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Abstract

This document is part and is in support of the complete proposal described in 802.11-13/r1301 (slides) and 802.11-13/1302r0 (text).

This document is the technical specification text as required in the TGaj selection procedure (802.11-12/1359r0).

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# 1. Overview

## 1.1 Scope

This amendment defines modifications to the IEEE P802.11ad Physical (PHY) layer and the Medium Access Control (MAC) layer to enable operation in the Chinese 59-64 GHz frequency band. The amendment shall maintain backward compatibility with 802.11ad when it operates in the 59-64 GHz frequency band.

## 1.2 Purpose

The purpose of the amendment is to support operation in the Chinese 59-64 GHz frequency band to enable multi-Gbps throughput.

# 2. Normative references

IEEE 802.11™-2012, IEEE Standard for Information Technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications

IEEE 802.11aa™-2012, IEEE Standard for Information Technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, Amendment 1: Prioritization of Management Frames

IEEE 802.11ae™-2012, IEEE Standard for Information Technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, Amendment 2: MAC Enhancements for Robust Audio Video Streaming

IEEE 802.11ad™-2012, IEEE Standard for Information Technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, Amendment 3: Enhancements for Very High Throughput in the 60GHz Band

IEEE 802.11ac™-2012, IEEE Standard for Information Technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, Amendment 4:Enhancements for Very High Throughput for Operation in Bands below 6 GHz

IEEE 802.11af™-2012, IEEE Standard for Information Technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, Amendment 5: TV White Spaces Operation

# 3. Definitions, acronyms, and abbreviations

## 3.1 Definitions

## 3.2 Definitions specific to IEEE802.11

## 3.3 Abbreviations and acronyms

***Insert the following abbreviations into 3.3 in alphabetic order:***

|  |  |
| --- | --- |
| CDMG | China directional multi-gigabit |
| DBC | dynamic bandwidth control |
| DCT | dynamic channel transfer |

# 6. Layer management

## 6.3 MLME SAP interface

***Insert the following subclauses, 6.3.95 to 6.3.95.9.4 after 6.3.94.3.4:***

### 6.3.95 DCT procedure

#### 6.3.95.1 General

This subclause describes the management procedures associated with the dynamic channel transfer mechanism.

#### 6.3.95.2 MLME-DCTMeasurement.request

##### 6.3.95.2.1 Function

This primitive requests transmission of a DCT Measurement Request frame to the DCT responder PCP/AP.

##### 6.3.95.2.2Semantics of the service primitive

The primitive parameters are as follows:

MLME- DCTMeasurement.request (

DCTResponderAddress,

DCTMeasurementRequest

)

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Type** | **Valid range** | **Description** |
| DCTResponderAddress | MAC Address | Any valid individual MAC address | Specifies the MAC address of the PCP/AP to which the DCT Measurement Request frame is transmitted. |
| DCTMeasurementRequest | DCT Measurement Request Action field | As defined in the DCT Measurement Request frame format | Specifies the parameters of the DCT Measurement Request. |

##### 6.3.95.2.3 When generated

This primitive is generated by the SME to request that a DCT Measurement Request frame be sent to the DCT responder PCP/AP..

##### 6.3.95.2.4 Effect on receipt

On receipt of this primitive, the MLME constructs and attempts to transmit a DCT Measurement Request frame.

#### 6.3.95.3 MLME-DCTMeasurement.indication

##### 6.3.95.3.1 Function

This primitive indicates that a DCT Measurement Request frame is received.

##### 6.3.95.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME- DCTMeasurement.indication (

DCTRequesterAddress,

DCTMeasurementRequest

)

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Type** | **Valid range** | **Description** |
| DCTRequesterAddress | MAC Address | Any valid individual MAC address | Specifies the MAC address of the PCP/AP from which the DCT Measurement Request frame is received. |
| DCTMeasurementRequest | DCT Measurement Request Action field | As defined in the DCT Measurement Request frame format | Specifies the parameters of the DCT Measurement. |

##### 6.3.95.3.3 When generated

This primitive is generated by the MLME when a valid DCT Measurement Request frame is received.

##### 6.3.95.3.4 Effect on receipt

On receipt of this primitive, the SME operates according to the procedure in 10.39.

#### 6.3.95.4 MLME-DCTMeasurement.report

##### 6.3.95.4.1 Function

This primitive requests transmission of a DCT Measurement Report frame to the DCT requester PCP/AP.

##### 6.3.95.4.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME- DCTMeasurement.report (

DCTResquesterAddress,

DCTMeasurementReport

)

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Type** | **Valid range** | **Description** |
| DCTRequesterAddress | MAC Address | Any valid individual MAC address | Specifies the MAC address of the PCP/AP to which the DCT Measurement Report frame is transmitted. |
| DCTMeasurementReport | DCT Measurement Report Action field | As defined in the DCT Measurement Report frame format | Specifies the parameters of the DCT Measurement. |

##### 6.3.95.4.3 When generated

This primitive is generated by the SME to request that a DCT Measurement Report frame be sent to the DCT requester PCP/AP.

##### 6.3.95.4.4 Effect on receipt

On receipt of this primitive, the MLME constructs and attempts to transmit a DCT Measurement Report frame.

#### 6.3.95.5 MLME-DCTMeasurement.confirm

##### 6.3.95.5.1 Function

This primitive indicates that a DCT Measurement Report frame was received.

##### 6.3.95.5.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME- DCTMeasurement.confirm (

DCTResponderAddress,

DCTMeasurementReport

)

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Type** | **Valid range** | **Description** |
| DCTResponderrAddress | MAC Address | Any valid individual MAC address | Specifies the MAC address of the PCP/AP from which the DCT Measurement Report frame was received. |
| DCTMeasurementReport | DCT Measurement Report Action field | As defined in the DCT Measurement Report frame format | Specifies the parameters of the DCT Measurement. |

##### 6.3.95.5.3 When generated

This primitive is generated by the MLME when a valid DCT Measurement Report frame is received.

##### 6.3.95.5.4 Effect on receipt

On receipt of this primitive, the SME operates according to the procedure in 10.39.

#### 6.3.95.6 MLME-DCT.request

##### 6.3.95.6.1 Function

This primitive requests transmission of a DCT Request frame to the DCT responder PCP/AP.

##### 6.3.95.6.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME- DCT.request (

DCTResponderAddress,

DCTRequest

)

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Type** | **Valid range** | **Description** |
| DCTResponderAddress | MAC Address | Any valid individual MAC address | Specifies the MAC address of the PCP/AP to which the DCT Request frame is transmitted. |
| DCTRequest | DCT Request Action field | As defined in the DCT Request frame format | Specifies the parameters of the DCT Request. |

##### 6.3.95.6.3 When generated

This primitive is generated by the SME to request that a DCT Request frame be sent to the DCT responder PCP/AP.

##### 6.3.95.6.4 Effect on receipt

On receipt of this primitive, the MLME constructs and attempts to transmit a DCT Request frame.

#### 6.3.95.7 MLME-DCT.indication

##### 6.3.95.7.1 Function

This primitive indicates that a DCT Request frame is received.

##### 6.3.95.7.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME- DCT.indication (

DCTRequesterAddress,

DCTRequest

)

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Type** | **Valid range** | **Description** |
| DCTRequesterAddress | MAC Address | Any valid individual MAC address | Specifies the MAC address of the PCP/AP from which the DCT Request frame is received. |
| DCTRequest | DCT Request Action field | As defined in the DCT Request frame format | Specifies the parameters of the DCT Request. |

##### 6.3.95.7.3 When generated

This primitive is generated by the MLME when a valid DCT Request frame is received.

##### 6.3.95.7.4 Effect on receipt

On receipt of this primitive, the SME operates according to the procedure in 10.39.

#### 6.3.95.8 MLME-DCT.response

##### 6.3.95.8.1 Function

This primitive requests transmission of a DCT Response frame to the DCT requester PCP/AP.

##### 6.3.95.8.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME- DCT. Response (

DCTResquesterAddress,

DCTResponse

)

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Type** | **Valid range** | **Description** |
| DCTRequesterAddress | MAC Address | Any valid individual MAC address | Specifies the MAC address of the PCP/AP to which the DCT Measurement Report frame is transmitted. |
| DCT Response | DCT Response Action field | As defined in the DCT Response frame format | Specifies the parameters of the DCT Response. |

##### 6.3.95.8.3 When generated

This primitive is generated by the SME to provide the results of a DCT Request.

##### 6.3.95.8.4 Effect on receipt

On receipt of this primitive, the MLME constructs and attempts to transmit a DCT Response frame.

#### 6.3.95.9 MLME-DCT.confirm

##### 6.3.95.9.1 Function

This primitive indicates that a DCT Response frame was received.

##### 6.3.95.9.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME- DCT.confirm (

DCTResponderAddress,

DCTResponse

)

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Type** | **Valid range** | **Description** |
| DCTResponderrAddress | MAC Address | Any valid individual MAC address | Specifies the MAC address of the PCP/AP from which the DCT Measurement Report frame was received. |
| DCTResponse | DCT Response Action field | As defined in the DCT Response frame format | Specifies the parameters of the DCT Response. |

##### 6.3.95.9.3 When generated

This primitive is generated by the MLME when a valid DCT Measurement Report frame is received.

##### 6.3.95.9.4 Effect on receipt

On receipt of this primitive, the SME operates according to the procedure in 10.39.

# 8. Frame formats

## 8.3 Format of individual frame types

### 8.3.4 Extension frames

#### 8.3.4.1 DMG Beacon

***Replace figure 8-34b with the following figure:***



F 1 **Figure 8-34b—Beacon Interval Control field**

***Insert the following paragraph and table 8-33b after the twentieth paragraph (“The PCP Association Ready field ….”) in 8.3.4.1:***

The CDMG Channel Splitting field indicates the channel bandwidth status of the BSS/PBSS, which is formatted in Table 8-33b.

T 1 **Table 8-33b—Bitmap field format of CDMG Channel Bandwidth**

|  |  |
| --- | --- |
| **CDMG Channel Bandwidth** | **Features** |
| 00 | 2.16GHz |
| 01 | 1.08GHz |
| 10 | Reserved |
| 11 | Reserved |

## 8.4 Management frame body components

### 8.4.1 Fields that are not information elements

#### 8.4.1.7 Reason Code field

***Insert the following rows into Table 8-36 in numeric order, and update the Reserved row accordingly:***

T 2 Table 8-36—Reason codes

|  |  |  |
| --- | --- | --- |
| **Reason Code** | **Name** | **Meaning** |
| 67 |  | Transmission link establishment in alternative channel failed. |
| 68 |  | The alterative channel is occupied. |
| 69-65535 |  | Reserved |

### 8.4.2 Information elements

#### 8.4.2.134 Extended Schedule element

***Replace Figure 8-401aa with the following figure:***

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Allocation Control | BF Control | Source AID | Destination AID | Allocation Start |
| Octets | 2 | 2 | 1 | 1 | 4 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Allocation Block Duration | Number of Blocks | Allocation Block Period | Number of Alternate TX BI | Number of Suspension BI |
| 2 | 1 | 2 | 2 | 2 |

F 2**Figure 8-401aa—Allocation field format**

***Change Table 8-183i as follows:***

T 2**Table 8-183i—AllocationType field values**

|  |  |  |  |
| --- | --- | --- | --- |
| **Bit 4** | **Bit 5** | **Bit 6** | **Meaning** |
| 0 | 0 | 0 | SP allocation in dedicated channel |
| 1 | 0 | 0 | CBAP allocation in dedicated channel |
| 0 | 1 | 0 | SP allocation in alternative channel |
| 1 | 1 | 0 | CBAP allocation in alternative channel |
| All other combinations | | | Reserved |

***Insert the following paragraphs at the end of 8.4.2.134:***

The Number of Alternate TX BI field will indicate the duration of transmission block in the alternate channel in terms of number of BI.

The Number of Suspension BI field will indicate the duration of between two consecutive transmission blocks in the alternate channel in terms of number of BI.

## 8.5 Action frame format details

### 8.5.8 Public Action details

#### 8.5.8.1 Public Action frames

***Insert the following rows into Table 8-210 in numeric order, and update the Reserved row accordingly:***

T 1**Table 8-210—Public Action field values**

|  |  |
| --- | --- |
| **Public Action field value** | **Description** |
| 18 | DCT Measurement Request |
| 19 | DCT Measurement Report |
| 20 | DCT Request |
| 21 | DCT Response |
| 22-255 | Reserved |

***Insert the following subclauses, 8.5.8.27 to 8.5.8.30 (including Table 8-221f, Table 8-221g,…..), after 8.5.8.26:***

#### 8.5.8.2 DCT Measurement Request frame

The DCT Measurement Request Action frame is transmitted by the DCT requester PCP/AP to a DCT responder PCP/AP to request all STAs in the DCT responder PCP/AP’s BSS（PBSS or Infrastructure BSS）to measure a specified channel or all other channels within supported operating class. The format of the DCT Measurement Request frame Action field is shown in Figure 8-460a.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Category | Public Action | Dialog Token | DCT Measurement Request Mode | Operating Class | Optional Subelements |
| Octets： | 1 | 1 | 1 | 1 | 1 | Variable |

F 2**Figure** **8-460a—DCT Measurement Request frame Action field format**

The Category field is set to 4 (representing Public), as specified in Table 8-38.

The Public Action field is set to 18 (representing DCT Measurement Request ), as specified in 8.5.8.1.

The Dialog Token field is set to a nonzero value chosen by the PCP/AP to uniquely identify the transaction.

The Measurement Request Mode subfield valid value and its meaning is defined in Table 8-221f. The Measurement Request Mode field is set to 1 to indicate that DCT requester PCP/AP requests all STAs within the DCT responder PCP/AP’s PBSS/Infrastructure BSS to measure all channels in the operating class specified in the following Operating Class field. The Measurement Request Mode field is set to 2 to indicate that DCT requester PCP/AP requests all STAs within the DCT responder PCP/AP’s PBSS/Infrastructure BSS to measure specified channel(s) indicated within the Optional Subelements field. Other values are reserved.

T 1**Table 8-221f—Valid values for the Measurement Request Mode**

|  |  |
| --- | --- |
| **DCT Measurement Request Mode Value** | **Meaning of Value** |
| 0 | Reserved |
| 1 | Measure all channels within the Operating Class. |
| 2 | Measure specified channel only. |
| 3-255 | Reserved |

The Operating Class field is valid only when the Measurement Request Mode field is set to 1. In all other cases, the Operating Class field is reserved. Operating Class field indicates the channel set for which the DCT measurement request applies. Country, Operating Class, and Channel Number together specify the channel frequency and spacing for which the DCT measurement request applies. Valid values of Operating Class are shown in Annex E.

The Optional Subelements field is present when the Measurement Request Mode field is set to 2. The Optional Subelements field format contains zero or more subelements, each consisting of a 1-octet Subelement ID field, a 1-octet Length field, and a variable-length Data field, as shown in Figure 8-402. The optional subelements are ordered by nondecreasing subelement ID.

The Subelement ID field values for the defined optional subelements are shown in Table 8-221g. A Yes in the Extensible column of a subelement listed in Table 8-221g indicates that the Length of the subelement might be extended in future revisions or amendments of this standard. When the Extensible column of an element is equal to Subelements, then the subelement might be extended in future revisions or amendments of this standard by defining additional subelements within the subelement. See 9.24.9.

T 1**Table 8-221g—Optional subelement IDs for DCT Measurement Request frame**

|  |  |  |  |
| --- | --- | --- | --- |
| **Subelement ID** | **Name** | **Length field**  **(octets)** | **Extensible** |
| 0 | Reserved |  |  |
| 1 | Channel Measurement Request | 3 | Yes |
| 2-220 | Reserved |  |  |
| 221 | Vendor Specific | 1 to 237 |  |
| 222-255 | Reserved |  |  |

The Channel Measurement Request subelement is used to specify the channel to be measured. The format of the DCT Channel Measurement Request subelement is shown in Figure 8-460b.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Subelement ID | Length | Measurement Token | Operating Class | Channel Number |
| Octets： | 1 | 1 | 1 | 1 | 1 |

F 3**Figure 8-460b—DCT Channel Measurement Request Subelement format**

The value of the subelement ID is set to 1 (representing Channel Measurement Request), as specified in Table 8-221g.

The Length field value is set to 3.

The Measurement Token is set to a nonzero number that is unique among the Channel Measurement Request Subelements in a particular DCT Measurement Request frame.

The Operating Class field indicates the channel set for which the channel measurement applies. Country, Operating Class, and Channel Number together specify the channel frequency and spacing for which the Channel Measurement Request applies. Valid values of Operating Class are shown in Annex E.

The Channel Number field is set to the channel number for which the Channel Measurement Request applies (as defined in 18.3.8.4.3).

#### 8.5.8.3 DCT Measurement Report frame

The DCT Measurement Report Action frame is transmitted by the DCT responder PCP/AP to the DCT requester PCP/AP to report the result of channel measurement. The format of the DCT Measurement Report frame Action field is shown in Figure 8-460c.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Category | Public Action | Dialog Token | DCT Measurement Report Mode | Operating Class | Optional Subelements |
| Octets： | 1 | 1 | 1 | 1 | 1 | Variable |

F 3**Figure 8-460c—DCT Measurement Report frame Action field format**

The Category field is set to 4 (representing Public), as specified in Table 8-38.

The Public Action field is set to 19 (representing DCT Measurement Report), as specified in 8.5.8.1.

The Dialog Token field value is copied from the corresponding received DCT Measurement Request frame.

