherwise}\end{cases}.$$

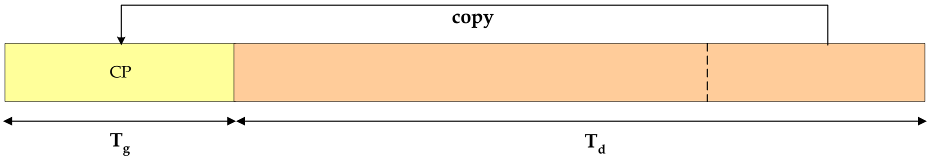

Figure 3-8 OFDM symbol with CP in UTP

3.2.6 Windowing

To minimize the leakage of OFDM signals to other bands, we can use windowing in the time domain. The baseband signal with windowing, denoted by $\hat{S}^i_{n,U}(t)$ is as follows:

i) when the square window is used

$$\hat{S}^i_{n,U}(t) = \tilde{S}^i_{n,U}(t),$$

ii) when the raised cosine window is used

$$\hat{S}^i_{n,U}(t) = \begin{cases} w(t+\alpha T_{sym}/2)\tilde{S}^i_{n,U}(t+T_d-\alpha T_{sym}/2), & -\alpha T_{sym}/2 \le t \le 0 \\ w(t+\alpha T_{sym}/2)\tilde{S}^i_{n,U}(t), & 0 \le t \le T_{sym} \\ w(t+\alpha T_{sym}/2)\tilde{S}^i_{n,U}(t-T_{sym}+T_g), & T_{sym} \le t \le (1+\alpha/2)T_{sym} \\ 0, & \text{otherwise} \end{cases}$$

where

$$w(t) = \begin{cases} 0.5+0.5\cos(\pi + t\pi/(\alpha T_{sym})), & 0 \le t \le \alpha T_{sym} \\ 1, & \alpha T_{sym} \le t \le T_{sym} \\ 0.5+0.5\cos((t-T_{sym})\pi/(\alpha T_{sym})), & T_{sym} \le t \le (1+\alpha)T_{sym} \\ 0, & \text{otherwise} \end{cases}.$$

Here, α is a roll-off factor which can be optimized within $\alpha < T_g/T_{sym}$ to minimize the leakage of OFDM signals. Finally, the baseband signal of antenna i, denoted by $S^i_U(t)$ is

$$S^i_U(t) = \sum_{n=-\infty}^{\infty} \hat{S}^i_{n,U}(t).$$

4 Channel Coding

Channel coding procedure includes CRC encoding (see Section 4.1), scrambling (see Section 4.2), FEC encoding (see Section 4.3), and bit interleaving (see Section 4.4). The basic block for SPDCH and DSDPCH passes the channel coding chain where the first subchannel sets the scrambling seed used in Section 4.2 and the data follows the coding chain up to the Bit interleaving. The bit-interleaved data is inputted to the symbol mapping. The process of channel coding is shown in Figure **4-1**.

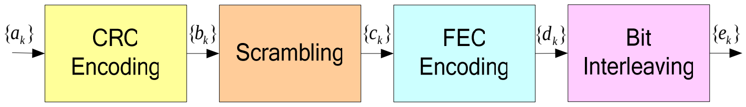

Figure 4-1 Channel coding process

4.1 CRC encoding

Error detection is provided on data blocks through Cyclic Redundancy Check (CRC). The size of the CRC is 8, 16, and 24 bits. The CRC length used for each data block is determined by the following Table 4-1 according to the length of the data block.

Table 4-1 Length of parity check bits attached by CRC encoding

SPDCH information size (Bytes)	CRC Size
N≤18	8
N≤108	16
otherwise	24

The entire data block is used in generating CRC parity bits for each data block. The parity bits are generated by one of the following cyclic generator polynomials.

$$g_{CRC24}(x) = x^{24} + x^{23} + x^{6} + x^{5} + x + 1$$

$$g_{CRC16}(x) = x^{16} + x^{12} + x^{5} + 1$$

$$g_{CRC8}(x) = x^{8} + x^{7} + x^{4} + x^{3} + x + 1$$

{Oct 28, 2005}

Let the bits in a data block be $a_0, a_1, ..., a_{Z-1}$, and the parity bits $p_{c,0}, p_{c,1}, ..., p_{c,L-1}$. The encoding is performed in a systematic form. The polynomial of the length 24

$$a_0 x^{Z+23} + a_1 x^{Z+22} + ... + a_{Z-1} x^{24} + p_{c,0} x^{23} + p_{c,1} x^{22} + ... + p_{c,22} x + p_{c,23}$$

yields a remainder equal to 0 when divided by $g_{CRC24}(x)$. The polynomial of the length 16

$$a_0 x^{Z+15} + a_1 x^{Z+14} + ... + a_{Z-1} x^{16} + p_{c,0} x^{15} + p_{c,1} x^{14} + ... + p_{c,14} x + p_{c,15}$$

yields a remainder equal to 0 when divided by $g_{CRC16}(x)$. The polynomial of the length 8

$$a_0 x^{Z+7} + a_1 x^{Z+6} + ... + a_{Z-1} x^{8} + p_{c,0} x^{7} + p_{c,1} x^{6} + ... + p_{c,6} x + p_{c,7}$$

yields a remainder equal to 0 when divided by $g_{CRC8}(x)$.