The Measurement Report Mode subfield valid value and description is defined in Table 8-221h. The Measurement Report Mode field is set to 0 to indicate no clear channel to which the DCT responder PCP/AP’s BSS to move within the operating class specified in the following Operating Class field, or the DCT request has been declined. The Measurement Report Mode field is set to 1 to indicate that all other channels within the operating class specified in the following Operating Class field are available for the DCT responder PCP/AP’s BSS. The Measure7ment Report Mode field is set to 2 to indicate that the clear channel for the DCT responder PCP/AP’s BSS is indicated by the optional DCT Measurement report subelement. Other values are reserved.

T 7**Table 8-221h—Valid values for the Measurement Request Mode**

|  |  |
| --- | --- |
| **DCT Measurement Report Mode Value** | **Description** |
| 0 | No available channel or the DCT request has been declined. |
| 1 | All other channels are available. |
| 2 | Available channel is indicated by the optional DCT Measurement report subelement. |
| 3-255 | Reserved |

The Operating Class field is valid only when the Measurement Request Mode field is set to 1. In all other cases, the Operating Class field is reserved. Operating Class field indicates the channel set for which the DCT measurement request applies. Country, Operating Class, and Channel Number together specify the channel frequency and spacing for which the DCT measurement request applies. Valid values of Operating Class are shown in Annex E.

The Optional Subelements field is present when the Measurement Report Mode field is set to 2 .The Optional Subelements field format contains zero or more subelements, each consisting of a 1-octet Subelement ID field, a 1-octet Length field, and a variable-length Data field, as shown in Figure 8-402. The optional subelements are ordered by nondecreasing subelement ID.

The Subelement ID field values for the defined optional subelements are shown in Table 8-221i. A Yes in the Extensible column of a subelement listed in Table 8-221i indicates that the Length of the subelement might be extended in future revisions or amendments of this standard. When the Extensible column of an element is equal to Subelements, then the subelement might be extended in future revisions or amendments of this standard by defining additional subelements within the subelement. See 9.24.9.

T 8**Table 8-221i—Optional subelement IDs for DCT Measurement Report frame**

|  |  |  |  |
| --- | --- | --- | --- |
| **Subelement ID** | **Name** | **Length field**  **(octets)** | **Extensible** |
| 0 | Reserved |  |  |
| 1 | Channel Measurement Report | 3 | Yes |
| 2-220 | Reserved |  |  |
| 221 | Vendor Specific | 1 to 237 |  |
| 222-255 | Reserved |  |  |

The Channel Measurement Report subelement is used to report the number of available channel to which the DCT responder PCP/AP’s BSS can move. The DCT Channel Measurement Report subelement format is as shown in Figure 8-460d.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Subelement ID | Length | Measurement Token | Operating Class | Channel Number |
| Octets： | 1 | 1 | 1 | 1 | 1 |

F 3**Figure 8-460d—DCT Channel Measurement Report Subelement format**

The value of the subelement ID is set to 1 (representing Channel Measurement Report), as specified in Table 8-221i.

The Length field value is set to 3.

The Measurement Token is copied from the corresponding channel measurement request subelement in the received DCT Measurement Request frame.

The Operating Class field indicates the channel set for which the channel measurement applies. Country, Operating Class, and Channel Number together specify the channel frequency and spacing for which the Channel Measurement Report applies. Valid values of Operating Class are shown in Annex E.

The Channel Number field is set to the channel number to which the DCT responder PCP/AP’s BSS can transfer (as defined in 18.3.8.4.3).

#### 8.5.8.4 DCT Request frame

The DCT Request Action frame is transmitted by the DCT requester PCP/AP to the DCT responder PCP/AP to request DCT responder PCP/AP’s BSS to move to an available channel reported in the DCT Measurement Report frame. The format of the DCT Request frame Action field is shown in Figure 8-460e.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Category | Public Action | Dialog Token | Request Type | Operating Class | New Channel Number |
| Octets： | 1 | 1 | 1 | 1 | 1 | 1 |

F 3**Figure 8-460e—DCT Request frame Action field format**

The Category field is set to 4 (representing Public), as specified in Table 8-38.

The Public Action field is set to 20 (representing DCT Request ), as specified in 8.5.8.1.

The Dialog Token field value is the same as corresponding value in DCT Measurement Request frame.

The Request Type field value is set to 0 to indicate that the requester PCP/AP requests the responder PCP/AP to tear down the DCT procedure or the DCT request is refused by the responder PCP/AP. The following Operation Class field, New Channel Number field are reserved. The Request Type field value is set to 1 to indicate that the DCT requester PCP/AP to request the DCT responder PCP/AP’s BSS to move to an available channel indicated by the following Operating Class field and New Channel Number field. Other values are reserved.

The Operating Class field indicates the channel set for which the DCT measurement request applies. Country, Operating Class, and Channel Number together specify the channel frequency and spacing for which the DCT request applies. Valid values of Operating Class are shown in Annex E. This field is valid only when the Request Type field sets to 1, otherwise reserved.

The New Channel Number field is set to the channel number to which the DCT requester PCP/AP request the DCT responder PCP/AP’s BSS to move (as defined in 18.3.8.4.3). This field is valid only when the Request Type field sets to 1, otherwise reserved.

#### 8.5.8.5 DCT Response frame

The DCT Response Action frame is transmitted by the DCT responder PCP/AP to the DCT requester PCP/AP to confirm that the DCT responder PCP/AP’s BSS is moving to the channel specified in the DCT request frame. The format of the DCT Response frame Action field is shown in Figure 8-460f.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | Category | Public Action | Dialog Token | Responder  Type | Operating Class | New Channel Number | Channel Switch Count |
| Octets： | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

F 3**Figure 8-460f—DCT Responder frame Action field format**

The Category field is set to 4 (representing Public), as specified in Table 8-38.

The Public Action field is set to 21 (representing DCT Response), as specified in 8.5.8.1.

The Dialog Token field value is copied from the corresponding received DCT Request frame.

The Operating Class field indicates the channel set for which the DCT measurement request applies. Country, Operating Class, and Channel Number together specify the channel frequency and spacing for which the DCT request applies. Valid values of Operating Class are shown in Annex E.

The New Channel Number field is set to the channel number copied from the corresponding DCT Request frame.

The Channel Switch Count field either is set to the number of TBTTs until the DCT responder PCP/AP sending the Channel Switch Announcement frame or element within its BSS switches to the new channel or is set to 0. A value of 1 indicates that the switch occurs immediately before the next TBTT. A value of 0 indicates that the switch occurs at any time after the frame containing the element is transmitted.

# 9. MAC sublayer functional description

## 9.24 MAC frame processing

### 9.24.9 Extensible subelement parsing

***Insert “Table 211g, Table 211i ” in the first sentence of the third paragraph.***

## 9.33 DMG channel access

### 9.33.10 Updating multiple NAV times

***Insert the following subclauses after 9.33.10:***

### 9.33.11 Opportunistic Transmission in Alternative Channels

A PCP/AP can support the scheduling of opportunistic data transmission between two or more DMG STAs in a channel in which the BSS or PBSS does not reside. The channel for such opportunistic transmission is termed the alternative channel while the channel in which BSS or PBSS reside is termed the dedicated channel as a contrast in this section. The spectrum access in the alternative channel is divided into three phases: scan, transmission and suspension. The three phases rotate cyclically until all the scheduled transmissions in the alternative channel are completed. During the scan phase, which lasts for at least aMaxBIDuration, devices scheduled to operate in the alternative channel shall scan the channel to determine whether the alternative channel is occupied by another network. During the transmission phase, the devices perform their data transmissions as per the schedule allocated by the AP/PCP. Devices that are scheduled to perform data transmissions at the later timeslots can continue to scan the channel to sense the presence of other networks in the alternative channel. The duration of the transmission phase is limited by the Number of Alternate TX BI field (8.4.2.134)in the Extended Schedule element (8.4.2.134), after which, all the devices shall suspend their transmission in the alternative channel for the duration indicated in the Number of Suspension BI field (8.4.2.134)in the Extended Schedule element. The duration indicated in the Number of Suspension BI field comprises of the duration of the suspension phase and the next scan phase. At the end of the suspension phase, a new scan phase commences and the whole process repeats again.

The PCP/AP shall schedule the Allocation Start time (8.4.2.134)such that all pair of devices that are scheduled for transmission in the alternative channel shall be able to perform the scan of the alternative channel for at least aMaxBIDuration before the Allocation Start time. If there is more than one pair of devices scheduled for transmission in the alternative channel, the source device of the pair of devices with the earliest transmission start time will be designated as the prime source STA implicitly. The prime source STA shall transmit an echo beacon frame after every aMaxBIDuration within the transmission phase if the duration of the transmission phase exceeds aMaxBIDuration. All other allocations’ start time shall be scheduled by PCP/AP to be later than the start time of the prime source STA by at least the time it takes the prime source to complete the transmission of the echo beacon frame.

The PCP/AP shall also ensure that in the immediate beacon interval after the allocated start time for each pair of devices, time will be scheduled for the PCP/AP to communicate with the devices during the AT (9.33.3). The devices will continue with their transmission if the alternative channel is unoccupied and a link can be established between the source and the destination. Otherwise, the devices will return to the dedicated channel to report the reason for the inability to complete the transmission during their allocated transmission slot. The PCP/AP shall assume that no response from a pair of devices during the scheduled transmission slot to mean that the transmission is successful. Otherwise, the devices are expected to transmit a DELTS frame (8.5.3.4)to delete the allocated schedule and report the reason for the inability to complete the transmission.

The access periods in the alternative channel can be scheduled to be either CBAPs or SPs but the earliest access period shall be a SP. The CBAPs in the alternative channel can be used by the AP/PCP to send more devices to operate in the alternative channel after the initial setup.

The devices operating in the alternative channel shall periodically return to the dedicated channel during the transmission or suspension phases to synchronize with the AP/PCP through receiving the beacons or announce frame send out by the AP/PCP. The AP/PCP shall schedule transmission slots in the AT in the immediate beacon interval after the end of a transmission phase to communicate with the devices operating in the alternative channel. All the devices shall return to the dedicated channel to communicate with the PCP/AP during these scheduled slots. During these ATs, the devices can report the failure to continue the scheduled transmission, if it happens, by sending a DELTS frame with the appropriate Reason Code (8.4.1.7). The PCP/AP can also use these ATs to schedule more devices to operate in the alternative channel. If PCP/AP received the information that the alternative channel is occupied by another network from any of the devices sent to the alternative channel, the PCP/AP shall inform the rest of the devices at the earliest possible time in these ATs to cease transmission in the alternative channel.

## 9.34 DMG PCP/AP CLUSTERING

### 9.34.6 Clustering for dynamic bandwidth

Details will be provided later.

## 9.35 DMG beamforming

### 9.35.2 Sector-level sweep (SLS) phase

#### 9.35.2.5 Sector Sweep ACK

***Insert the following sentences at the end of this subsection:***

In purpose of spatial sharing, an SSW-ACK frame shall also be sent by the responder to the PCP/AP with the best TX sector, which indicates the beamforming information between the initiator and the responder.

## 9.39 DMG relay operation

***Insert the following subclause, 9.40 (including Figure 9-81, 9-82, 9-83a, 9-83b, 9-84a, 9-84b, 9-84c, 9-85a, 9-85b. ), after 9.39:***

## 9.40 Dynamic Bandwidth Control Mechanism

### 9.40.1 General

A CDMG PCP/AP can use dynamic bandwidth control (DBC) mechanism to fulfill individual logic channels and improve spatial sharing with interference mitigation.

According to the channelization scheme as described in Annex E.1, each large frequency band is allowed to be divided into two small frequency bands which can accommodate two individual BSS/PBSSs.

After the channel scanning, a new PCP/AP operates as below:

1. If a large band is available, it can start its BSS/PBSS either in this large band or in one of small bands within the large band.
2. If one of small bands within a large band is occupied but its adjacent small band is available, it can consider starting its BSS/PBSS in this unoccupied small band.
3. If a large band or both small bands within a large band are occupied, it can join the existing BSS/PBSS as a non-PCP/non-AP STA. Alternatively, if the existing BSS/PBSS supports the DMG PCP/AP clustering mechanism (9.34), it also can join as a member PCP/AP STA.
4. If a large band is occupied by an existing PCP/AP from another BSS/PBSS, it can request this PCP/AP to split the large band into two small bands. After that, two PCPs/APs will individually operate in their own small bands.

For Operation 1, the procedure of establishing a new BSS/PBSS on a large band is described in 9.33. However, to establish a new BSS/PBSS on a small band, PCP/AP not only needs to follow the DMG channel access mechanism as described in 9.33, but also must periodically transmit the Notification frame to notify other PCPs/APs that this small band is currently in use by this PCP/AP, which is detailed in 9.40.2.2.

For Operation 2, the procedure of establishing a new BSS/PBSS is described in 9.40.2.3.

For Operation 3, the DMG PCP/AP clustering that supports the DBC mechanism is described in 9.34.

For Operation 4, the channel splitting procedure is described in 9.40.3. After that, if one of PCP/AP terminates the services in its small band, the other PCP/AP operating in the adjacent small band have two options: 1) Continue to operate in the current small band, as described in 9.40.2.4; 2) Expand its bandwidth from the small band to the large band to maintain its BSS/PBSS services.

In addition, DBC mechanism supports the backward compatibility and interoperation with DMG STAs. If either a large band or a small band is occupied by a CDMG BSS/PBSS, any other DMG STA that finds the current BSS/PBSS after channel scanning still can join as a non-PCP/non-AP STA.

### 9.40.2 Channel Access in Small Band

#### 9.40.2.1 Co-existence between CDMG devices and DMG devices

The channelization scheme defined in this standard is shown in Annex E. Each STA that supports DBC mechanism is able to operate in either a large band (Channel 2 and 3) or a small band (Channel 5, 6, 7 and 8). However, DMG devices can only operate in a large band (Channel 2 and 3).

If a CDMG BSS/PBSS operates in a large band, the late coming DMG devices can easily detect the presence of this BSS/PBSS by hearing the DMG Beacon frames transmitted by the current PCP/AP within the current large band. Similarly, if an DMG BSS/PBSS operates in a large band, the late coming CDMG devices also can detect the presence of the DMG BSS/PBSS by hearing the DMG Beacon frames transmitted by DMG PCP/AP within the current large band.

However, if a CDMG BSS/PBSS operates in a small band, the late coming DMG devices are still possible to operate in the corresponding large band since they cannot hear any DMG Beacon frame transmitted by PCP/AP in this large band. As a result, CDMG BSS/PBSS and DMG BSS/PBSS may interfere with each other.

To avoid the inter-band interference and to provide the co-existence between CDMG BSS/PBSS and DMG BSS/PBSS, CDMG PCP/AP operating in a small band shall periodically send the DMG Beacon frames in the corresponding large band to notify other DMG PCP/APs that the current frequency band is occupied.

#### 9.40.2.2 BSS/PBSS Establishment in Small Band within a Large Band

A new PCP/AP can start its BSS/PBSS in any small band of an unoccupied large band.

First, the new PCP/AP sets a TSF timer to record the beacon interval (BI) duration in the large band and arranges a notification period (NP) at the beginning of beacon interval, which is shown in Figure 9-81. Here, the NP consists of at least a BTI, or A-BFT, or ATI, which is similar to the definition of BHI. During the BTI of a NP, PCP/AP transmits Notification frames to notify other PCPs/APs that the occupancy status of the channels within the large band. Thus, the beacon interval starts from the beginning of its NP, and the total length is limited by the Beacon Interval field (8.4.1.3).





F 8 **Figure 9-81—A PCP/AP starts its BSS/PBSS in Channel 5 within Channel 2**

At the end of NP, the PCP/AP will switch from the large band to the intended small band. To ensure that PCP/AP has enough time to successfully process the band switching, a Guard Intervals (GI) is inserted after the NP. Note that the switching time between the large band and small band and vice versa depend on the implementation of RF circuit. Thus, different devices may have the different lengths of GIs.

After switching to the small band, the PCP/AP must set another TSF timer to record the small band beacon interval (SBBI) duration. The SBBI duration is the same with the BI duration defined in 9.33(DMG channel access), which consists of BHI and DTI. Besides, the SBBI duration in the small band must be set as an integer factor of the BI duration in the large band in terms of TUs, and the maximum length of SBBI can be set as the same length of BI.

In order to switch back to the large band and successfully execute the NP at the beginning of the next BI, the PCP/AP must allocate a SP at the end of DTI of the last SBBI that overlaps the current BI, and this period is called quiet period (QP). The QP duration starts from the beginning of the GI duration prior to the next NP until to the end of the current SBBI, i.e., the QP should cover the NP as well as the GIs before and after the NP as shown in Figure 9-81.

#### 9.40.2.3 BSS/PBSS Establishment in Adjacent Small Band within a Large Band

Before the establishment of a BSS/PBSS, the new PCP/AP must do channel scanning to know the occupancy status of a large band and the small bands within it by hearing the DMG Beacon frames or Notification frames.

As introduced in 9.40.2.2, one of small bands within a large band is occupied, but its adjacent small band is unoccupied. In this case, if a new PCP/AP comes, it can start its BSS/PBSS in the adjacent small band and the related procedure is given as below.

Figure 9-82 shows an example that the first PCP/AP, called PCP/AP 1, operates in Channel 5 within Channel 2; later, the second PCP/AP, called PCP/AP 2, starts another BSS/PBSS in the adjacent Channel 6.



F 9 Figure 9-82—PCP/AP 1 first starts a BSS/PBSS in Channel 5 within Channel 2; later, PCP/AP 2 starts another BSS/PBSS in the adjacent Channel 6.

PCP/AP 2 may join the PCP/AP 1’s BSS/PBSS, send a Notification Period Request frame (8.5.20.27) to PCP/AP 1 during the following ATI, SP, or CBAP, and request PCP/AP 1 to allocate NPs for transmitting Notification frames in the large band. This method also applies to the non-PCP/non-AP STA that joined in PCP/AP 1’s BSS/PBSS but later intends to initialize another BSS/PBSS in which it performs the role of PCP/AP. Alternatively, PCP/AP 2 also may send an Extended Notification Period Request frame (8.5.20.27) to PCP/AP 1 during the following ATI through the inter/intra-BSS communication. The Notification Period Request frame or Extended Notification Period Request frame must contain the information that indicates the required length of NPs, etc.

After receiving the Notification Period Request frame or the Extended Notification Period Request frame, PCP/AP 1 may reject the PCP/AP 2’s request for NP allocation if it has accepted the request from other PCP/AP or it cannot satisfy this request. Otherwise, PCP/AP 1 shall allocate a SP with the same position in each beacon interval as the PCP/AP 2’s NP, and reply it through an Extended Schedule element contained in a Notification Period Response frame or an Extended Notification Period Response frame to notify the starting time and the length of the allocated NP duration for PCP/AP 2, the length of PCP/AP 1’s BI duration, etc.

After obtaining the information such as NP duration and BI duration, PCP/AP 2 shall start its BSS/PBSS following the similar procedure with the PCP/AP as described in 9.40.2.2. PCP/AP 2 sets a TSF timer to record its BI duration in the large band, called BI 2. Thus, the BI 2 starts from the beginning of NP 2, its length should be set as the same with BI 1, and so on.

To minimize the bandwidth switch cost between small bands and large band, two NPs in one beacon interval allocated for PCP/AP 1 and PCP/AP 2, i.e., NP 1 and NP 2, should be arranged consecutively without interspaces. Moreover, in order to not moving the TBTT of PCP/AP 1, NP 2 should be arranged prior to the next the NP 1, i.e., at the end of the current BI 1, which is shown in Figure 9-82. Therefore, each PCP/AP needs only switch from its own small band to the large band once to transmit its Notification frames and subsequently receive the Notification frames from the other PCP/AP during their corresponding NPs and then switch back to its small band to continue its services.

Following the NP 1, PCP/AP 1 (or 2) will prepare to switch from Channel 2 to the intended Channel 5 (or 6), and start its SBBI 1 (or 2) accordingly. To ensure that PCP/AP 1 (or 2) has enough time to successfully process the band switching, a GI must be inserted between the NP 1 and SBBI 1 (or 2). Note that due to the hardware diversity, different devices may have the different lengths of GIs.

To consider the interference mitigation and co-existence with other BSSs/PBSSs, each PCP/AP should periodically send Notification frames in its own NP duration and hear from each other to detect the occupancy status of the adjacent small band, unless it terminates the BSS/PBSS services.

In order to successfully switch back to the large band before the next BI, each PCP/AP must allocate a QP at the end of DTI of the last SBBI that overlaps the current BI, i.e., QP 1 or QP 2. The QP duration should cover the NP 1 and NP 2 as well as the GIs before and after the NPs as shown in Figure 9-82.

To counter the time drift due to clock offset between PCP/AP 1 and 2, two PCP/APs must be synchronized during each beacon interval. The synchronization can be fulfilled by TSF with PCP/AP 2 receiving the Timestamp field (8.4.1.10) contained in Notification frames transmitted by PCP/AP 1 during the NP 1.

If there exists a CDMG device that joined the BSS/PBSS of PCP/AP 1 before and has been allocated the SPs or CBAPs as shown in Figure 9-85b, PCP/AP 2 still can start its BSS/PBSS in the adjacent small band according to the procedures mentioned above. However, in the following medium access time, PCP/AP 1 and PCP/AP 2 must abide the channel access mechanism (9.33.6) and the backward compatibility and interoperation policy (9.40.4) to operate.

#### 9.40.2.4 Cease BSS/PBSS Services in Small Band

Suppose that only one of small bands within a large band is occupied as shown in Figure 9-81. If the PCP/AP ceases its BSS/PBSS services in this small band, the current large band will become idle.

Suppose that both small bands within a large band are occupied as shown in Figure 9-82. Later, if one PCP/AP ceases its BSS/PBSS services, the other PCP/AP will operate as follows.

First, the PCP/AP that proceeds to operate in the small band will not hear any Notification frame transmitted from the other one that ceases its BSS/PBSS services. To guard against the possibility of dropped frames, the PCP/AP shall wait for aMaxExpireDuration, which is an integer multiple of beacon intervals in the large band, starting from when the last frame from the other PCP/AP is received, before making the decision that the other adjacent PCP/AP’s network has ceased its network operation. After which, the PCP/AP confirms that the other one has ceased its services in the adjacent small band.

As illustrated in Figure 9-82, if the PCP/AP 2 ceases its services, then from the next beacon interval, PCP/AP 1 will not allocate any SP for the PCP/AP 2’s NP. Therefore, the QP duration only covers the NP 1 as well as GIs, which is illustrated in Figure 9-81.

However, if the PCP/AP 1 ceases its services, the time duration allocated for NP 1 will be wasted in Channel 6, which is illustrated in Figure 9-83a. To improve the channel utilization rate, the PCP/AP 2 may choose to move its TBTT backward for a NP 1’s length in the large band, and also reduce the QP 2’s duration to only cover the NP 2 as well as GIs before and after NP 2, which is illustrated in Figure 9-83b.





F 8 Figure 9-83a—PCP/AP 1 ceases its service in Channel 5



F 8 Figure 9-83b—PCP/AP 2 moves its TBTT in Channel 2

### 9.40.3 Channel Splitting of Large Band

If the new PCP/AP does the channel scanning before the establishment of a BSS/PBSS and knows the current large band is occupied by hearing the DMG Beacon frames transmitted by another PCP/AP, it may request the existing PCP/AP for channel splitting of this large band.

Figure 9-84a illustrates that a BSS/PBSS is currently operating in the Channel 2 with its PCP/AP denoted by PCP/AP 1. Then, a new PCP/AP 2 requests the PCP/AP 1 to split the Channel 2 into Channel 5 and Channel 6.



F 8 **Figure 9-84a—PCP/AP 1 operates in Channel 2**

PCP/AP 2 may join the current BSS/PBSS, send a Channel Splitting Request frame (8.5.20.25) to PCP/AP 1 during the ATI, SP, or CBAP, and request PCP/AP 1 to split Channel 2 into Channel 5 and Channel 6 in the following medium time. This method also applies to the non-PCP/non-AP STA that joined in current BSS/PBSS before but later intends to initialize another BSS/PBSS in one of small bands in which it performs the role of PCP/AP. Alternatively, PCP/AP 2 also may send an Extended Channel Splitting Request frame (8.5.8.27) to PCP/AP 1 during the ATI through the inter/intra-BSS communication.

PCP/AP 1 has the right to decide whether to split the large band or not. If the PCP/AP 1 decides to split, it shall notify all of its non-PCP/non-AP STAs with the channel number to which it will move and the switch time until it switches to the new channel through a Channel Switch Announcement element (8.4.2.21) contained in the DMG Beacon and/or Announce frames. Here, the switch time is set until to the beginning of the first SBBI after channel splitting. Furthermore, PCP/AP 1 shall also response the PCP/AP 2 with a Channel Splitting Response frame (8.5.20.26) or an Extended Channel Splitting Response frame (8.5.8.28) which contains a Channel Switch Announcement element to indicate the new channel number and the switch time after channel splitting, etc. Besides, the Channel Splitting Response frame and the Extended Channel Splitting Response frame should also contain an Extended Schedule element to indicate the starting time and the length of the NP duration allocated for each PCP/AP within the large band, the length of BI duration after channel splitting, etc.

Otherwise, if the PCP/AP 1 cannot split the channel, it will reply a Channel Splitting Response frame or an Extended Channel Splitting Response frame with the Channel Splitting field equal to 0 to reject the requesting PCP/AP.

After obtaining the necessary information about the NP durations and the BI duration, the PCP/AP 1 and the PCP/AP 2 operate with the similar procedures as described in 9.40.2.3. As illustrated in Figure 9-84b, each PCP/AP sets a TSF timer to record its BI duration in the large band, called BI 1 or BI 2. The BI duration starts from the beginning of the corresponding NP, its length should be set as the same value of the BI duration given by the Channel Splitting Response frame and the Extended Channel Splitting Response frame, and so on. After switching to the small band, each PCP/AP must also set another TSF timer to record the SBBI duration, called SBBI 1 or SBBI 2. The SBBI consists of BHI and DTI, and its length can be individually set by each PCP/AP as an integer factor of the BI duration in terms of TUs, and the maximum length of SBBI can be equal to the length of BI.



F 8 Figure 9-84b—PCP/AP 2 requests PCP/AP 1 for channel splitting in Channel 2

To minimize the bandwidth switch cost between small bands and large band at PCP/AP 1 and PCP/AP 2, the NP 1 and NP 2 in one beacon interval should be arranged consecutively without interspaces. PCP/AP 1 may arrange the NP 2 after the NP 1, as illustrated in Figure 9-84b. Alternatively, PCP/AP 1 also may arrange the NP 2 before the NP 1, as illustrated in Figure 9-82. Thus, each PCP/AP needs only switch from its own small band to the large band once to transmit its Notification frames and subsequently receive the Notification frames from the other PCP/AP during their corresponding NPs and then switch back to its small band in every BI.

Figure 9-84b illustrates an example of channel splitting. Following the NP 2, each PCP/AP switches from Channel 2 to its own Channel 5 or Channel 6 and starts its SBBI 1 or SBBI 2. To ensure that PCP/AP 1 (or 2) has enough time to successfully process the band switching, a GI must be inserted between the NP 2 and SBBI 1 (or 2). Note that due to the hardware diversity, different devices may have the different lengths of GIs.

All the non-PCP/non-AP STAs that have joined in the PCP/AP 1’s BSS/PBSS must suspend their operating in the large band and switch to the corresponding small band before the switch time set by the Channel Switch Count field contained in the Channel Switch Announcement element. Later, if a new non-PCP/non-AP STA intends to join any of two BSSs/PBSSs in the corresponding small band, it needs only to do channel scanning and then follows the standard procedures to do DMG Beamforming (9.35), STA Authentication and Association (10.3), etc.

After channel splitting, any of the two PCP/APs operating in the small band should periodically switches to the large band to send its own Notification frames and hear from each other to detect the occupancy status of the adjacent small band during NPs, unless it ceases their BSS/PBSS service.

In order to successfully switch back to the large band before the next BI, each PCP/AP must allocate a QP at the end of DTI of the last SBBI that overlaps the current BI, i.e., QP 1 or QP 2. The QP duration should cover the NP 1 and NP 2 as well as the GIs before and after the NPs as shown in Figure 9-82.

In addition, to counter the time drift due to clock offset between PCP/AP 1 and 2, two PCP/APs must be synchronized during each beacon interval. The synchronization can be fulfilled by TSF with the requesting PCP/AP 2 receiving the Timestamp field (8.4.1.10) contained in Notification frames transmitted by the requested PCP/AP 1 during its NPs.

### 9.40.4 Channel Expansion of Small Bands

For Operation 4 in 9.40.1, if one of BSSs/PBSSs that operate in two different small bands in the same large band ceases the services, the other PCP/AP may expand its bandwidth from the small band to the large band to maintain its BSS/PBSS services.

As introduced in 9.40.2.4, the PCP/AP that proceeds to operate in the small band will not hear any Notification frame transmitted from the other one that ceases its BSS/PBSS services. To guard against the possibility of dropped frames, the PCP/AP shall wait for aMaxExpireDuration, which is an integer multiple of beacon intervals in the large band, starting from when the last frame from the other PCP/AP is received, before making the decision that the other adjacent PCP/AP’s network has ceased its network operation. After which, the PCP/AP confirms that the other one has ceased its services in the adjacent small band.

Figure 9-84c illustrates that the PCP/AP 2 is absent from Channel 6 and the PCP/AP 1 prepares to expand its channel bandwidth from the current Channel 5 to Channel 2.



F 8 Figure 9-84c—After the PCP/AP 2 ceases its services, the PCP/AP 1 starts the channel expansion

If the PCP/AP 1 intends to expand its channel bandwidth, it shall inform all of its non-PCP/non-AP STAs with the channel number of the intended large band and the switch time through a Channel Switch Announcement element (8.4.2.21) contained in the DMG Beacon and/or Announce frames. Here, the switch time is set to the end of a subsequent SBBI.

During the channel expansion, PCP/AP shall continue to transmit the Notification frames within its scheduled NPs. However, after the end of NPs in the last SBBI, it shall not switch back to the small band. The PCP/AP shall remain in the large band, waiting for an Idle Period (IP) to pass until the end of the current SBBI, and then initiates a new beacon interval by setting its new TSF timer in the following medium time as illustrated in Figure 9-84c. Obviously, the PCP/AP shall maintain its BSS/PBSS services without interruption due to the smooth switching and continuity from the small band to the large band.

During the channel expansion, PCP/AP 1 may receive the Notification Period Request frame or the Extended Notification Period Request frame from another PCP/AP. In this case, if PCP/AP 1 grants this request and the channel switch time is long enough to transmit frames containing the Channel Switch Announcement element, it shall inform all of its non-PCP/non-AP STAs to continue to operate in the current Channel 5, and response the requesting PCP/AP to start a new BSS/PBSS in the adjacent Channel 6 as described in 9.40.2.3.

Non-PCP/non-AP STAs that want to join any of two BSSs/PBSSs can directly tune into the intended small band to do channel scanning and receive the DMG Beacon frames that are sent by the present PCP/AP, and then follow the standard procedures to do DMG Beamforming (9.35), STA Authentication and Association (10.3), etc.

### 9.40.5 Backward Compatibility and Interoperation

The DBC mechanism not only solves the co-existence problem between CDMG BSS/PBSS and DMG BSS/PBSS, but only supports the backward compatibility and interoperation with DMG STAs. Even if a BSS/PBSS operates in a large band or a small band, the DMG STA still can join as a non-PCP/non-AP STA after it does the channel scanning and finds the current BSS/PBSS.

In Figure 9-84a, if a CDMG BSS/PBSS is operating in a large band, a late coming DMG device receives the DMG Beacon frames transmitted by the current BSS/PBSS after channel scanning and then joins as a non-PCP/non-AP STA following the standard procedures to do DMG Beamforming (9.35), STA Authentication and Association (10.3), etc.

In Figure 9-81, if a CDMG BSS/PBSS is operating in one of small bands within a large band and its adjacent small channel is unoccupied, a late coming DMG device receives the Notification frames transmitted by the current BSS/PBSS after channel scanning, does the DMG Beamforming (9.35) during the A-BFT of NPs, does the STA Authentication and Association (10.3) during the following ATI of NPs, and eventually joins as a non-PCP/non-AP STA but operates in the large band only.

After joining the current BSS/PBSS, the PCP/AP sends the Notification frames and/or Announce frames that contains the Extended Schedule element (8.4.2.134) to DMG non-PCP/non-AP STAs and allocates their SPs or CBAPs in the large band, which is illustrated in the 9-85a. Note that, the SPs or CBAPs allocated in either the large band or the small band cannot overlap with each other.



F 8 Figure 9-85a—The PCP/AP that operates in one small band while its adjacent small band is unoccupied allows the DMG devices to join as non-PCP/non-AP STAs and allocates their SPs or CBAPs in the large band only.

When the allocated SP or CBAP comes, the Source AID STAs and the Destination AID STAs set by Allocation field contained in the Extended Schedule element (8.4.2.134) will communicate with each other during this period. Moreover, if the source STAs or destination STAs are CDMG devices and previously operate in the small band, they must switch to the large band to communicate with the DMG non-PCP/non-AP STA. After that, the CDMG devices may switch back to the small band.

In Figure 9-82, if two small bands within a large band are both unoccupied by two different CDMG BSSs/PBSSs, a late coming DMG device receives the Notification frames transmitted by one of or both BSSs/PBSSs after channel scanning. First, it chooses which channel to join. Next, it does the DMG Beamforming (9.35) during the A-BFT of NPs in the large band as well as does the STA Authentication and Association (10.3) during the following ATI of NPs. Last, it joins as a non-PCP/non-AP STA but operates in the large band only.

After joining the current BSS/PBSS, the PCP/AP sends the Notification frames and/or Announce frames that contain the Extended Schedule element (8.4.2.134) to DMG non-PCP/non-AP STAs and allocates their SPs or CBAPs in the large band according to the allocation rules in 9.33.6, which is illustrated in the 9-85b.



F 8 **Figure 9-85b. The PCP/AP that operates in one small band while its adjacent small band is also occupied allows the DMG devices to join as non-PCP/non-AP STAs and allocates their SPs or CBAPs in the large band only.**

Different with the previous case in Figure 9-85b, the SP or CBAP allocation for DMG non-PCP/non-AP STAs must abide two conditions:

1. It cannot overlap with any existing allocation.
2. In the following channel access time, two PCP/APs in two different small bands cannot allocate any SP or CBAP overlapping with this one.

To satisfy the two conditions above, the PCP/AP that supports the DMG non-PCP/non-AP STAs must hear the Extended Schedule elements contained in the Notification frames transmitted by the adjacent PCP/AP to know about the allocations of channel access time. Alternatively, the PCP/AP also can send the Information Request frame (8.5.20.4) during the ATI of NPs in the large band to know about the allocations of the adjacent PCP/AP, and the adjacent PCP/AP replies with the Information Response frame (8.5.20.5) to response.