The bits after CRC attachment are denoted by $b_0, b_1, ..., b_{K-1}$, where $K = Z + L$. The relation between them is

$$b_k = a_k,\ k = 0, 1, ..., Z-1,$$

$$b_k = p_{c,k-Z},\ k = Z, Z+1, ..., K-1.$$

4.2 Scrambling

Data scrambling is performed on data transmitted on the DL and UL. The scrambling is initialized on each FEC block. The pseudo random binary sequence generator is

$$g(x) = 1 + x^7 + x^{15}$$

Each data to be transmitted enters sequentially into the scrambler, MSB first. The initial seed value is used to calculate the scrambling bits, which are added in binary field by an XOR operation with the serialized bit stream of each FEC block. The randomizer sequence is applied to all input bits: information bits and CRC parity bits. The seed value is determined by MACID that is allocated by the upper layer and is defined in the following Table 4-2.

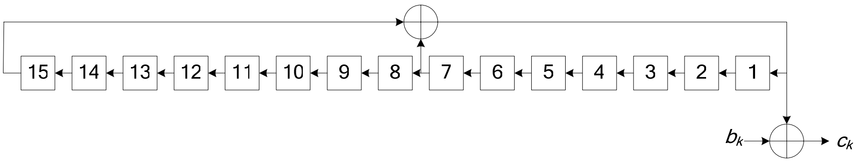

Figure 4-2 **Pseudo random binary sequence generator for data scrambling**

Table 4-2 Initial seed value of scrambler

Physical Channel	**Register(** $m_{15}m_{14}...m_1$ **)**
SPDCH, DSDPCH	$100(\text{MACID})_2$

H-ARQ requires the identical scrambler pattern for each H-ARQ attempt. For H-ARQ operation, the scrambler is initialized with the identical seed value.

The bit outputted from the scrambler is applied to the encoder and is denoted by

$$d_k, k = 0, 1, 2, ..., K - 1$$

4.3 FEC encoding

The mandatory coding method is LDPC coding, and convolutional Turbo coding is optional.

The encoding block size depends on the type of resources, the number of information bits, with the limitation of maximum block size.

4.3.1 LDPC encoding

The LDPC code is based on a set of one or more fundamental LDPC codes. Each of the fundamental codes is a systematic linear block code. Using the methods described in the following tables, various code rates and block sizes can be accommodated by using the fundamental codes.

Each LDPC code in the set of LDPC codes is defined by an m-by-n matrix H, where n is the length of the code and m is the number of parity check bits. The number of systematic bits is k = n - m.

The matrix H is defined as

$$\mathbf{H} = \begin{bmatrix} \mathbf{P}_{0,0} & \mathbf{P}_{0,1} & \mathbf{P}_{0,2} & \cdots & \mathbf{P}_{0,n_b-1} \\ \mathbf{P}_{1,0} & \mathbf{P}_{1,1} & \mathbf{P}_{1,2} & \cdots & \mathbf{P}_{1,n_b-1} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \mathbf{P}_{m_b-1,0} & \mathbf{P}_{m_b-1,1} & \mathbf{P}_{m_b-1,2} & \cdots & \mathbf{P}_{m_b-1,n_b-1} \end{bmatrix},$$

where, $\mathbf{P}_{i,j}$ is one of a set of z-by-z permutation matrices or a z-by-z zero matrix. The matrix H is expanded from a base matrix $\mathbf{H_b}$, with non-binary entries, of size m_b-by-n_b, where $n = z \cdot n_b$ and $m = z \cdot m_b$, with z a positive integer. The base matrix is expanded by replacing each nonzero entry with a z-by-z permutation matrix, and each zero entry with a z-by-z zero matrix. The base matrix size n_b is defined differently depending on the type of resource and UL/DL.

The permutations used are circular right shifts, and the set of permutation matrices contains the z-by-z identity matrix and circular right shifted versions of the identity matrix. Each 0 in $\mathbf{H_b}$ is replaced by z-by-z zero matrix, and each non zero entry x in $\mathbf{H_b}$ is replaced by a circular shift size x - 1. The matrix $\mathbf{H_b}$ can then be directly expanded to $\mathbf{H}$.