After obtaining the existing allocation information, the PCP/AP sends the Notification frames and/or Announce frames that contain the Extended Schedule element (8.4.2.134) to DMG non-PCP/non-AP STAs and the adjacent PCP/AP to allocate their SPs or CBAPs in the large band according to the allocation rules in 9.33.6.

In the following channel access time, two PCPs/APs shall not allocate any new SP or CBAP overlapping with the existing ones allocated either in the large band or in the small band.

# 10. MLME

## 10.31 Spatial sharing and interference mitigation for DMG STAs

### 10.31.3 Achieving spatial sharing and interference mitigation

***Replace the Paragraph 5 with the following paragraphs:***

The decision process at the PCP/AP to perform spatial sharing of a candidate and an existing SP is given as below.

As informed by the STAs participated in the beamforming trainings through SSW-ACK frames (9.35.2.5), the PCP/ AP is able to establish a table that includes the beamforming results among any two STAs in the network including PCP/AP and non-PCP/AP STAs, and, non-PCP/AP STA and non-PCP/AP STA.

As long as any two pair of devices involved in an existing SP and a candidate SP does not fall in the coverage region of the selected sectors at both the source and destination devices of each other, then the PCP/AP can consider to schedule the existing SP and the candidate SP time-overlapping with each other for spatial sharing. Furthermore, if any two pair of devices satisfies the above constraint, and meanwhile all the sector number differences between two best sectors which are chosen by one source device to two different destination devices are greater than 1, it gives more space to implement spatial sharing and interference mitigation among the existing SP and candidate SP.

## 10.38 DMG MAC sublayer parameters

***Insert the following subclause, 10.39 (including Figure 10-39), after 10.38:***

## 10.39 DCT procedures

### 10.39.1 General

Regulations that apply to the 60GHz band in China allow RLANs operating in the Chinese 60 GHz band to use channel with 1.08GHz or 2.16GHz bandwidth, which requires a mechanism to coordinate the allocation of operating channel. This subclause describes such a mechanism, referred to as Dynamic Channel Transfer (DCT). This mechanism may improve the flexibility and channel utilization efficiency when RLANs operate in Chinese 60Ghz frequency band, in case that the bandwidth of vacant channel can not satisfy the operating requirements of RLANs.

This subclause describes DCT procedures that can be used to satisfy these and similar future regulatory requirements. The procedures might also satisfy comparable needs in other frequency bands and may be useful for other purposes.

A device is DCT capable if the value of its local MIB variable dot11DynamicChannelTransferImplemented is true. A STA that is a DCT capable device advertises the capability by including the DCT capability element in Beacon, DMG Beacon, (Re)Association Request, (Re)Association Response, Information Request, Information Response, Probe Request, Probe Response, Announce, DCT Setup Request, DCT Setup Response.

PCP/AP shall use the DCT procedures defined in 10.39.1 to 10.39.6 if its local MIB variable dot11DynamicChannelTransferActivated is true. The MIB variable dot11DynamicChannelTransferActivated shall be set to true when PCP/AP require DCT procedures. It may also be set to true in other circumstances. The DCT procedures provide for the following:

* Assessing current channel condition (see 10.39.2)
* Requesting of measurements for new channel for the DCT responder BSS (see 10.39.3)
* Reporting of the result of measurements(see 10.39.4)
* Requesting existing BSS to migrate to a new channel (see 10.39.5)
* Operating on target channel(see 10.39.6)



F 3**Figure 10-39—Procedure of Dynamic Channel Transfer**

Figure 8-460g depicts the procedure of the Dynamic Channel Transfer. The figure is only an example of the basic procedure and is not meant to be exhaustive of all possible uses case. In the figure, the parameter n corresponds to the number of DCT Measurement Request and DCT Measure Report frame exchanges until the requirement of operating channel or bandwidth for the DCT requester PCP/AP is met. The detailed procedure of Dynamic Channel Transfer is described in following subclauses.

### 10.39.2 Assessing current channel condition

The DCT requester PCP/AP that intend to start a new BSS can assess available channel passively by performing channel scan or a Clear Channel Assessment(CCA) or by receiving DMG beacon frame sent by PCP/AP within one or more exciting PBSS or Infrastructure BSS. If the available channel bandwidth could not satisfy the operating requirements for RLANs, its PCP/AP can use the DCT procedure (10.39) to request one or more existing BSS to move to a new operating channel.

### 10.39.3 Requesting of measurements for new channel for the DCT responder BSS

The DCT requester PCP/AP shall send DCT Measurement Request frame (see 8.5.8.27) to a DCT responder PCP/AP to request one or more STAs in the DCT responder PCP/AP’s BSS to measure all other channels within supported operating class when DCT Measurement Request Mode is set to 1,or to measure one or more channels indicated by the Optional Subelements field when DCT Measurement Request Mode is set to 0. The responder PCP/AP can decide to measure one or more channels requested by requester PCP/AP after receiving the DCT measurement request. The algorithm to choose the channel to be measured is beyond the scope of this standard.

The DCT responder PCP/AP can use Radio Measurement procedure (see 10.11) to perform channel measurement.

### 10.39.4 Reporting of the result of measurements

Any result of a channel measurement request shall be returned without undue delay to the DCT responder PCP/AP using one or more measurement report frames. The result may be the completed measurement or an indication that the STA is unable to complete the measurement request.

After receiving the result of channel measurement from all STAs , the DCT responder PCP/AP shall transmit DCT Measurement Report frame (see 8.5.8.28) to the DCT requester PCP/AP to report the result of the DCT Measurement Request. The Measurement Report Mode field is set to 0 to indicate that there is no clear channel to which the DCT responder PCP/AP’s BSS to move within the operating class specified in the following Operating Class field, or the DCT request has been declined. The Measurement Report Mode field is set to 1 to indicate that all other channels within the operating class specified in the following Operating Class field are available for the DCT responder PCP/AP’s BSS. The Measurement Report Mode field is set to 2 to indicate that the clear channel for the DCT responder PCP/AP’s BSS is indicated by the optional DCT Measurement report subelement.

The DCT Measurement Report frames shall contain the same Dialog Token field as the corresponding DCT Measurement Request frame.

The DCT responder PCP/AP shall assess the DCT request and DCT measurement request against its capabilities and the impact on its BSS’s performance. The DCT request and the DCT measurement request may be refused by the DCT responder PCP/AP for some reason such as the BSS is busy. The reasons for refusing a DCT measurement request are beyond the scope of this standard but may include reduced quality of service, unacceptable power consumption, measurement scheduling conflicts, or other significant factors.

### 10.39.5 Requesting existing BSS to migrate to a new channel

For operating on an occupied channel , the DCT requester PCP/AP may make use of the information of Supported Operating Class and the results of measurements undertaken by the DCT responder PCP/AP and other STAs in same BSS to assist the selection of a new available channel for the DCT responder PCP/AP’s BSS . The algorithm to choose a new channel is beyond the scope of this standard, but shall satisfy applicable regulatory requirements, including uniform spreading rules and channel testing rules. The DCT requester PCP/AP shall request DCT responder PCP/AP and other STAs in it’s BSS to migrate to a new available channel indicated in the DCT Measurement Report frame by transmitting DCT Request frame (see 8.5.8.29) to the DCT responder PCP/AP .

The decision to switch to a new operating channel in a BSS shall be made only by the DCT responder PCP/AP. After receiving the DCT Request frame, the DCT responder PCP/AP shall transmit DCT Response frame (see 8.5.8.30) to DCT requester PCP/AP to confirm the DCT request and shall inform associated STAs that the PCP/AP is moving to a new channel and maintain the association by advertising the switch using Channel Switch Announcement elements or Extended Channel Switch Announcement element in Beacon frames, Probe Response frames, and Channel Switch Announcement frames until the intended channel switch time.

The DCT responder PCP/AP shall assess the DCT request against its capabilities and the impact on its BSS’s performance. The DCT request may be refused by the DCT responder PCP/AP for some reason such as the BSS is busy. The reasons for refusing a DCT measurement request are beyond the scope of this standard but may include reduced quality of service, unacceptable power consumption, measurement scheduling conflicts, or other significant factors.

### 10.39.6 Networking on target channel

The DCT requester PCP/AP shall listen on the target channel after channel switch time indicated by Channel Switch Count field in the DCT Response frame. Once the target channel is clear, the DCT requester PCP/AP can operate with other STAs on target channel.

# China directional multi-gigabit(CDMG) PHY specification

## 25.1 CDMG PHY Introduction

### 25.1.1 Scope

The CDMG PHY supports three modulation methods:

* A control modulation using CMCS 0 (the Control PHY – see 25.4)
* A single carrier (SC) modulation using CMCS 1-CMCS 9 (the moderate rate (MR) SC PHY – see 25.6), CMCS 10-CMCS 17 (the high rate (HR) SC PHY – see 25.7), and CMCS 30-CMCS 36 (the low power SC PHY – see 25.8)
* An OFDM modulation using CMCS 18-MCS 29 (the OFDM PHY – see 25.5)

All these modulation methods share a common preamble (see 25.3.6).

The services provided to the MAC by the CDMG PHY consist of two protocol functions, defined as follows:

1. A PHY convergence function, which adapts the capabilities of the physical medium dependent (PMD) system to the PHY service. This function is supported by the physical layer convergence procedure (PLCP), which defines a method of mapping the PLCP service data units (PSDU) into a framing format (PPDU) suitable for sending and receiving PSDUs between two or more STAs using the associated PMD systems.
2. A PMD system whose function defines the characteristics and method of transmitting and receiving data through a wireless medium between two or more STAs. Depending on the CDMG CMCSs, these STAs support a mixture of CDMG SC PHY, CDMG OFDM PHY, CDMG low power SC PHY, and CDMG Control PHY.

### CDMG PHY functions

The CDMG PHY contains three functional entities: the PHY convergence function (PLCP), the layer management function (PLME) and the PMD function. Each of these functions is described in detail in to 25.11. The CDMG PHY service is provided to the MAC through the PHY service primitives defined in Clause 12.

#### 25.1.2.1 CDMG PLCP subplayer

In order to allow the MAC to operate with minimum dependence on the PMD sublayer, a PHY convergence sublayer is defined (PLCP). The PLCP sublayer simplifies the PHY service interface to the MAC services.

#### CDMG PMD sublayer

The CDMG PMD sublayer provides a means to send and receive data between two or more STAs. This subclause is concerned with the SC and OFDM modulation.

#### 25.1.2.3 PHY management entity (PLME)

The PLME performs management of the local PHY functions in conjunction with the MLME.

#### 25.1.2.4 Service specification method

The models represented by figures and state diagrams are intended to be illustrations of the functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation; the actual method of implementation is left to the discretion of the CDMG PHY compliant developer. The service of a layer or sublayer is the set of capabilities that it offers to a user in the next higher layer (or sublayer). Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation.

## 25.2 CDMG PHY service interface

### 25.2.1 Introduction

The PHY interfaces to the MAC through the TXVECTOR, RXVECTOR, and the PHYCONFIG\_VECTOR. The TXVECTOR supplies the PHY with per packet transmit parameters. Using the RXVECTOR, the PHY informs the MAC of the received packet parameters. Using the PHYCONFIG\_VECTOR, the MAC configures the PHY for operation, independent of frame transmission or reception.

This interface is an extension of the generic PHY service interface defined in 7.3.4.

### 25.2.2 TXVECTOR and RXVECTOR parameters

The parameters in Table 25-1 are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request service primitive and/or as part of the RXVECTOR parameter list in the PHY-RXSTART.indication service primitive.

T 9Table 25-1—TXVECTOR and RXVECTOR parameters

| **Parameter** | **Value** | **TXVECTOR** | **RXVECTOR** |
| --- | --- | --- | --- |
| CMCS | The CMCS field indicates the modulation and coding scheme used in the transmission of the packet. Values are integers in the range 0-36.   * An CMCS of 0 indicates the use of Control PHY. * CMCS values of 1-9 indicate use of MR SC modulations. The value is a index to Table 25-12. * CMCS values of 10-17 indicate use of HR SC modulations. The value is a index to Table 25-15. * CMCS values of 18-29 indicates use of OFDM modulations. The value is an index toTable 25-9. * CMCS values of 30-36 indicate use of Low Power SC PHY the value is an index to Table 25-20. | Y | Y |
| LENGTH | Indicates the number of octets in the PSDU in the range of 0-262143. A value of zero indicates a packet in which no data part follows the header | Y | Y |
| ADD-PPDU | Enumerated Type:   * ADD-PPDU indicates that this PPDU is immediately followed by another PPDY with no IFS or preamble on the subsequent PPDU. * NO-ADD-PPDU indicates no additional PPDU follows this PPDU. | Y | Y |
| PACKET-TYPE | Enumerated Type:   |  | | --- | | * TRN-R-PACKET indicates either a packet whose data part is followed by one or more TRN-R subfields, or a packet that is requesting TRN-R subfields to be appended to a future response packet. * TRN-T-PACKET indicates a packet whose data part is followed by one or more TRN-T subfields.   This field is reserved if TRN-LEN is 0. | | Y | Y |
| TRN-LEN | |  |  | | --- | --- | | |  | | --- | | TRN-LEN indicates the length of the training field. Values are 0-64 in multiples of 4. A value of N indicates that the AGC has 4N subfields and that the TRN-R/T field has 5N subfields . | | | Y | Y |
| AGGREGATION | Indicates whether the PSDU contains an A-MPDU.  Enumerated Type:   * AGGREGATED indicates this is a packet with A-MPDU aggregation. * NOT\_AGGREGATED indicates this is a packet without A-MPDU aggregation. | Y | Y |
| RSSI | The allowed values for the RSSI parameter are in the range from 0 through RSSI maximum. This parameter is a measure by the PHY of the power observed at the antennas used to receive the current PPDU. RSSI shall be measured during the reception of the PLCP preamble. RSSI is intended to be used in a relative manner, and it shall be a monotonically increasing function of the received power. | N | Y |
| SNR | This parameter indicates the SNR measured during the reception of a control PHY packet. Values are -13dB to 50.75dB in 0.25dB steps | N | Y |
| ANT-CONFIG | |  | | --- | | Indicates which antenna configuration(s) is to be used throughout the transmission of the packet, and when to switch between configurations.  Values are implementation dependent. | | Y | N |
| CHAN-MEASUREMENT | Channel as measured during the reception of TRN-T subfields. Each measurement includes 63 complex numbers. | N | Y |
| TIME\_OF\_DEPARTURE\_REQUESTED | Enumerated type:   * TRUE indicates that the MAC entity requests that the PHY PLCP entity measures and reports time of departure parameters corresponding to the time when the first frame energy is sent by the transmitting port. * FALSE indicates that the MAC entity requests that the PHY PLCP entity neither measures nor reports time of departure parameters. | O | N |
| RX\_START\_OF\_FRAME\_OFFSET | 0 to 232-1. An estimate of the offset (in 10 nanosecond units) from the point in time at which the start of the preamble corresponding to the incoming frame arrived at the receive antenna port to the point in time at which this primitive is issued to the MAC. | N | Y |
| |  | | --- | | DTP\_TYPE | | |  | | --- | | Enumerated:  STATIC indicating static tone paring.  DYNAMIC indicating dynamic tone pairing. | | Y | Y |
| |  | | --- | | DTP\_INDICATOR | | |  | | --- | | Takes values 0 or 1 to indicate a DTP update (see 9.38) | | Y | Y |
| |  | | --- | | BEAM\_TRACKING\_REQUEST | | |  | | --- | | This parameter indicates whether beam tracking is requested. Enumerated type:  Beam tracking requested or Beam tracking not requested | | Y | Y |
| |  | | --- | | LAST\_RSSI | | |  |  | | --- | --- | | In the TXVECTOR, LAST\_RSSI indicates the received power level of the last packet with a valid PHY header that was received a SIFS period before transmission of the current packet, otherwise it is 0 (9.3.2.3.3 SIFS).  In the RXVECTOR, LAST\_RSSI indicates the value of the LAST\_RSSI field from the PCLP header of the received packet.   * Valid values are integers in the range 0-15: * Values of 2-14 represent power levels (-71+value×2) dBm.  |  | | --- | | * A value of 15 represents power greater than or equal to -42 dBm. * A value of 1 represents power less than or equal to -68 dBm. * A value of 0 indicates that the previous packet was not received a SIFS period before the current transmission. | | | Y | Y |
| Turnaround | Set to 1 or 0 as specified in 9.3.2.3.3 SIFS | Y | Y |

### 25.2.3 TXSTATUS Parameters

The parameters listed in Table 25-2 are defined as part of the TXSTATUS parameter list in the PHYTXSTART.confirm(TXSTATUS) service primitive.

T 10Table25-2—TXSTATUS parameters

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| TIME\_OF\_DEPARTURE | When the first frame energy is sent by the transmitting port, in units equal to 1/TIME\_OF\_DEPARTURE\_ClockRate.  This parameter is present only if TIME\_OF\_DEPARTURE\_REQUESTED is true in the corresponding request. |
| TIME\_OF\_DEPARTURE\_ClockRate | 0 to 216-1. The clock rate, in units of MHz, is used to generate the TIME\_OF\_DEPARTURE value. This parameter is present only if TIME\_OF\_DEPARTURE\_REQUESTED is true in the corresponding request. |
| TX\_START\_OF\_FRAME\_OFFSET | 0 to 232-1. An estimate of the offset (in 10 nanosecond units) from the point in time at which the start of the preamble corresponding to the frame was transmitted at the transmit antenna port to the point in time at which this primitive is issued to the MAC. |

## 25.3 Common parameters

### 25.3.1 Channelization

STAs compliant with the physical layer defined in clause operate in the channels defined in Annex E and shall support at least channel number 2.