The matrix $\mathbf{H_b}$ can be partitioned into two sections; the one that corresponds to the systematic bits and the other one that corresponds to the parity-check bits, such that $\mathbf{H_b} = \left[\mathbf{H_{b1}} \quad \mathbf{H_{b2}}\right]$. Thus, $\mathbf{H_{b2}}$ can be expressed in a lower triangular form. The specific parity-check matrices of the fundamental codes are to be determined.

The LDPC code flexibly supports different block sizes for each code rate through the use of an expansion factor. The matrix $\mathbf{H_b}$ has its own basic columns and a column in $\mathbf{H_b}$ can represent different numbers of columns in $\mathbf{H}$ according to the expansion factor. The expansion by the factor of n is achieved by expanding the z-by-z circular shit matrix into an nz-by-nz circular shift matrix, with the same shift value. By doing so, all shift values specified in $\mathbf{H_b}$ are conserved in the expanded matrix and the length of codes are expanded by the factor of n.

Table 4-3, Table 4-4, and Table 4-5 specify the block sizes and code rates of the LDPC codes for DL and UL. The optional block sizes are written in italic face and the information sizes in solid cells (as opposed to dotted cells) painted with the same color are encoded with a single parity check matrix by using some appropriate method like codeword shortening.

Table 4-3 LDPC block sizes and code rates for DL

N (bits)	# Sub channel (chunks)	K (bytes)					# Symbols		
		2	3	4	5	6	QPSK	16QAM	64QAM
180	1	6	9	12	15	18	90	45	30
360	*2*	*12*	*18*	*24*	*30*	*36*	*180*	*90*	*60*
540	3	18	27	36	45	54	270	135	90
720	4	24	36	48	60	72	360	180	120
900	*5*	*30*	*45*	*60*	*75*	*90*	*450*	*225*	*150*
1080	6	36	54	72	90	108	540	270	180
1260	7	42	63	84	105	126	630	315	210
1440	*8*	*48*	*72*	*96*	*120*	*144*	*720*	*360*	*240*
1620	9	54	81	108	135	162	810	405	270
1800	10	60	90	120	150	180	900	450	300
1980	*11*	*66*	*99*	*132*	*165*	*198*	*990*	*495*	*330*
2160	12	72	108	144	180	216	1080	540	360
2340	13	78	117	156	195	234	1170	585	390
2520	*14*	*84*	*126*	*168*	*210*	*252*	*1260*	*630*	*420*
2700	*15*	*90*	*135*	*180*	*225*	*270*	*1350*	*675*	*450*
2880	*16*	*96*	*144*	*192*	*240*	*288*	*1440*	*720*	*480*
3060	*17*	*102*	*153*	*204*	*255*	*306*	*1530*	*765*	*510*
3240	*18*	*108*	*162*	*216*	*270*	*324*	*1620*	*810*	*540*
3420	*19*	*114*	*171*	*228*	*285*	*342*	*1710*	*855*	*570*
3600	*20*	*120*	*180*	*240*	*300*	*360*	*1800*	*900*	*600*

Table 4-4 LDPC block sizes and code rates of localized resources for UL

N (bits)	# Sub channel (chunks	K (bytes)					# Symbols		
		3	4	6	8	9	QPSK	16QAM	64QAM

	)								
96	1	3	4	6	8	9	48	24	16
192	2	6	8	12	16	18	96	48	32
288	3	9	12	18	24	27	144	72	48
384	4	12	16	24	32	36	192	96	64
480	5	15	20	30	40	45	240	120	80
576	6	18	24	36	48	54	288	144	96
672	7	21	28	42	56	63	336	168	112
768	8	24	32	48	64	72	384	192	128
864	9	27	36	54	72	81	432	216	144
960	10	30	40	60	80	90	480	240	160
1056	11	33	44	66	88	99	528	264	176
1152	12	36	48	72	96	108	576	288	192
1248	13	39	52	78	104	117	624	312	208
1344	14	42	56	84	112	126	672	336	224
1440	15	45	60	90	120	135	720	360	240
1536	16	48	64	96	128	144	768	384	256
1632	*17*	*51*	*68*	*102*	*136*	*153*	*816*	*408*	*272*
1728	*18*	*54*	*72*	*108*	*144*	*162*	*864*	*432*	*288*
1824	*19*	*57*	*76*	*114*	*152*	*171*	*912*	*456*	*304*
1920	*20*	*60*	*80*	*120*	*160*	*180*	*960*	*480*	*320*