The channel center frequency is defined as:

*Channel center frequency = Channel starting frequency + Channel spacing × Channel number*

where channel starting frequency, channel spacing and channel number are as defined in Annex E.

### 25.3.2 Transmit Mask

The transmitted spectrum shall adhere to the transmit spectrum mask shown in the Figure 25-1. The transmit spectrum shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 0.94 GHz, -17 dBr at a 0.6 GHz offset, -25 dBr at a 1.35 GHz offset and -30 dBr at a 1.53 GHz offset and above, inside the channels allowed for the regulatory domain in which the device is transmitting. The resolution bandwidth shall be set to 1 MHz.

The transmitted spectrum shall be measured on data packets longer than 10 us without training fields.



F 20Figure 25-1—Transmit Mask

### 25.3.3 Common requirements

#### 25.3.3.1 Introduction

The subclause describes the common requirement from all 5 CDMG PHYs: CPHY, MR SC, HR SC, OFDM and Low Power SC.

For all the PHYs, all defined fields are transmitted bit 0 first in time.

#### 25.3.3.2 Tx RF Delay

As defined at 17.3.8.5 and its value is implementation dependent.

#### 25.3.3.3 Center Frequency Tolerance

##### 25.3.3.3.1 General

The transmit and receive temperature range shall be ±20 ppm maximum.

##### 25.3.3.3.2 Center Frequency Tolerance

The transmitter center frequency shall converge to within 1ppm of its final value within 0.9 μs from the start of the packet.

#### 25.3.3.4 Symbol Clock Tolerance

The symbol clock frequency tolerance shall be ±20 ppm maximum.

The transmit center frequency and the symbol clock frequency shall be derived from the same reference oscillator.

#### 25.3.3.5 Tx Center Frequency Leakage

The transmitter center frequency leakage shall not exceed –23 dB relative to the overall transmitted power or, equivalently, in OFDM (CMCS 18-29), +2.5 dB relative to the average energy of a subcarrier, measured over a subcarrier spacing bandwidth.

#### 25.3.3.6 Transmit Ramp up and Ramp Down

The transmit power-down ramp is defined as the time it takes the transmitter to fall from greater than 90% to less than 10% of the maximum power to be transmitted in the frame.

The transmit power-on ramp shall be less than 10 ns.

#### 25.3.3.7 Antenna Setting

Antenna setting shall remain constant for the transmission of the entire packet except for the case of transmission of BRP-TX packets (see 25.11.2.2). During the transmission of BRP-TX packets it shall remain constant for the transmission of the STF, CE and Data field.

#### 25.3.3.8 Maximum Input Requirement

The receiver maximum input level is the maximum power level at the receive antenna(s) of the incoming signal, in dBm, present at the input of the receiver for which the error rate criterion (defined in 25.3.3.9) is met. A compliant receiver shall have a receiver maximum input level at the receive antenna(s) of at least 10 microwatts/cm2 for each of the modulation formats that the receiver supports.

#### 25.3.3.9 Receive Sensitivity

For CMCS 0, the PER shall be less than 5% for a PSDU length of 256 octets with the CMCS dependent input levels listed in Table 25-3 defined at the antenna port(s). For the other CMCSs, the PER shall be less than 1% for a PSDU length of 4096 octets with the CMCS dependent input levels listed in Table 25-3 defined at the antenna port(s).

NOTE – For RF power measurements performed over the air, the input level shall be corrected to compensate for the antenna gain in the implementation. The gain of the antenna is the maximum estimated gain by the manufacturer. In the case of the phased-array antenna, the gain of the phased-array antenna is the maximum sum of estimated element gain minus 3 dB implementation loss.

Table 25-3 assumes 5 dB implementation loss and 10 dB noise factor (Noise Figure).

T 11Table 25-3—Receiver Sensitivity

|  |  |
| --- | --- |
| **CMCS Index** | **Receive Sensitivity (dBm)** |
| 0 | -81 |
| 1 | -71 |
| 2 | -69 |
| 3 | -68 |
| 4 | -67 |
| 5 | -65 |
| 6 | -66 |
| 7 | -65 |
| 8 | -64 |
| 9 | -62 |
| 10 | -58 |
| 11 | -57 |
| 12 | -56 |
| 13 | -54 |
| 14 | -50 |
| 15 | -49 |
| 16 | -48 |
| 17 | -46 |
| 18 | -69 |
| 19 | -67 |
| 20 | -66 |
| 21 | -65 |
| 22 | -63 |
| 23 | -61 |
| 24 | -59 |
| 25 | -57 |
| 26 | -56 |
| 27 | -54 |
| 28 | -52 |
| 29 | -50 |
| 30 | -67 |
| 31 | -63 |
| 32 | -60 |
| 33 | -60 |
| 34 | -60 |
| 35 | -60 |
| 36 | -60 |

### 

### 25.3.4 Timing Related Parameters

T 12Table 25-4— Timing Related Parameters

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| NSD: Number of data subcarriers | 336 |
| NSP: Number of pilot subcarriers | 16 |
| NDC: Number of DC subcarriers | 3 |
| NST: Total Number of subcarriers | 355 |
| NSR: Number of subcarriers occupying half of the overall BW | 177 |
| ΔF: subcarrier frequency spacing | 2.5781MHz(1320MHz/512) |
| Fs: OFDM sample rate | 1320MHz |
| Fc: SC chip rate | 880MHz = ⅔ Fs |
| Ts: OFDM Sample Time | 0.76ns=1/Fs |
| Tc: SC Chip Time | 1.14ns=1/Fc |
| TDFT: IDFT/DFT period | 0.388 us |
| TGI: Guard Interval duration | 97 ns= TDFT/4 |
| Tseq | 14.6 ns=128×Tc |
| TSTF: Detection sequence duration | 3054.5 ns=21× Tseq |
| TCE: Channel Estimation sequence duration | 1309.1 ns=9×Tseq |
| TSYM: Symbol Interval | 0.485µs= TDFT+TGI |
| THEADER: Header Duration | 0.485 µs=TSYM (OFDM)  1.75 µs =3×512×Tc (SC) |
| FCCP: Control PHY chip rate | 880MHz |
| TCCP: Control PHY chip time | 1.14 ns = 1/FCP |
| TSTF-CP: Control PHY short training field duration | 7.5636 µs =52× Tseq |
| TCE-CP: Control PHY channel estimation field duration | 1309.1 ns=9×Tseq |
| TData | NSYM×TSYM (OFDM)  NBLKS×(512+64)×Tc (SC)   |  | | --- | | NOTE–*NSYM* is defined in 25.5.3.2.3.3 and *NBLKS* is defined in 25.6.3.2.3.3. | |

T 13Table 25-5— Frequently used parameters

|  |  |
| --- | --- |
| **Symbol** | **Explanation** |
|  | Number of coded bits per symbol |
|  | Number of data bits per symbol |
|  | Number of coded bits per single carrier |
|  | Code rate |

### 25.3.5 Mathematical conventions in the signal description

#### 25.3.5.1 General

The transmitted signal is described in complex base-band signal notation. The actual transmitted signal is related to the complex baseband signal *r*(*t*) by the following relation:



where

 represents the real part of a complex variable;

 is the center frequency of the carrier.

The transmitted RF signal is generated by modulating the complex baseband signal, which consists of several fields. The fields and the timing boundaries for the various fields are shown in Figure 25-2.



F 3Figure 25-2—Packet structure

The time offset, , determines the starting time of the corresponding field.



Where:



Each OFDM base band waveform , for the fields above, is defined via the discrete inverse Fourier transform as



Where

* is the complex constellation point to be transmitted on subcarrier *k.*
* *n* is the discrete time index.
* The window  is user defined and is used to smooth the transition between fields.

The base band waveform for fields defined by time domain sequences or for single carrier transmission is:



Where

is the *n*’th constellation point.

Conversion from the sampled digital domain to the continuous time domain is beyond the scope of this document. Filtering for pulse shaping such as in GMSK is beyond the scope of this specification.

#### 25.3.5.2 The windowing function

The windowing function is used to smooth the transition between adjacent fields in the packetwhere OFDM modulation is employed. No windowing is applied to preamble fields or to SC modulated fields**.** The windowing function is different from being equivalent to “1” only in the transition region.



F 25Figure 25-3—Illustration of the windowing function

An example of a windowing function is given by:



The transition region creates an overlap (with length *TR*) between adjacent fields. The field wave form  is extended cyclically to fill the part of the transition region in which it is undefined. If the transition region vanishes (i.e., *TR*=0), the windowing function degenerates to a rectangular window. The choice of windowing function is implementation dependent, as long as transmit EVM and transmit mask requirements are met.

### 25.3.6 A Common Preamble

#### 25.3.6.1 General

The preamble is the part of the PPDU that is used for packet detection, AGC, frequency offset estimation, synchronization, IQ imbalance estimation, indication of modulation (SC or OFDM) and channel estimation. The format of the preamble is common to both OFDM packets and SC packets. The preamble is composed of two parts: the Short Training field and the Channel Estimation field.



F 3Figure 25-4—The preamble

#### 25.3.6.2 The Short Training field

The Short Training field is composed of 18 repetitions of sequences Ga128(*n*) of length 128 defined in 21.11, a single frequency sequence (SFS) of length 256 that used for IQ imbalance estimation, followed by a single repetition of –Ga128(*n*).

The waveform for the Short Training field is:



Where mod is the modulus operation.

#### 25.3.6.3 The Channel Estimation field

The Channel Estimation field is used for channel estimation, as well as indication which modulation is going to be used for the packet. The Channel Estimation field is composed of a concatenation of two sequences Gu512(*n*) and Gv512(n) where the last 128 samples of Gu512(*n*) are equal to the last 128 samples used in the Short Training field. They are followed by a 128 samples sequence Gv128(n) equal to the first 128 samples of both Gu512(*n*) and Gv512(n).

The Gu512 and Gv512 Golay sequences are defined as,



When the data field of the packet is modulated using single carrier, the Gu512 and Gv512 fields are concatenated in the order illustrated in Figure 25-5. When the data field of the packet is modulated using OFDM, the Gu512 and Gv512 fields are concatenated in the order illustrated in Figure 25-6.



F 3Figure 25-5—Channel Estimation field for SC Packets



F 3Figure 25-6—Channel Estimation field for OFDM Packets

The waveform for the channel estimation sequence is:



Note that sequences Gu512(*n*) and Gv512(*n*) are defined for 0≤*n*≤511. For other *n* they are set to zero.

#### 25.3.6.4 Transmission of the Preamble BRP fields in an OFDM packet

See 21.3.6.4.

### 25.3.7 HCS calculation for headers of Control PHY, OFDM PHY and SC PHY

See 21.3.7.

### 25.3.8 Common LDPC parity matrices

See 21.3.8.

### 25.3.9 Scrambler

See 21.3.9.

### 25.3.10 Received channel power indicator (RCPI) measurement

The RCPI is a measure of the received RF power in the selected channel as measured at the CDMG Antenna output. This parameter shall be measured by the PHY of the received RF power in the channel measured over the preamble of the received frame. RCPI shall be a monotonically increasing, logarithmic function of the received power level defined in dBm. The allowed values for the Received Channel Power Indicator (RCPI) parameter shall be an 8 bit value in the range from 0 through 220, with indicated values rounded to the nearest 0.5 dB as follows:

 0: Power < –110 dBm

 1: Power = –109.5 dBm

 2: Power = –109.0 dBm

And so on up to:

 220: Power > 0 dBm

 221–254: reserved

 255: Measurement not available

where: RCPI = int{(Power in dBm +110) × 2} for 0 dBm > Power > –110 dBm

RCPI shall equal the received RF power with an accuracy of ± 5 dB (95% confidence interval) within the specified dynamic range of the receiver. The received RF power shall be determined assuming a receiver noise equivalent bandwidth equal to the channel width multiplied by 1.1. The relative error between RF power measurements made within a 1 second interval should be less than +/- 1 dB.

## 25.4 CDMG Control PHY

### 25.4.1 Introduction

Transmission and reception of Control PHY PPDUs is mandatory. Control PHY uses the same chip rate as the SC PHY. Control PHY is transmitted when the TXVECTOR indicates CMCS 0.

The modulation and coding scheme for the Control PHY is shown in the table below.

T 14Table 25-6—Modulation and coding scheme for the Control PHY

|  |  |  |  |
| --- | --- | --- | --- |
| **CMCS index** | **Modulation** | **Code rate** | **Data rate** |
| 0 | DBPSK | 1/2\* | 13.75 Mbps\* |
| |  | | --- | | \* Code rate and data rate may be lower due to codeword shortening | | | | |

### 25.4.2 Frame Format

The Control PHY frame is composed of the Preamble, Header, Data field, and possibly AGC and TRN-R/T field. This is shown in Figure 25-7.



F 3Figure 25-7—Control PHY Frames

### 25.4.3 Transmission

#### 25.4.3.1 Preamble

##### 25.4.3.1.1 General

The preamble is the part of the Control PHY PPDU that is used for packet detection, AGC, frequency offset estimation, synchronization, indication of frame type and channel estimation.

The preamble is composed of two parts as shown in Figure 25-8: the Short Training field and the Channel Estimation field.



F 3Figure 25-8—Control PHY Preamble

##### 25.4.3.1.2 Short Training field

The Short Training field is composed of 50 repetitions of sequences Gb128(*n*) of length 128, followed by a single -Gb128(n) sequence (for synchronization) and then a single -Ga128(n) sequence. The sequences Ga128(*n*) and Gb128(*n*) are defined in 21.11.

The waveform for the Short Training field is:

Where mod is the modulus operation. Note that sequences Ga128(*n*) and Gb128(*n*) are defined for 0≤*n*≤127. For other *n* they are set to zero.

##### 25.4.3.1.3 Channel Estimation field

The Channel Estimation field is the same as the Channel Estimation field of the SC PHY, as defined in Figure 25-5 of subclause .

#### 25.4.3.2 Header

See 21.4.3.2.

#### 25.4.3.3 Data field

See 21.4.3.3

### 25.4.4 Performance requirements

#### 25.4.4.1 Transmit Requirements

##### 25.4.4.1.1 Introduction

Transmitter performance requirements of the CPHY are defined in 25.4.4.1.2.

##### 25.4.4.1.2 Transmit EVM

The transmit EVM accuracy test shall be performed by instrumentation capable of converting the transmitted signal into a stream of complex samples, with sufficient accuracy in terms of I/Q arm amplitude and phase balance, dc offsets, phase noise, etc. The instrumentation shall perform carrier lock, symbol timing recovery and amplitude adjustment while making the measurements. The instrumentation shall incorporate a rake receiver or equalizer to minimize error resulting from multipath. If used, the equalizer shall be trained using information in the preamble (STF and/or CEF). For the CPHY EVM, the signal is first de-spread using Ga32. The EVM is then calculated on the resulting symbols according to the formula below:

* 

Where  is the number of samples to be measured and Ns should be greater than 511, is the average power of the constellation, is the complex coordinates of the measured symbol *i*, and  is the complex coordinates of the ideal constellation point for the measured symbol *i*.

The test equipment should use a root-raised cosine filter with roll-off factor of 0.25 for the pulse shaping filter when conducting EVM measurement.

The transmit pulse shaping used is left to the implementer.

The EVM shall not exceed a data-rate dependent value according to Table 25-7.

T 15Table 25-7—EVM requirement for control PHY

|  |  |  |
| --- | --- | --- |
| **CMCS Index** | **Description** | **EVM Value [dB]** |
| 0 | CPHY Modulation | -6 |

#### 25.4.4.2 Rx Requirements

##### 25.4.4.2.1 Introduction

This section describes the performance requirement from the CPHY receiver.

##### 25.4.4.2.2 CCA

The start of a valid CDMG Control PHY transmission at a receive level greater than the minimum sensitivity for control PHY (-78dBm), shall cause CCA to indicate busy with a probability > 90% within 3 us.

## 25.5 CDMG OFDM PHY

### 25.5.1 Introduction

Transmission and reception of OFDM PHY PPDUs is optional.

### 25.5.2 Frame Format

An OFDM frame is composed of the Short Training Field (STF), the channel estimation field (CE), the Header, OFDM symbols and optional training fields (see 25.11.2.2.2), as shown in Figure 25-9.



F 3Figure 25-9—OFDM frame format

### 25.5.3 Transmission

#### 25.5.3.1 Header

##### 25.5.3.1.1 General

In the OFDM PHY, the preamble is followed by the PLCP header. The PLCP header consists of several fields which define the details of the PPDU being transmitted. The encoding and modulation of the header is described in .

The header fields are described in Table 25-8.