Table 4-5 LDPC block sizes and code rates of distributed resources for UL

N (bits)	**# Sub channel (chunks)**	**K (bytes)**					**# Symbols**		
		4	**6**	**8**	**10**	**12**	**QPSK**	**16QAM**	**64QAM**
120	1	4	6	8	10	12	60	30	20
240	2	8	12	16	20	24	120	60	40

360	3	12	18	24	30	36	180	90	60
480	4	16	24	32	40	48	240	120	80
600	5	20	30	40	50	60	300	150	100
720	6	24	36	48	60	72	360	180	120
840	7	28	42	46	70	84	420	210	140
960	8	32	48	64	80	96	480	240	160
1080	9	36	54	72	90	108	540	270	180
1200	10	40	60	80	100	120	600	300	200
1320	11	44	66	88	110	132	660	330	220
1440	12	48	72	96	120	144	720	360	240
1560	13	52	78	104	130	156	780	390	260
1680	14	56	84	112	140	168	840	420	280
1800	15	60	90	120	150	180	900	450	300
1920	16	64	96	128	160	192	960	480	320
2040	17	68	102	136	170	204	1020	510	340
2160	18	72	108	144	180	216	1080	540	360
2280	19	76	114	152	190	228	1140	570	380
2400	20	80	120	160	200	240	120	600	400

LDPC encoding is performed with the $m \times n$ parity-check matrix. The output parity check bits after LDPC encoding are denoted by $p_0, p_1, \ldots, p_{N-K-1}$.

If the input information bits are denoted by $c_0, c_1, \ldots, c_{K-1}$ and the output codeword bits by $d_0, d_1, \ldots, d_{N-1}$, the relation between them is

$$d_k = c_k, k = 0, 1, \ldots, K-1$$

$$d_k = p_{k-K}, k = K, K+1, \ldots, N-1$$

The codeword outputted from the LDPC encoder satisfies the following condition.

$$\mathbf{Hd} = \mathbf{0}$$

where, $\mathbf{d} = (d_0 d_1 ... d_{N-1})^T$

4.3.2 Convolutional turbo encoding

The convolutional turbo code encoder uses a parallel concatenated convolutional code with two 8-state constituent encoders and one internal interleaver. The coding rate of convolutional turbo code is 1/3. The structure of convolutional turbo encoder is depicted in **Figure** 4-3.

The transfer function of the 8-state constituent code is:

$$G(D) = \left[1, \frac{g_1(D)}{g_0(D)}\right],$$

where

$$g_0(D) = 1 + D^2 + D^3,$$

$$g_1(D) = 1 + D + D^3.$$

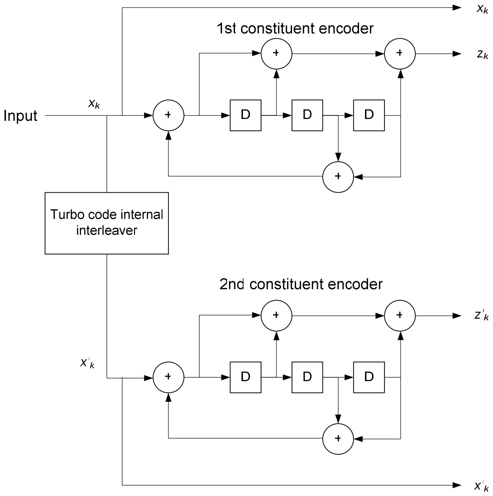

Figure 4-3 Convolutional turbo encoder

Since convolutional turbo code employs the tail-biting property, the initial state where the encoding begins is determined prior to the encoding. The state of the encoder is denoted $S\left(0 \le S \le 7\right)$ with S the value read binary (left to right) out of the constituent encoder memory. The circulation states of each constituent encoder, denoted by Sc_1 and Sc_2, respectively, are determined by the following operations:

1. Initialize the encoder with state 0. Encode the sequence in the natural order for the determination of Sc_1 or in the interleaved order for determination of Sc_2. In both cases the final state of the encoder is S_{N-1}^{0};
2. According to the length N of the sequence, use the following Table 4-6 to find Sc_1 and Sc_2

Table 4-6 Circulation state lookup table

$N_{\text{mod}7}$	S_{N-1}^{0}							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	0	6	3	5	7	1	4	2
2	0	4	5	1	2	6	7	3
3	0	3	4	7	1	2	5	6
4	0	2	6	4	5	7	3	1
5	0	5	7	2	6	3	1	4
6	0	7	1	6	3	4	2	5

The encoding procedure is performed in the following way. First, the first encoder after initialization by the circulation state Sc_1 is fed with the sequence in the natural order. Then the second encoder after initialization by the circular state Sc_2 is fed by the interleaved sequence.

The order in which the encoded bit is fed into the subpacket generation block is :

$$\begin{aligned} & x, z, x', z' = \\ & x_0, z_0, x'_0, z'_0, x_1, z_1, x'_1, z'_1, \ldots, x_{N-1}, z_{N-1}, x'_{N-1}, z'_{N-1} \end{aligned}$$

The block lengths and code rates for convolutional turbo code are differently defined depending on the type of resource and UL/DL. Table 4-7,

Table 4-8, and

Table 4-9 show the block lengths and code rates for different cases. The optional block sizes are written in italic face.

Table 4-7 Convolutional turbo block sizes and code rates for DL

N (bits)	**# Sub channel (chunks)**	**K (bytes)**					**# Symbols**		
		2	**3**	**4**	**5**	**6**	**QPSK**	**16QAM**	**64QAM**
180	1	6	9	12	15	18	90	45	30
360	*2*	*12*	*18*	*24*	*30*	*36*	*180*	*90*	*60*
540	3	18	27	36	45	54	270	135	90
720	4	24	36	48	60	72	360	180	120
900	*5*	*30*	*45*	*60*	*75*	*90*	*450*	*225*	*150*
1080	6	36	54	72	90	108	540	270	180
1260	7	42	63	84	105	126	630	315	210
1440	*8*	*48*	*72*	*96*	*120*	*144*	*720*	*360*	*240*
1620	9	54	81	108	135	162	810	405	270
1800	10	60	90	120	150	180	900	450	300
1980	*11*	*66*	*99*	*132*	*165*	*198*	*990*	*495*	*330*
2160	12	72	108	144	180	216	1080	540	360
2340	*13*	*78*	*117*	*156*	*195*	*234*	*1170*	*585*	*390*
2520	*14*	*84*	*126*	*168*	*210*	*252*	*1260*	*630*	*420*
2700	*15*	*90*	*135*	*180*	*225*	*270*	*1350*	*675*	*450*
2880	*16*	*96*	*144*	*192*	*240*	*288*	*1440*	*720*	*480*
3060	*17*	*102*	*153*	*204*	*255*	*306*	*1530*	*765*	*510*
3240	*18*	*108*	*162*	*216*	*270*	*324*	*1620*	*810*	*540*
3420	*19*	*114*	*171*	*228*	*285*	*342*	*1710*	*855*	*570*
3600	*20*	*120*	*180*	*240*	*300*	*360*	*1800*	*900*	*600*

Table 4-8 Convolutional turbo block sizes and code rates of localized resources for UL

N (bits)	**# Sub channel (chunks)**	**K (bytes)**					**# Symbols**		
		3	**4**	**6**	**8**	**9**	**QPSK**	**16QAM**	**64QAM**

96	1	3	4	6	8	9	48	24	16
192	2	6	8	12	16	18	96	48	32
288	3	9	12	18	24	27	144	72	48
384	4	12	16	24	32	36	192	96	64
480	5	15	20	30	40	45	240	120	80
576	6	18	24	36	48	54	288	144	96
672	7	21	28	42	56	63	336	168	112
768	8	24	32	48	64	72	384	192	128
864	9	27	36	54	72	81	432	216	144
960	10	30	40	60	80	90	480	240	160
1056	11	33	44	66	88	99	528	264	176
1152	12	36	48	72	96	108	576	288	192
1248	13	39	52	78	104	117	624	312	208
1344	14	42	56	84	112	126	672	336	224
1440	15	45	60	90	120	135	720	360	240
1536	16	48	64	96	128	144	768	384	256
1632	*17*	*51*	*68*	*102*	*136*	*153*	*816*	*408*	*272*
1728	*18*	*54*	*72*	*108*	*144*	*162*	*864*	*432*	*288*
1824	*19*	*57*	*76*	*114*	*152*	*171*	*912*	*456*	*304*
1920	*20*	*60*	*80*	*120*	*160*	*180*	*960*	*480*	*320*

Table 4-9 Convolutional turbo block sizes and code rates of distributed resources for UL

N (bits)	# Sub channel (chunks)	K (bytes)					# Symbols		
		4	6	8	10	12	QPSK	16QAM	64QAM
120	1	4	6	8	10	12	60	30	20
240	2	8	12	16	20	24	120	60	40

360	3	12	18	24	30	36	180	90	60
480	4	16	24	32	40	48	240	120	80
600	5	20	30	40	50	60	300	150	100
720	6	24	36	48	60	72	360	180	120
840	7	28	42	46	70	84	420	210	140
960	8	32	48	64	80	96	480	240	160
1080	9	36	54	72	90	108	540	270	180
1200	10	40	60	80	100	120	600	300	200
1320	11	44	66	88	110	132	660	330	220
1440	12	48	72	96	120	144	720	360	240
1560	13	52	78	104	130	156	780	390	260
1680	14	56	84	112	140	168	840	420	280
1800	15	60	90	120	150	180	900	450	300
1920	16	64	96	128	160	192	960	480	320
2040	17	68	102	136	170	204	1020	510	340
2160	18	72	108	144	180	216	1080	540	360
2280	19	76	114	152	190	228	1140	570	380
2400	20	80	120	160	200	240	120	600	400

To achieve various code rates with a single convolutional turbo encoder, the appropriate puncturing is required for each code rate. Table 4-10,

Table 4-11, and

Table 4-12 show the puncture pattern for each code rate. The 1 and 0 in the puncture pattern represent the transmitted and punctured bits, respectively.