T 16Table 25-8—OFDM Header fields

|  |  |  |  |
| --- | --- | --- | --- |
| **Field Name** | **Number of bits** | **Start Bit** | **Description** |
| Scrambler Initialization | 7 | 0 | bits X1-X7 of the initial scrambler state. |
| MCS | 6 | 7 | Index into the Modulation and Coding Scheme table |
| Length | 18 | 13 | Number of data octets in the PSDU. Range 0-262143. |
| Additional PPDU | 1 | 31 | |  | | --- | | Contains a copy of the parameter ADD-PPDU from the TXVECTOR. A value of 1 indicates that this PPDU is immediately followed by another PPDU with no IFS or preamble on the subsequent PPDU. A value of 0 indicates that no additional PPDU follows this PPDU. | |
| Packet type | 1 | 32 | |  | | --- | | Corresponds to the TXVECTOR parameter PACKET-TYPE.   * Packet Type = 0 indicates either a packet whose data part is followed by one or more TRN-R subfields, or a packet that is requesting TRN-R subfields to be appended to a future response packet. * Packet Type = 1 indicates a packet whose data part is followed by one or more TRN-T subfields.   The field is reserved when the Training Length field is 0. | |
| Training Length | 5 | 33 | |  | | --- | | Corresponds to the TXVECTOR parameter TRN-LEN.  If the Beam Tracking Request field is 0, the Training Length field indicates the length of the training field. The use of this field is defined in 25.11.2.2.3. A value of 0 indicates that no training field is present in this PPDU.  If the Beam Tracking Request field is 1 and the Packet Type field is 1, the Training Length field indicates the length of the training field. If the Packet Type field is 0, the Training Length field indicates the length of the training field requested for receive training. | |
| Aggregation | 1 | 38 | Set to 1 to indicate that the PPDU in the data portion of the packet contains an A-MPDU; otherwise, set to 0. |
| Beam Tracking Request | 1 | 39 | |  | | --- | | Corresponds to the TXVECTOR parameter BEAM\_TRACKING\_REQUEST.  Set to 1 to indicate the need for beam tracking (9.35.7); otherwise, set to 0.  The Beam Tracking Request field is reserved when the Training Length field is 0. | |
| Tone Pairing Type | 1 | 40 | |  | | --- | | Set to 0 to indicate Static Tone Pairing;  Set to 1 to indicate Dynamic Tone Pairing.  Only valid if CMCS field value is in the range of 13-17; otherwise reserved . | |
| DTP Indicator | 1 | 41 | |  | | --- | | Bit flip used to indicate DTP update.  Only valid when the Tone Pairing Type field is 1 and the CMCS field value is in the range of 13-17; otherwise reserved. | |
| Last RSSI | 4 | 42 | |  | | --- | | Contains a copy of the parameter LAST\_RSSI from the TXVECTOR. When set to 0, this field reserved and ignored by the receiver.  The value is an unsigned integer:   * Values of 2-14 represent power levels (-71+value×2) dBm. * A value of 15 represents a power greater than or equal to -42 dBm. * A value of 1 represents a power less than or equal to -68 dBm.   Value of 0 indicates that the previous packet was not received a SIFS period before the current transmission. | |
| Turnaround | 1 | 46 | As defined in Table 25-1. |
| Reserved | 1 | 47 | Set to 0, ignored by receiver |
| HCS | 16 | 48 | Header check sequence. Definition of this field calculation is in . |

All the numeric fields are encoded in unsigned binary, least significant bit first.

Reserved bits are set to 0 by the transmitter and shall be ignored by the receiver.

If the Additional PPDU field is equal to 1, the Training Length field shall be set to 0.

##### 25.5.3.1.2 Modulation and Coding Scheme

The modulation and coding scheme field specifies the modulation and code rate used in the PPDU. The modulation and coding schemes for OFDM modulations are defined in Table 25-9.

T 17Table 25-9—Modulation and Coding Scheme for CDMG OFDM

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **CMCS index** | **Modulation** | **Code Rate** | **NBPSC** | **NCBPS** | **NDBPS** | **Data Rate (Mbps)** |
| 18 | SQPSK | 1/2 | 1 | 336 | 168 | 346.50 |
| 19 | SQPSK | 5/8 | 1 | 336 | 210 | 433.125 |
| 20 | QPSK | 1/2 | 2 | 672 | 336 | 693.00 |
| 21 | QPSK | 5/8 | 2 | 672 | 420 | 866.25 |
| 22 | QPSK | 3/4 | 2 | 672 | 504 | 1039.50 |
| 23 | 16-QAM | 1/2 | 4 | 1344 | 672 | 1331.00 |
| 24 | 16-QAM | 5/8 | 4 | 1344 | 840 | 1732.50 |
| 25 | 16-QAM | 3/4 | 4 | 1344 | 1008 | 2079.00 |
| 26 | 16-QAM | 13/16 | 4 | 1344 | 1092 | 2252.25 |
| 27 | 64-QAM | 5/8 | 6 | 2016 | 1260 | 2598.75 |
| 28 | 64-QAM | 3/4 | 6 | 2016 | 1512 | 3118.50 |
| 29 | 64-QAM | 13/16 | 6 | 2016 | 1638 | 3378.375 |

A device that supports OFDM shall support CMCSs 18-22 for both Tx and Rx.

##### 25.5.3.1.3 Generation of the HCS bits

Calculation of the HCS for bits 0-47 of the header is defined in .

##### 25.5.3.1.4 Header encoding and modulation

See 21.5.3.1.4.

#### 25.5.3.2 The Data field

See 21.5.3.2.

### 25.5.4 Performance requirements

#### 25.5.4.1 Transmit Requirements

##### 25.5.4.1.1 Introduction

This subclause describes the performance requirement from the OFDM PHY transmitter.

##### 25.5.4.1.2 Transmit EVM

The transmit EVM accuracy test shall be performed by instrumentation capable of converting the transmitted signal into a stream of complex samples, with sufficient accuracy in terms of I/Q arm amplitude and phase balance, dc offsets, phase noise, etc.

The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or an equivalent procedure:

a) Start of frame shall be detected.

b) Transition from short sequences to channel estimation sequences shall be detected, and fine timing (with one sample resolution) shall be established.

c) frequency offsets shall be estimated and corrected.

d) The frame shall be de-rotated according to estimated frequency offset.

e) The complex channel response coefficients shall be estimated for each of the subcarriers using information contained in the preamble (STF and/or CEF).

f) For each of the data OFDM symbols: transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, derotate the subcarrier values according to estimated phase, and divide each subcarrier value with a complex estimated channel response coefficient.

g) For each data-carrying subcarrier, compute the Euclidean distance to the ideal location for the symbol, or pilot.

h) Compute the RMS average of all errors in a packet. It is given by:



Where:

is the number of frames

*i* is theframe index

*k* is thecarrier index

*K* is the set of pilot and data subcarriers {1,2, …, (NSR – 1), (NSR + NDC), (NSR+NDC+1),…, NST}

*j* is the symbol index

 is the numer of symbols

 is the total number of subcarriers.

*I\*,Q\** is the ideal constellation point, for I and Q respectively.

P0 is the average power of the constellation (*I\*,Q\**) computed over the *i*th frame

The measurements shall occur only on the OFDM symbols, the measurement shall be performed on at least 10 frames with 16 symbols at least in each of them. Random data shall be used.

The EVM RMS error shall not exceed an CMCS dependent value as found in the table below:

T 18Table 25-10—EVM requirements for OFDM

|  |  |  |  |
| --- | --- | --- | --- |
| **CMCS Index** | **Modulation** | **Coding Rate** | **EVM Value [dB]** |
| 18 | SQPSK | ½ | -7 |
| 19 | SQPSK | 5/8 | -9 |
| 20 | QPSK | ½ | -10 |
| 21 | QPSK | 5/8 | -11 |
| 22 | QPSK | ¾ | -13 |
| 23 | 16QAM | ½ | -15 |
| 24 | 16QAM | 5/8 | -17 |
| 25 | 16QAM | ¾ | -19 |
| 26 | 16QAM | 13/16 | -20 |
| 27 | 64QAM | 5/8 | -22 |
| 28 | 64QAM | ¾ | -24 |
| 29 | 64QAM | 13/16 | -26 |

##### 25.5.4.1.3 Tx Flatness

When using the OFDM PHY and only while transmitting OFDM symbols the average energy of the OFDM Symbols constellations in each of the subcarriers with indices –146 to –2 and +2 to +145 shall deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the subcarriers with indices –147 to –177 and +147 to +177 shall deviate no more than +2/–4 dB from the average energy of subcarriers with indices –177 to –2 and +2 to +177.

##### 25.5.4.1.4Time of Departure accuracy

The Time of Departure accuracy test evaluates TIME\_OF\_DEPARTURE against aTxPmdTxStartRMS and aTxPmdTxStartRMS against TIME\_OF\_DEPARTURE\_ACCURACY\_TEST\_THRESH as defined in Annex T with the following test parameters:

* MULTICHANNEL\_SAMPLING\_RATE is 1320x106 sample/s
* FIRST\_TRANSITION\_FIELD is Short Training field
* SECOND\_TRANSITION\_FIELD is Channel Estimation field
* TRAINING\_FIELD is Channel Estimation field
* TIME\_OF\_DEPARTURE\_ACCURACY\_TEST\_THRESH is 80 ns

NOTE — The indicated windowing applies to the time of departure accuracy test equipment, and not the transmitter or receiver.

#### 25.5.4.2 Rx Requirements

##### 25.5.4.2.1 Introduction

This section describes the performance requirement for an OFDM receiver.

##### 25.5.4.2.2 CCA

The start of a validCDMG OFDM PHY or CDMG SC PHY transmission at a receive level greater than the minimum sensitivity for CMCS 1 (-68dBm), shall cause CCA to indicate busy with a probability >90% within 1us.

## 25.6 CDMG MR SC PHY

### 25.6.1 Introduction

Transmission and reception of MR SC PHY PPDUs is mandatory for select CMCSs.

### 25.6.2 Frame format

The MR SC frame is composed of the Short Training Field (STF), the channel estimation field (CE), the Header, SC blocks and optional training fields, as shown in Figure 25-10.



F 3Figure 25-10—MR SC frame format

### 25.6.3 Transmission

#### 25.6.3.1 Header

##### 25.6.3.1.1 General

In the MR SC PHY, the preamble is followed by the header. The header consists of several fields which define the details of the PPDU to be transmitted. The encoding and modulation of the header is described in subclause 25.6.3.1.4.

The header fields are described in Table 25-11.

T 19Table 25-11—11MR SC Header fields

|  |  |  |  |
| --- | --- | --- | --- |
| **Field Name** | **Number of bits** | **Start Bit** | **Description** |
| Scrambler Initialization | 7 | 0 | bits X1-X7 of the initial scrambler state. |
| MCS | 6 | 7 | Index into the Modulation and Coding Scheme table |
| Length | 18 | 13 | Number of data octets in the PSDU. Range 0-262143. |
| Additional PPDU | 1 | 31 | |  | | --- | | Contains a copy of the parameter ADD-PPDU from the TXVECTOR. A value of 1 indicates that this PPDU is immediately followed by another PPDU with no IFS or preamble on the subsequent PPDU. A value of 0 indicates that no additional PPDU follows this PPDU. | |
| Packet type | 1 | 32 | |  | | --- | | Corresponds to the TXVECTOR parameter PACKET-TYPE.   * Packet Type = 0 indicates either a packet whose data part is followed by one or more TRN-R subfields, or a packet that is requesting TRN-R subfields to be appended to a future response packet. * Packet Type = 1 indicates a packet whose data part is followed by one or more TRN-T subfields.   The field is reserved when the Training Length field is 0. | |
| Training Length | 5 | 33 | |  | | --- | | Corresponds to the TXVECTOR parameter TRN-LEN.  If the Beam Tracking Request field is 0, the Training Length field indicates the length of the training field. The use of this field is defined in 25.11.2.2.3. A value of 0 indicates that no training field is present in this PPDU.  If the Beam Tracking Request field is 1 and the Packet Type field is 1, the Training Length field indicates the length of the training field. If the Packet Type field is 0, the Training Length field indicates the length of the training field requested for receive training. | |
| Aggregation | 1 | 38 | Set to 1 to indicate that the PPDU in the data portion of the packet contains an A-MPDU; otherwise, set to 0. |
| Beam Tracking Request | 1 | 39 | |  | | --- | | Corresponds to the TXVECTOR parameter BEAM\_TRACKING\_REQUEST.  Set to 1 to indicate the need for beam tracking (9.35.7); otherwise, set to 0.  The Beam Tracking Request field is reserved when the Training Length field is 0. | |
| Last RSSI | 4 | 40 | |  | | --- | | Contains a copy of the parameter LAST\_RSSI from the TXVECTOR. When set to 0, this field reserved and ignored by the receiver.  The value is an unsigned integer:   * Values of 2-14 represent power levels (-71+value×2) dBm. * A value of 15 represents a power greater than or equal to -42 dBm. * A value of 1 represents a power less than or equal to -68 dBm.   Value of 0 indicates that the previous packet was not received a SIFS period before the current transmission. | |
| |  | | --- | | Turnaround | | 1 | 44 | |  | | --- | | As defined in Table 25-1. | |
| Reserved | 3 | 45 | Set to 0, ignored by receiver |
| HCS | 16 | 48 | Header check sequence. Definition of this field calculation is in . |

All the numeric fields are encoded in unsigned binary, least significant bit first.

Reserved bits are set to 0 by the transmitter and shall be ignored by the receiver.

If the Additional PPDU field is equal to 1, the Training Length field shall be set to 0.

##### 25.6.3.1.2 Modulation and Coding Scheme

The modulation and coding scheme defines the modulation and code rate that is used in the PPDU. The modulation and coding schemes for MR SC are defined in Table 25-12.

T 20Table 25-12—Modulation and Coding Scheme for MR SC

| **CMCS Index** | **Modulation** | **NCBPS** | **Repetition** | **Code Rate** | **Data Rate (Mbps)** |
| --- | --- | --- | --- | --- | --- |
| 1 | π/2-BPSK | 1 | 2 | 1/2 | 192.5 |
| 2 | π/2-BPSK | 1 | 1 | 1/2 | 385 |
| 3 | π/2-BPSK | 1 | 1 | 5/8 | 481.25 |
| 4 | π/2-BPSK | 1 | 1 | 3/4 | 577.5 |
| 5 | π/2-BPSK | 1 | 1 | 13/16 | 625.625 |
| 6 | π/2-QPSK | 2 | 1 | 1/2 | 770 |
| 7 | π/2-QPSK | 2 | 1 | 5/8 | 962.5 |
| 8 | π/2-QPSK | 2 | 1 | 3/4 | 1155 |
| 9 | π/2-QPSK | 2 | 1 | 13/16 | 1251.25 |

##### 25.6.3.1.3 Generation of the HCS bits

Calculation of the HCS for bits 0-47 of the header is defined in subclause .

##### 25.6.3.1.4 Header encoding and modulation

See 21.6.3.1.4.

#### 25.6.3.2 The Data field

##### 25.6.3.2.1 General

The data field consists of the payload data of the PSDU and possible padding. The data are padded with zeros, scrambled, encoded and modulated as described in the following subclauses.

##### 25.6.3.2.2 Scrambler

See 21.6.3.2.2.

##### 25.6.3.2.3 Encoding

1. See 21.6.3.2.3

##### 25.6.3.2.4 Modulation Mapping

###### 25.6.3.2.4.1 General

The coded and padded bit stream is converted into a stream of complex constellation points according to the modulation specified in the CMCS table.

###### 25.6.3.2.4.2 π/2-BPSK Modulation

In π/2-BPSK modulation, the input bit stream is mapped according to the following equation: , where ck is the kth input coded (or scrambled pad) bit. Each output symbol is then rotated according to the following equation:.

+1

-1

+i

-i

1

0

F 3Figure 25-11—BPSK constellation bit encoding

NOTE – With appropriate choice of transmit filtering, π/2-BPSK is equivalent to a precoded pulse-shaped MSK (e.g., GMSK). The precoder is simply , where bin,k is the scrambled input stream, bin,-1 is 0, and bout,k is the input to the (G)MSK modulator.

###### 25.6.3.2.4.3 π/2-QPSK Modulation

In π/2-QPSK modulation, the input bit stream is grouped into sets of 2 bits and mapped according to the following equation: , where k is the output symbol index, k = 0, 1, …. Each output symbol is then rotated according to the following equation: .



F 3Figure 25-12—QPSK constellation bit encoding

##### 25.6.3.2.5 Symbol Blocking and Guard Insertion

Each group of NCBPB bits is pre-pended by π/2-BPSK symbols generated by the 64 point Golay sequence Ga64 defined in 21.11. NCBPB values are shown in Table 25-13. The starting index for the first symbol for π/2 rotation is 0.

T 21Table 25-13—Values of NCBPB

| Symbol Mapping | NCBPB |
| --- | --- |
| π/2-BPSK | 448 |
| π/2-QPSK | 896 |

If the Additional PPDU field within the PLCP header is equal to 0, the final block transmitted is 8 followed by the same Golay sequence guard interval. If the Additional PPDU field within the PLCP 9 header is equal to 1, the final block transmitted of the last PPDU in an A-PPDU is followed by the 10 same Golay sequence guard interval.

448 symbols

448 symbols

448 symbols

64

64

64

GI

DATA

GI

DATA

GI

DATA

64

GI

F 3Figure 25-13—Block transmission

### 25.6.4 Performance requirements

#### 25.6.4.1 Transmit Requirements

##### 25.6.4.1.1 Transmit EVM

The transmit EVM accuracy test shall be performed by instrumentation capable of converting the transmitted signal into a stream of complex samples, with sufficient accuracy in terms of I/Q arm amplitude and phase balance, dc offsets, phase noise, etc.