Table 4-10 Puncture Pattern for convolutional turbo coding for DL

Code rate	**4/15**
x_k	1111

z_k	1111
x'_k	1110
z'_k	1111
Code rate	**2/5**
x_k	1111
z_k	1011
x'_k	0000
z'_k	1110
Code rate	**8/15**
x_k	11111111
z_k	10101010
x'_k	00000000
z'_k	01010100
Code rate	**2/3**
x_k	1111
z_k	1000
x'_k	0000
z'_k	0010
Code rate	**4/5**
x_k	11111111
z_k	10000000
x'_k	00000000
z'_k	00001000

Table 4-11 Puncture Pattern for convolutional turbo coding of localized resources for UL

Code rate	**1/4**
x_k	1111
z_k	1111
x'_k	1111

z'_k	1111
Code rate	**1/3**
x_k	1111
z_k	1111
x'_k	0000
z'_k	1111
Code rate	**1/2**
x_k	1111
z_k	1010
x'_k	0000
z'_k	0101
Code rate	**2/3**
x_k	1111
z_k	1000
x'_k	0000
z'_k	0010
Code rate	**3/4**
x_k	111111
z_k	100000
x'_k	000000
z'_k	000100

Table 4-12 Puncture Pattern for convolutional turbo coding of distributed resources for UL

Code rate	**4/15**
x_k	1111
z_k	1111
x'_k	1110
z'_k	1111
Code rate	**2/5**

x_k	1111
z_k	1011
x'_k	0000
z'_k	1110
Code rate	**8/15**
x_k	11111111
z_k	10101010
x'_k	00000000
z'_k	01010100
Code rate	**2/3**
x_k	1111
z_k	1000
x'_k	0000
z'_k	0010
Code rate	**4/5**
x_k	11111111
z_k	10000000
x'_k	00000000
z'_k	00001000

The order of punctured bits is

$$\begin{aligned} d'_{4k} &= x_k, k = 0,\ldots,N-1 \\ d'_{4k+1} &= z_k, k = 0,\ldots,N-1 \\ d'_{4k+2} &= x'_k, k = 0,\ldots,N-1 \\ d'_{4k+3} &= z'_k, k = 0,\ldots,N-1 \end{aligned}$$

The codeword outputted from the convolutional turbo encoder is given as:

$$d_k = d'_{I(k)}, k = 0,\ldots,n,$$

where $l(k)$ is the smallest index such that $l(k) > l(k-1)$ and $l(k)$ is an index not to be punctured, where $l(0)$ is the smallest index not to be punctured.

4.3.3 H-ARQ support for FEC encoding

The transmission orders of the encoded bits for H-ARQ support are specified in the Table 4-13,

Table 4-14, and

Table 4-15. Incremental redundancy based H-ARQ is taking into account the puncture pattern. For each retransmission, different parity bits are used to create the retransmission FEC block. The indices of transmitted bits are predefined or can be easily deduced from the retransmission order and the number of received bits. The parity bits are transmitted in the ascending order. The parity bits that have already been transmitted are not considered for retransmission. If all the parity bits are retransmitted at least once, the retransmission of the parity bits that have already been transmitted is now allowed. At the receiver, the received signals are depunctured according to its specific puncture pattern, and then the combination is performed at bit metrics level.

Table 4-13 Order of convolutional turbo coded bits to be retransmitted for DL H-ARQ

Codeword bit type	Order of rx. bits
x_k	- - - - - - - -
z_k	(9)(2)(11)(4)(13)(6)(15)(8)
x'_k	(17)(21)(19)(23)(18)(22)(20)(24)
z'_k	(1)(10)(3)(12)(5)(14)(7)(16)

Table 4-14 Order of convolutional turbo coded bits to be retransmitted of localized resources for UL H-ARQ

Type	Order of rx. bits
x_k	- - - - - - - -
z_k	(9)(2)(11)(4)(13)(6)(15)(8)
x'_k	(17)(21)(19)(23)(18)(22)(20)(24)
z'_k	(1)(10)(3)(12)(5)(14)(7)(16)