The instrumentation shall perform carrier lock, symbol timing recovery and amplitude adjustment while making the measurements. The equalizer shall be trained using information in the SC preamble (STF and/or CEF). For the MR SC PHY EVM, measuring Ns samples at the sample rate, the measured symbols should not contain the first and the last hundred symbols of a given packet (ramp up/down). The EVM is calculated according to the formula below:



Where Ns is the number of samples to be measured Ns should be 1000, is the average power of the constellation, is the complex coordinates of the measured symbol *i*,  is the complex coordinates of the ideal constellation point for the measured symbol *i*, and (*I*o*, Q*o) is the complex DC term chosen to minimize EVM.

The test equipment should use a root-raised cosine filter with roll-off factor of 0.25 for the pulse shaping filter when conducting EVM measurement.

The transmit pulse shaping used is left to the implementer.

The relative constellation error (EVM) shall not exceed a CMCS dependent value according to the table below.

T 25Table 25-14—Modulation and Coding Scheme for MR SC

|  |  |  |  |
| --- | --- | --- | --- |
| **CMCS Indexes** | **Modulation** | **Coding Rate** | **EVM Value [dB]** |
| 1 | π/2-BPSK | ½ with repetition | -6 |
| 2 | π/2-BPSK | 1/2 | -7 |
| 3 | π/2-BPSK | 5/8 | -9 |
| 4 | π/2-BPSK | 3/4 | -10 |
| 5 | π/2-BPSK | 13/16 | -12 |
| 6 | π/2-QPSK | 1/2 | -11 |
| 7 | π/2-QPSK | 5/8 | -12 |
| 8 | π/2-QPSK | 3/4 | -13 |
| 9 | π/2-QPSK | 13/16 | -15 |

##### 25.6.4.1.2 Time of Departure accuracy

The Time of Departure accuracy test evaluates TIME\_OF\_DEPARTURE against aTxPmdTxStartRMS and aTxPmdTxStartRMS against TIME\_OF\_DEPARTURE\_ACCURACY\_TEST\_THRESH as defined in Annex T with the following test parameters:

* MULTICHANNEL\_SAMPLING\_RATE is 880x106 sample/s
* FIRST\_TRANSITION\_FIELD is Short Training field
* SECOND\_TRANSITION\_FIELD is Channel Estimation field
* TRAINING\_FIELD is Channel Estimation field
* TIME\_OF\_DEPARTURE\_ACCURACY\_TEST\_THRESH is 80 ns

NOTE — The indicated windowing applies to the time of departure accuracy test equipment, and not the transmitter or receiver.

#### 25.6.4.2 Rx Requirements

##### 25.6.4.2.1 Introduction

This subclause describes the receiver requirements of the CDMG MR SC PHY.

##### 25.6.4.2.2 CCA

The start of a valid CDMG SC PHY transmission at a receive level greater than the minimum sensitivity for CMCS 1 (-68dBm) shall cause CCA to indicate busy with a probability > 90% within 1 us. The receiver shall hold the carrier sense signal busy for any signal 20 dB above the minimum sensitivity for CMCS 1.

## 25.7 CDMG HR SC PHY

### 25.7.1 Introduction

Transmission and reception of HR SC PHY PPDUs is optional.

### 25.7.2 Frame format

The HR SC frame is composed of the Short Training Field (STF), the channel estimation field (CE), the Header, SC blocks and optional training fields, as showing in the figure below.



F 3Figure 25-14—HR SC frame format

### 25.7.3 Transmission

#### 25.7.3.1 Header

##### 25.7.3.1.1 General

In the HR SC PHY, the header contains two parts, the first part is the same as the header of the MR SC PHY given in 25.6.3.1, and the last BLK is the training BLK (TBLK) that used to estimate distorted constellation, so as to react the nonlinearity of power amplifier (PA). The header of HR SC PHY is given in the figure below.



F 3Figure 25-15—Header of HR SC PHY

The first part of header consists of several fields which define the details of the PPDU to be transmitted. The fields of the first part are the same as that in Table 25-11.The encoding and modulation is also the same as that described in subclause 25.6.3.1.4.

##### 25.7.3.1.2 Modulation and Coding Scheme

The modulation and coding scheme defines the modulation and code rate that is used in the PPDU. The modulation and coding schemes for HR SC are defined in the table below.

T 23Table 25-15—Modulation and Coding Scheme for HR SC

| **CMCS Index** | **Modulation** | **NCBPS** | **Repetition** | **Code Rate** | **Data Rate (Mbps)** |
| --- | --- | --- | --- | --- | --- |
| 10 | π/2-16QAM | 4 | 2 | 1/2 | 1540 |
| 11 | π/2-16QAM | 4 | 1 | 5/8 | 1925 |
| 12 | π/2-16QAM | 4 | 1 | 3/4 | 2310 |
| 13 | π/2-16QAM | 4 | 1 | 13/16 | 2502.5 |
| 14 | π/2-64QAM | 6 | 1 | 1/2 | 2310 |
| 15 | π/2-64QAM | 6 | 1 | 5/8 | 2887.5 |
| 16 | π/2-64QAM | 6 | 1 | 3/4 | 3465 |
| 17 | π/2-64QAM | 6 | 1 | 13/16 | 3453.75 |

#### 25.7.3.2 The Data field

##### 25.7.3.2.1 General

The data field consists of the payload data of the PSDU and possible padding. The data are padded with zeros, scrambled, encoded and modulated as described in the following subclauses.

##### 25.7.3.2.2 Scrambler

See 21.6.3.2.2.

##### 25.7.3.2.3 Encoding

See 21.6.3.2.3

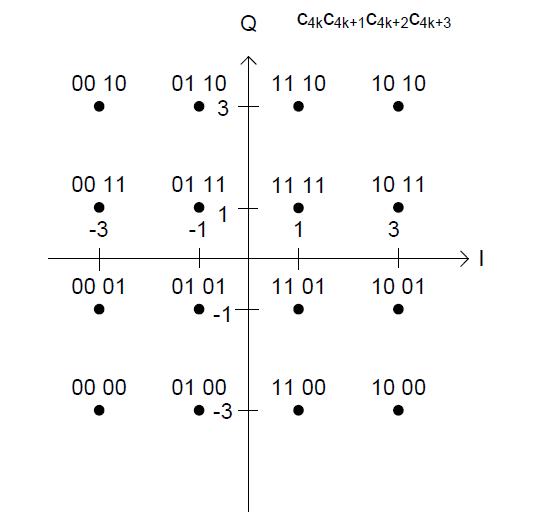
##### 25.7.3.2.4 Modulation Mapping

###### 25.7.3.2.4.1 General

The coded and padded bit stream is converted into a stream of complex constellation points according to the modulation specified in the CMCS table.

###### 25.7.3.2.4.2 π/2-16QAM Modulation

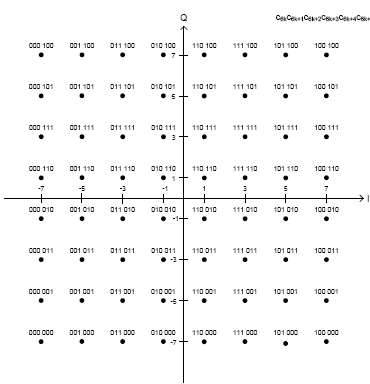
In π/2-16QAM modulation, the input bit stream is grouped into sets of 4 bits and mapped according to the following equation: , where k is the output symbol index, k = 0, 1, …. Each output symbol is then rotated according to the following equation: .



F 35Figure 25-16—16QAM constellation bit encoding

###### 25.7.3.2.4.3 π/2-64QAM Modulation

In π/2-64QAM modulation, the input bit stream is grouped into sets of 6 bits and mapped according to the following equation: , where k is the output symbol index, k = 0, 1, …. Each output symbol is then rotated according to the following equation: .



F 36Figure 25-17—64QAM constellation bit encoding

##### 25.7.3.2.5 Symbol Blocking and Guard Insertion

Each group of NCBPB bits is pre-pended by π/2-BPSK symbols generated by the 64 point Golay sequence Ga64 defined in 21.11. NCBPB values are shown in the following table. The starting index for the first symbol for π/2 rotation is 0.

T 26Table 25-18—Values of NCBPB

| **Symbol Mapping** | **NCBPB** |
| --- | --- |
| π/2-16QAM | 1792 |
| π/2-64QAM | 2688 |

If the Additional PPDU field within the PLCP header is equal to 0, the final block transmitted is 8 followed by the same Golay sequence guard interval. If the Additional PPDU field within the PLCP 9 header is equal to 1, the final block transmitted of the last PPDU in an A-PPDU is followed by the 10 same Golay sequence guard interval.

448 symbols

448 symbols

448 symbols

64

64

64

GI

DATA

GI

DATA

GI

DATA

64

GI

F 36Figure 25-18—Block transmission

### 25.7.4 Performance requirements

#### 25.7.4.1 Transmit Requirements

##### 25.7.4.1.1 Transmit EVM

The transmit EVM accuracy test shall be performed by instrumentation capable of converting the transmitted signal into a stream of complex samples, with sufficient accuracy in terms of I/Q arm amplitude and phase balance, dc offsets, phase noise, etc.

The instrumentation shall perform carrier lock, symbol timing recovery and amplitude adjustment while making the measurements. The equalizer shall be trained using information in the SC preamble (STF and/or CEF). For the MR SC PHY EVM, measuring Ns samples at the sample rate, the measured symbols should not contain the first and the last hundred symbols of a given packet (ramp up/down). The EVM is calculated according to the formula below:



Where Ns is the number of samples to be measured Ns should be 1000, is the average power of the constellation, is the complex coordinates of the measured symbol *i*,  is the complex coordinates of the ideal constellation point for the measured symbol *i*, and (*I*o*, Q*o) is the complex DC term chosen to minimize EVM.

The test equipment should use a root-raised cosine filter with roll-off factor of 0.25 for the pulse shaping filter when conducting EVM measurement.

The transmit pulse shaping used is left to the implementer.

The relative constellation error (EVM) shall not exceed a CMCS dependent value according to the table below.

T 27Table 25-19—Modulation and Coding Scheme for MR SC

|  |  |  |  |
| --- | --- | --- | --- |
| **CMCS Indexes** | **Modulation** | **Coding Rate** | **EVM Value [dB]** |
| 10 | π/2-16QAM | 1/2 | -19 |
| 11 | π/2-16QAM | 5/8 | -20 |
| 12 | π/2-16QAM | 3/4 | -21 |
| 13 | π/2-16QAM | 13/16 | -23 |
| 14 | π/2-64QAM | 1/2 | -24 |
| 15 | π/2-64QAM | 5/8 | -25 |
| 16 | π/2-64QAM | 3/4 | -26 |
| 17 | π/2-64QAM | 13/16 | -28 |

##### 25.7.4.1.2 Time of Departure accuracy

The Time of Departure accuracy test evaluates TIME\_OF\_DEPARTURE against aTxPmdTxStartRMS and aTxPmdTxStartRMS against TIME\_OF\_DEPARTURE\_ACCURACY\_TEST\_THRESH as defined in Annex T with the following test parameters:

* MULTICHANNEL\_SAMPLING\_RATE is 880x106 sample/s
* FIRST\_TRANSITION\_FIELD is Short Training field
* SECOND\_TRANSITION\_FIELD is Channel Estimation field
* TRAINING\_FIELD is Channel Estimation field
* TIME\_OF\_DEPARTURE\_ACCURACY\_TEST\_THRESH is 80 ns

NOTE — The indicated windowing applies to the time of departure accuracy test equipment, and not the transmitter or receiver.

#### 25.7.4.2 Rx Requirements

##### 25.7.4.2.1 Introduction

This subclause describes the receiver requirements of the CDMG HR SC PHY.

##### 25.7.4.2.2 CCA

The start of a valid CDMG SC PHY transmission at a receive level greater than the minimum sensitivity for CMCS 1 (-68dBm) shall cause CCA to indicate busy with a probability > 90% within 1 us. The receiver shall hold the carrier sense signal busy for any signal 20 dB above the minimum sensitivity for CMCS 1.

## 25.8 CDMG low power SC PHY

### 25.8.1 Introduction

The CDMG low power SC PHY is an optional SC mode. This mode can provide lower processing power requirements for CDMG tranceivers.

### 25.8.2 Transmission

#### 25.8.2.1 Preamble

The CDMG low power SC PHY uses the same preamble as the CDMG MR SC PHY.

#### 25.8.2.2 Header

##### 25.8.2.2.1 General

The CDMG low power SC PHY header fields are the same fields as in the CDMG MR SC PHY (see Table 25-11 in ).

The CDMG low power SC PHY modulation and coding schemes are listed in Table 25-20.

T 28Table 25-20—Low power SC Modualtion and Coding Schemes

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **CMCS** | **Modulation** | **Effective Code Rate** | **Coding Scheme** | **NCPB** | **Rate (Mbps)** |
| 30 | π/2-BPSK | 13/28 | RS(224,208)+Block-Code(16,8) | 392 | 313 |
| 31 | π/2-BPSK | 13/21 | RS(224,208)+Block-Code(12,8) | 392 | 417 |
| 32 | π/2-BPSK | 52/63 | RS(224,208)+SPC(9,8) | 392 | 556 |
| 33 | π/2-QPSK | 13/28 | RS(224,208)+Block-Code(16,8) | 392 | 625.5 |
| 34 | π/2-QPSK | 13/21 | RS(224,208)+Block-Code(12,8) | 392 | 834 |
| 35 | π/2-QPSK | 52/63 | RS(224,208)+SPC(9,8) | 392 | 1112 |
| 36 | π/2-QPSK | 13/14 | RS(224,208)+Block-Code(8,8) | 392 | 1251.5 |

##### 25.8.2.2.2 eader encoding and modulation

See 21.7.2.2.2.

#### 25.8.2.3 Data field

See 21.7.2.3.

## 25.9 PLCP transmit procedure

The PLCP transmit procedure is shown in Figure 21-18. In order to transmit data, a PHY-TXSTART.request primitive shall be enabled so that the PHY entity shall be in the transmit state. Further, the PHY shall be set to operate at the appropriate frequency through station management via the PLME, as specified in 25.13. Other transmit parameters, such as CMCS and transmit power, are set via the PHY-SAP with the PHYTXSTART.request(TXVECTOR), as described in 25.2.2.

The PLCP shall then issue a PMD\_TXSTART.request primitive, and transmission of the PLCP preamble shall start, based on the parameters passed in the PHY-TXSTART.request primitive. The preamble format (control PHY, SC or OFDM) depend on the CMCS in the PHY\_TXSTART.req. The PLCP shall calculate the length of the packet according the CMCS and the length specified in the PHY\_TXSTART.request primitive, adding padding bits if necessary.

The PHY continues with the encoding and transmission of the header according to the PHY\_TXSTART.req(TXVECTOR) parameters. The PHY proceeds with PSDU transmission through a series of data octet transfers from the MAC. The data are encoded as described in 25.4.3.2.3, 25.5.3.2.3, and 25.6.3.2.3. The encoded data are then modulated as described in 25.4, 25.5, 25.6, and 25.8, depending on the CMCS requested in the PHY\_TXSTART.req. Transmission can be prematurely terminated by the MAC through the primitive PHY-TXEND.request. PHY-TXSTART shall be disabled by receiving a PHYTXEND.request primitive.

Transmission of the PSDU is completed with the transmission of the last bits of the (encoded) PSDU. If no TRN-T/R fields are specified in the PHY-TXSTART.req, the PLCP shall issue PMD-TXEND after the transmission of the last bits. If TRN-T and TRN-R are requested in the PHY-TXSTART.req, the transmission continues with the transmission of AGC subfields and TRN-T/R subfields. The PCLP issues the PMD-TXEND after the transmission of the last TRN-T/R subfield, and then it issues a PHY\_TXEND.confirm primitive to the MAC. The packet transmission shall be completed, and the PHY entity shall enter the receive state (i.e., PHYTXSTART shall be disabled). Each PHY-TXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY.

A typical transmit state machine is shown in Figure 21-19.

## 25.10 PLCP receive procedure

A typical PLCP receive procedure is shown in Figure 21-20.

Upon receiving the STF, PMD\_RSSI.ind shall report received signal strength to the PCLP, this indicates activity to the MAC through PHY\_CCA.ind(BUSY).

After the PHY-CCA.indication(BUSY) is issued, the PHY entity shall search for the CE field and begin receiving the CE field. During the reception of the CE field, the PMD indicates to the PLCP the type of PHY of the packet. The PHY demodulates the header according to the PHY type determined during the PLCP. If the CE field indicated a SC PHY, the receiver is capable of receiving low-power SC PHY, and dot11LowPowerSCPHYActivated is true, then the PHY shall attempt to demodulate both a SC header and an SC low-power header. The PLCP shall decode the header and indicate to the PMD the CMCS, length and other parameters needed for the demodulation of the packet. At the end of the data portion of the packet, the PHY shall indicate PHY\_RXEND.ind(No\_Error) to the MAC. If the header indicated the presence of training field, the PMD shall continue to receive these training fields after the data portion of the packet. After the end of these fields, the PMD shall send the measurements to the PLCP using the PMD\_CHAN\_MEAS.ind. After the end of the training fields, the PHY shall indicate PHY\_CCA.ind(Idle).

In the case of signal loss before the decoding of the header or in the case of an invalid header, the PHY shall maintain PHY\_CCA.ind(BUSY) for any signal 20 dB higher from the receive sensitivity of CMCS 1. In the case of signal loss after decoding of a valid header, the PHY shall indicate PHY\_CCA.ind(BUSY) for the expected duration of the packet, including AGC and TRN-T/R fields.

A typical receive state machine is shown in Figure 21-21.

## 25.11 Beamforming

### 25.11.1 Beamforming concept

Beamforming enables a pair of STAs to train their transmit and receive antennas for subsequent communication. A beamformed link is established following the successful completion of BF training, which is described in 9.35.

CDMG STAs use a quasi-omni antenna pattern. The antenna gain of the main beam of a quasi-omni antenna pattern shall be at most 15 dB lower than the antenna gain in the main beam for a directional pattern.

### 25.11.2 Beamforming PHY frame format

#### 25.11.2.1 TX sector sweep

The packets sent during TX sector sweep are Control PHY packets as defined in .

#### 25.11.2.2 Beam refinement

##### 25.11.2.2.1 General

Beam refinement is a process where a STA can improve its antenna configuration (or antenna weight vectors) both for transmission and reception. If the SLS beamforming training did not include a RSS, as in the case where both devices have more than one transmit sector per antenna, beam refinement can serve as the first receive antenna configuration training. The procedure of beam refinement is described in 9.35.6.4.

In the beam refinement procedure, BRP packets are used to train the receiver and transmitter antenna. There are two types of BRP packets: BRP-RX packets and BRP-TX packets:

* BRP-RX packets are packets that have TRN-R training sequences appended to them. These packetsenable receiver antenna weight vector training.
* BRP-TX packets are packets that have TRN-T training sequences appended to them. The transmitting STA may change antenna configuration at the beginning of each sequence. The receiving STA performs measurements on these sequences and sends feedback to the STA that transmits the BRP-TX packet.

##### 25.11.2.2.2 Beam refinement packet structure

Each Beam Refinement packet is composed of an MPDU, A-MPDU or MMPDU followed by a training field containing an AGC training field and a receiver training field.



F 37Figure 25-19—Beam refinement packet structure

##### 25.11.2.2.3 Beam Refinement packet header fields

The packet type and training length fields present within the SC header and control PHY header are used to indicate, respectively, that a packet is beam refinement packet and the length of the training fields.

A value of 0x0 in the packet type field indicates a BRP-RX packet (TRN-R field is present).

A value of 0x1 in the packet type field indicates a BRP-TX packet (TRN-T field is present).

A value of *N* in the training length field indicates that the AGC has 4*N* subfields and that the TRN-R/T field has 5*N* subfields.

The value *N* in the training length field of a BRP-RX packet is equal to the value of the L-RX field requested by the intended receiver of the BRP-RX packet at a previously received BRP request field (see 7.3a.4).

##### 25.11.2.2.4 BRP packet duration

The minimum duration of the data field of a BRP packet when sent in an MR-SC PHY is aBRPminSCblocks SC blocks (see 25.6.3.2.5) and, if needed, the data field of the packet shall be extended by extra zero padding to generate the required number of MR-SC blocks. Table 25-21 contains the values of NCWmin for each CMCS necessary to compute the padding described in 25.6.3.2.3.3.

T 29Table 25-21—Zero filling for MR-SC BRP packets

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **CMCS index** | **Modulation** | **NCBPS** | **Repetition** | **Code rate** | **Data rate (Mbps)** | **NCWmin** |
| 1 | π/2-BPSK | 1 | 2 | 1/2 | 192.5 | 12 |
| 2 | π/2-BPSK | 1 | 1 | 1/2 | 385 | 12 |
| 3 | π/2-BPSK | 1 | 1 | 5/8 | 481.25 | 12 |
| 4 | π/2-BPSK | 1 | 1 | 3/4 | 577.5 | 12 |
| 5 | π/2-BPSK | 1 | 1 | 13/16 | 625.625 | 12 |
| 6 | π/2-QPSK | 2 | 1 | 1/2 | 770 | 23 |
| 7 | π/2-QPSK | 2 | 1 | 5/8 | 962.5 | 23 |
| 8 | π/2-QPSK | 2 | 1 | 3/4 | 1155 | 23 |
| 9 | π/2-QPSK | 2 | 1 | 13/16 | 1251.25 | 23 |

The minimum duration of the data field of a BRP packet when sent in an HR-SC PHY is aBRPminSCblocks SC blocks and, if needed, the data field of the packet shall be extended by extra zero padding to generate the required number of HR-SC blocks.

The minimum duration of the data field of a BRP packet when sent in an OFDM PHY is aBRPminOFDMblocks OFDM blocks and, if needed, the data field of the packet shall be extended by extra zero padding to generate the required number of OFDM symbols.

The minimum duration of the data field of a BRP packet when sent with the low-power SC PHY is NBLK\_MIN low-power SC blocks (see 21.7.2.3.3).

##### 25.11.2.2.5 Beam Refinement AGC field

The beam refinement AGC fields are composed of 4*N* repetitions of the sequence [Ga64 Ga64 Ga64 Ga64 ] when the packet is transmitted using the OFDM or SC PHY and [Gb64 Gb64 Gb64 Gb64 ] when the packet is transmitted using the Control PHY. The sequences are transmitted using rotated π/2-BPSK modulation. Any transmit signal transients that occur due to this TX AWV configuration change shall completely settle by the end of the first Ga64 or Gb64 subsequence.

In a BRP-TX packet, the transmitter may change the TX AWV configuration at the beginning of each AGC field. The set of AWVs used for the AGC subfields should be the same as that used for the TRN-T subfields. In a BRP-RX packet, the transmitter shall use the same TX AWV as in the preamble and data fields of the packet.

##### 25.11.2.2.6 Beam Refinement TRN-R field

The TRN-R fields enable receiver AWV training. The TRN-R fields have the form shown in Figure 25-20.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| CE | R1 | R2 | R3 | R4 | CE | R5 | R6 | R7 | R8 | … |

F 3Figure 25-20—TRN-R field definition

Each subfield CE matches the Channel Estimation field that is transmitted in the packet preamble. The 4N fields R1 through R4N each consist of the sequence [Ga128 -Gb128 Ga128 Gb128 Ga128]. The sequences Ga128 and Gb128 are defined in Table 21-24 and Table 21-25, respectively, in 21.11.. The sequences are transmitted using rotated π/2-BPSK modulation.

##### 25.11.2.2.7 Beam Refinement TRN-T field

The TRN-T field enables transmitter AWV training. The TRN-T field has the form shown in Figure 25-21.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| CE | T1 | T2 | T3 | T4 | CE | T5 | T6 | T7 | T8 | … |

F 3Figure 25-21—TRN-T field definition

Each subfield CE matches the Channel Estimation field that is transmitted in the packet preamble. The 4N fields T1 through T4N each consist of the sequence [Ga128 -Gb128 Ga128 Gb128 Ga128]. The sequences Ga128 and Gb128 are defined in Table 21-24 and Table 21-25, respectively, in 21.11. The sequences are transmitted using rotated π/2-BPSK modulation. When transmitting the CE subfield, the transmitter shall use the same AWV as in the preamble and data fields of the packet. Any transmit signal transients that occur due to TX AWV configuration changes between subfields shall settle by the end of the first 64 samples of the subfield.

##### 25.11.2.2.8 Channel Measurement

The good autocorrelation properties of the Golay sequence enable reconstructing part of the impulse response of the channel between the transmitter and the receiver. The receiver should find the tap with largest amplitude in the channel during the CE field of the BRP-RX. It selects thereafter the set of taps that is measured around the tap with the largest amplitude, according to the value of dot11ChanMeasFBCKNtaps. It can select a contiguous set of taps or select a noncontiguous set of taps, and include the tap delays subfield as part of the subfield measurement. It then measures the phase and amplitude of the corresponding channel taps in each of the TRN-T field repetition (except for those using the CE AWV configuration). The beam refinement feedback subfield *k*-1 is the relative amplitude and phase of this tap in the *k*’th repetition compared to this tap in the first TRN-T subfield.

##### 25.11.2.2.9 BRP resampling in an OFDM packet

The BRP AGC, CE, and Tn/Rn fields are specified at the SC chip rate (Tc). When appended to an OFDM packet, the signal is resampled as defined in 25.3.3.2.

## 25.12 CDMG PLME

The subsection is the same as the subsection 21.12, except that the symbol/throughput rate are halved.

## 25.13 CDMG PMD subplayer

The subsection is the same as the subsection 21.13, except that the symbol/throughput rate are halved.

# Annex B (normative) Protocol Implementation conformance Statement (PICS) proforma

## B.4 PICS proforma

***Insert the following subclause, B.4.27 to B.4.27.2, after B.4.26:***

### B.4.27 CDMG features

#### B.4.27.1 CDMG MAC features

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Item** | **Protocol capability** | **References** | **Status** | **Support** |
|  | Are the following MAC protocol features supported? |  |  |  |
| CDMG-M1 | Dynamic bandwidth control | 8.3.4.1, 9.40 | TBD | Yes, No, N/A |
| CDMG-M2 | Dynamic Channel Transfer | 6.3.95, 8.5.8.27-30, 10.39 | TBD | Yes, No, N/A |
| CDMG-M3 | Opportunistic transmissions | 8.4.1.7, 8.4.2.134, 9.33.11 | TBD | Yes, No, N/A |
| CDMG-M4 | Spatial sharing mechanism | 9.35.2.5, 10.31.3 | TBD | Yes, No, N/A |
| CDMG-M5 | Clustering for dynamic bandwidth | 9.34.6 | TBD | Yes, No, N/A |
| … | … | … | … | … |
|  |  |  |  |  |
|  |  |  |  |  |

#### B.4.27.2 CDMG PHY features

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Item** | **Protocol capability** | **References** | **Status** | **Support** |
|  | Are the following PHY protocol features supported? |  |  |  |
| CDMG-P1 | China Modulation and coding schemes (CMCS) |  |  |  |
| CDMG-P1.1 | CMCS 0 of Control PHY | 25.4 | TBD | Yes, No, N/A |
| CDMG-P1.2 | CMCS 1-9 of MR SC PHY | 25.6 | TBD | Yes, No, N/A |
| CDMG-P1.3 | CMCS 10-17 of HR SC PHY | 25.7 | TBD | Yes, No, N/A |
| CDMG-P1.4 | CMCS 18-29 of OFDM PHY | 25.5 | TBD | Yes, No, N/A |
| CDMG-P1.5 | CMCS 30-36 of Low power SC PHY | 25.8 | TBD | Yes, No, N/A |
| CDMG-P2 | IQ imbalance/PA nonlinearity estimation and compensation | 25.7, 25.5 | TBD | Yes, No, N/A |
| CDMG-P3 | Enhanced Mobile Device Support Mode |  | TBD | Yes, No, N/A |
| … | … | … | … | … |

# Annex E (normative) Country elements and operating classes

## E.1 Country information and operating classes

***Insert the following table, table E-4, after Table E-3：***

T 30Table E-4—Operating Classes in the China

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Operating Class** | **Global operating class (See Table E-5 Global operating classes)** | **Channel starting frequency(GHz)** | **Channel spacing (MHz)** | **Channel set** | **Behavior limits set** |
| 1 | 181 | 59.4 | 2160 | 2,3 | — |
| 2 | 182 | 59.4 | 1080 | 5,6,7,8 | — |
| 2~255 | Reserved | Reserved | Reserved | Reserved | Reserved |

***Change Table E-4 to Table E-5, and change the rows as follows :***

T 31Table E-5—Global operating classes

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Operating Class** | **Non-global operating class(es)** | **Channel starting frequency(GHz)** | **Channel spacing**  **(MHz)** | **Channel set** | **Behavior limits set** |
| 180 | E-1-34, E-2-18, E-3-59,E-4-1 | 56.16 | 2160 | 1,2,3,4 | — |
| 182 | E-4-2 | 59.40 | 1080 | 5,6,7,8 | — |
| 183-191 | Reserved | Reserved | Reserved | Reserved | Reserved |

***Insert the following txt, AnnexAA, after Annex Z:***

# Annex AA (informative) N-phase beamforming codebook

## AA.1 Introduction

This appendix puts forward a method for *N*-phase beamforming codebook design. The codebook can not only be used in the multi-beam switching system, but also be applied to 1-D (dimensional) uniform linear phased antenna array and 2-D (dimensional) uniform phased antenna array. The device can simply choose this beamforming codebook for directional transmission during communication.

## AA.2 1-D (dimensional) antenna array

As to the 1-D uniform linear antenna array, all antenna array elements should linearly distribute with the interval of λ/2 while λ denotes the carrier’s wavelength. The beam codebook is a data matrix **W,** andeach element of **W** defines the corresponding antenna array element’s weights. For phased antenna array, the weights define the phase misalignment, so the element *wm,k* of **W** satisfies |*wm,k*|=1. Formula (1) gives an example of a beam codebook matrix, among which *M* denotes the number of antenna elements and *K* denotes the numbers of beam patterns. Each column of the codebook matrix specifies a certain beam pattern, and all columns cover the whole space together. The columns of **W** number from 0. Figure 1 shows an arrange mode of 1-D uniform linear antenna array.

 (1)

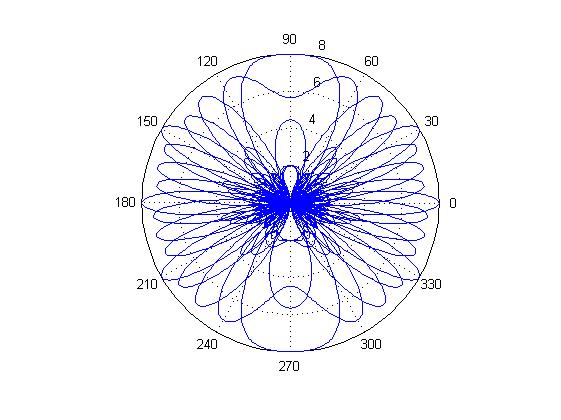
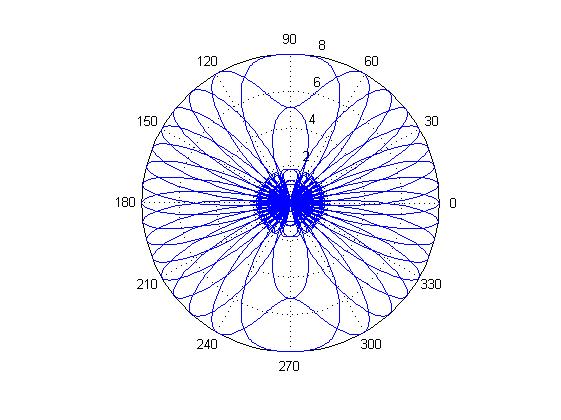


F 41Figure AA-1—An arrange mode of 1-D uniform linear antenna array

*N*-phase beam codebook is shown in Formula (2). The matrix’s element of line *m* and column *k* denotes the *k*th beam’s *m*th antenna element’s weights. Let *K* denote the number of beams and *M* denote the number of antenna elements. The function fix(*x*) returns the biggest integer which is smaller or equal to *x*. The modulo arithmetic function mod(*x*, *y*) is defined as mod(*x*, *y*)=*x*-*y*×fix(*x*/*y*). *N* denotes the discrete phases’ number and the size of *N* is free while each beam gain’s loss generated by the codebook becomes smaller with the increase of *N.* Generally, *N* should satisfy *N*≥4 which means 2bit discrete phase to ensure the beam codebook’s performance gain. Meanwhile, *N* should also satisfy *N*≤2*M* for no more performance gain will be acquired when *N*＞2*M*.

 (2)

Figure 2 shows the codebook’s beam patterns when *m*=8 and *k*=16. Figure 2-*a* shows the beam patterns when *N*=4, and Figure 2-*b* shows the beam patterns when *N*=16.

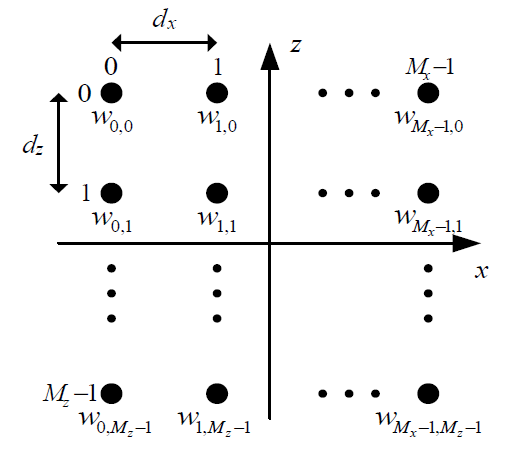
 

(*a*) (*b*)

F 42**Figure AA-2—Beam patterns generated by the proposed codebook**

## AA.3 2-D (dimensional) antenna array

A beam of 2-D linear antenna array is made up of two mutually perpendicular 1-D uniform linear antenna arrays. Figure 3 shows an arrange mode of 2-D uniform linear antenna array. The antenna elements are arranged in the mutually perpendicular directions of *x* and *z*, and the antenna elements’ number in the direction of *x* is *Mx* with the spacing of *dx* while the antenna elements’ number in the direction of *z* is *Mz* with the spacing of *dz*.



F 43**Figure AA-3—An arrange mode of 2-D uniform linear antenna array**

Each beam pattern of 2-D antenna array is actually superposition of two beam patterns of 1-D antenna array. The weights of antenna elements of 2-D antenna array should be calculated as follows:

 (3)

Among which  and  separately stands for the beam weights of *x* and *z*.

**Revision History**

|  |  |  |  |
| --- | --- | --- | --- |
| Revision | comments | Date | remark |
| R0 | Initial version of the TGaj complete proposal specification(60GHz) | November 8, 2013 |  |
| R1 | Added revision history. Removed subclause 25.7.3.1.3 TBLK based on comments and suggestions by Jianhan(MTK). Fixed some typos here and there. Changed clause 22 to clause 25 because the clause number 22~24 have already used by other amendments for 802.11. | January 8, 2014 |  |
|  |  |  |  |
|  |  |  |  |