Table 4-15 Order of convolutional turbo coded bits to be retransmitted of distributed resources for UL H-ARQ

Type	Order of rx. bits
x_k	- - - - - - -
z_k	-(6)(2)(8)(3)(10)
x'_k	(11)(13)(15)(12)(14)(16)
z'_k	(5)(1)(7)-(9)(4)

4.4 Bit interleaving

The bit interleaving procedure permutes the transmission order of codeword bits in order to transmit the codeword bits that are associated with a single information bit through the spatially and temporally separated resources for diversity gain. The procedure is performed in the way of block interleaving with random permutation. The size of rows of the block interleaver is different depending on the type of resource and UL/DL. The size of rows for DL, R, is fixed to $R = 30$ regardless of the length of interleaver input bit sequence N, and the size of rows for the localized and distributed resources of UL is fixed to $R = 16$ and $R = 20$, respectively. The number of columns C is determined as N / R. The output bits of the bit interleaver e_k are related to the input bits d_l by the following rule:

$$e_k = d_{\pi(k)}, k = 0,1,2,...,N-1,$$

where the mapping $\pi(k)$ is determined through the following steps.

1. Fill the index from 0 to $N-1$, inclusive, in the interleaver row by row in the conventional way of the block interleaver.
2. Permute a sequence i ($i = 0,1,\ldots,2^{\lceil \log_2(R) \rceil}-1$) to make a new sequence j according to the following rule:

$$j \leftarrow \log_{\alpha^{ib}}\left(\alpha^{i_0} + \alpha^{i}\right), i = 0,1,...,2^{\lceil \log_2(R) \rceil}-2$$
$$j \leftarrow \log_{\alpha^{ib}}\left(\alpha^{i_0}\right), i = 2^{\lceil \log_2(R) \rceil}-1$$

   where α is a root of the primitive polynomial used to construct $GF\left(2^{\lceil \log_2(R) \rceil}\right)$ specified in Table 4-16. α^{i_b} is primitive in $GF\left(2^{\lceil \log_2(R) \rceil}\right)$ and i_0 is an integer between 0 and $2^{\lceil \log_2(R) \rceil}-1$, inclusive. The constants i_b and i_0 are specified in Table 4-17, Table 4-19, and Table 4-21. Furthermore, by definition $\log_{\alpha^{i_b}}(0) = 2^{\lceil \log_2(R) \rceil} - 1$.

3. Discard the numbers larger than R from the obtained sequence j to make the permutation of length R for the inter-row permutation j'.
4. Permute each row with the permutation j'.
5. Permute a sequence i ($i = 0,1,\ldots,2^{\lceil \log_2(C) \rceil} - 1$) for a permuted row k to make a new sequence $j(k)$ according to the following rule:

$$j(k) \leftarrow \log_{\alpha^{i_b}}\left(\alpha^{i_0} + \alpha^{l}\right),\ l = 0,1,\ldots,2^{\lceil \log_2(C) \rceil} - 2$$

$$j(k) \leftarrow \log_{\alpha^{i_b}}\left(\alpha^{i_0}\right),\ i = 2^{\lceil \log_2(C) \rceil} - 1$$

where α is a root of the primitive polynomial used to construct $GF\left(2^{\lceil \log_2(C) \rceil}\right)$, which is specified in Table 4-16. α^{i_b} is primitive in $GF\left(2^{\lceil \log_2(C) \rceil}\right)$ and i_0 is an integer between 0 and $2^{\lceil \log_2(C) \rceil} - 1$, inclusive. The constants i_b and i_0 are specified in Table 4-18, Table 4-20, and Table 4-22. Furthermore, by definition $\log_{\alpha^{i_b}}(0) = 2^{\lceil \log_2(C) \rceil} - 1$

6. Discard the numbers larger than C from the obtained sequence $j(k)$ to make the permutation of length C for the intra-row permutation $j'(k)$ for row k.
7. Permute each entry of row k with the permutation $j'(k)$.

Table 4-16 primitive polynomials for intra- and inter-row permutation

#of columns(C)	$C \le 16$	$C \le 32$	$C \le 64$	$C \le 128$
Primitive polynomials	$x^4 + x + 1$	$x^5 + x^2 + 1$	$x^6 + x + 1$	$x^7 + x^3 + 1$

Table 4-17 parameters for inter-row permutation for DL

#of columns(C)	$C \le 16$		$C \le 32$		$C \le 64$		$C \le 128$	
	i_b	i_o	i_b	i_o	i_b	i_o	i_b	i_o
values	25	28	2	13	12	27	18	9

Table 4-18 parameters for intra-row permutation for DL

{Oct 28, 2005}

#of columns(C)	≤16		≤32		≤64		≤128	
Row index	i_b	i_o	i_b	i_o	i_b	i_o	i_b	i_o
0	13	3	19	2	13	29	82	24
1	4	3	27	4	25	41	41	24
2	8	12	23	2	20	33	38	29
3	11	14	26	28	43	25	9	126
4	1	12	8	3	20	30	122	117
5	11	15	4	13	2	50	107	58
6	1	8	14	6	23	8	126	50
7	7	7	28	29	59	16	83	106
8	8	7	14	19	1	40	8	84
9	1	1	22	22	46	10	76	118
10	8	13	14	5	43	51	92	66
11	2	7	16	10	32	12	48	42
12	14	12	18	6	4	40	126	124
13	13	4	19	17	26	0	124	83
14	4	5	21	21	46	24	91	21
15	11	7	16	11	53	2	42	28
16	7	2	27	18	62	60	92	33
17	14	0	13	12	59	3	100	41
18	14	2	11	1	22	15	39	25
19	7	14	29	2	29	58	60	25
20	8	6	22	2	47	53	38	19
21	14	10	19	0	53	47	72	56
22	2	2	5	11	29	60	7	34
23	7	15	2	21	62	42	70	91
24	8	0	24	1	5	36	102	108
25	8	9	5	20	11	9	99	72
26	4	13	7	11	38	36	75	84
27	8	3	28	19	20	26	36	81
28	11	1	11	27	40	13	126	54
29	11	8	15	16	22	50	100	18

1

Table 4-19 parameters for inter-row permutation for UL localized resource

#of columns(C)	≤ 8		≤ 16		≤ 32		≤ 64		≤ 128	
	i_b	i_o	i_b	i_o	i_b	i_o	i_b	i_o	i_b	i_o
value	1	1	2	14	14	3	14	6	8	1

Table 4-20 parameters for intra-row permutation for UL localized resource

#of columns(C)	≤ 8		≤ 16		≤ 32		≤ 64		≤ 128	
row index	i_b	i_o	i_b	i_o	i_b	i_o	i_b	i_o	i_b	i_o
0	5	2	13	1	25	28	2	16	86	114
1	2	5	14	9	20	26	61	35	6	81
2	2	4	14	10	20	13	46	23	15	103
3	3	3	2	10	3	13	2	13	71	49
4	4	1	1	15	8	21	4	54	46	37
5	6	4	11	5	15	2	1	25	21	80
6	3	5	11	12	7	14	40	10	120	90
7	5	4	1	6	14	31	40	45	20	106
8	5	7	13	4	16	12	46	44	56	14
9	6	2	8	12	9	29	22	1	103	65
10	4	0	14	4	13	1	22	31	59	60
11	3	0	11	8	19	31	53	9	11	39
12	3	7	2	14	29	18	10	63	30	6
13	5	3	11	2	29	27	4	0	73	67
14	2	0	13	3	27	9	58	61	52	7
15	5	1	4	10	21	24	58	28	27	95

Table 4-21 parameters for inter-row permutation for UL distributed resources

#of columns(C)	$C \leq 8$		$C \leq 16$		$C \leq 32$		$C \leq 64$		$C \leq 128$	
	i_b	i_o	i_b	i_o	i_b	i_o	i_b	i_o	i_b	i_o
Value	2	20	26	16	4	16	9	28	21	31

Table 4-22 parameters for intra-row permutation for UL distributed resources

#of columns(C)	$C \le 8$		$C \le 16$		$C \le 32$		$C \le 64$		$C \le 128$	
row index	i_b	i_o	i_b	i_o	i_b	i_o	i_b	i_o	i_b	i_o
0	4	0	13	9	8	30	61	12	97	109
1	1	7	7	0	1	3	46	63	44	107
2	3	1	14	12	9	26	46	59	25	110
3	2	7	4	2	28	1	47	5	84	33
4	1	2	11	15	14	31	1	47	119	63
5	4	3	2	4	18	13	34	33	34	2
6	2	2	8	5	8	27	19	54	98	36
7	3	7	8	9	13	11	1	2	30	6
8	5	3	1	8	14	21	2	24	60	9
9	5	1	11	7	22	12	52	42	66	93
10	3	5	8	3	26	9	13	40	52	66
11	2	0	14	10	3	14	31	19	90	38
12	6	7	7	10	12	29	22	48	5	114
13	1	3	14	4	12	5	29	11	62	49
14	2	5	13	7	5	12	26	60	103	65
15	3	6	7	8	30	4	13	42	114	72
16	3	4	4	5	28	0	4	49	13	81
17	2	1	2	8	4	29	32	44	90	59
18	5	7	14	3	1	21	37	54	7	15
19	6	3	14	2	12	11	53	60	98	87