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| 30.5.8 Single Carrier PPDU Transmission |
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Abstract

This document proposes specification text for subclause 30.5.8 of the spec describing Single Carrier (SC) PPDU transmission, [1], [2].

**30.5.8 Single carrier PPDU transmission**

*Editor: current section 30.5.8 should be replaced with the section proposed in this document, section 30.3.3.2.2 should be removed*

**30.5.8.1 General**

This subclause defines a waveform for SC non-EDMG duplicate and EDMG PPDU transmission over 2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz channel using *NTX* transmit chains.

The spatial mapping methods definition is provided in 30.5.8.2. The non-EDMG duplicate PPDU transmission shall be as defined in 30.5.8.3. The EDMG SU PPDU transmission shall be as defined in 30.5.8.4. The EDMG MU PPDU transmission shall be as defined in 30.5.8.5.

The frequently used symbol notations in this subclause are summarized in Table 1.

Table 1: Frequently used parameters

|  |  |
| --- | --- |
| **Symbol** | **Explanation** |
|  | Space-time stream number |
|  | Total number of space-time streams over all users |
|  | User number |
|  | Total number of users |
|  | Transmit chain number |
|  | Total number of transmit chains |
|  | SC chip rate, equal to 1.76 GHz |
|  | SC chip time duration, equal to 1/*Fc* |
|  | Number of contiguous 2.16 GHz channels used for PPDU transmission, 1 ≤ *NCB* ≤ 4 |
|  | Spatial mapping matrix of size *NTX* by *NSTS* |
|  | Up-sampling parameter |

**30.5.8.2 Spatial mapping**

The spatial mapping defines the method of *NSTS* space-time streams to *NTX* transmit chains mapping, where *NSTS* ≤ *NTX*, which may be implemented by means of spatial mapping matrix **Q** of size *NTX* by *NSTS* or Cyclic Shift Diversity (CSD). The spatial mapping matrix **Q** is independent on the chip time index or subcarrier index and is constant in time.

The standard defines four basic mappings, including direct mapping, indirect mapping, digital beamforming, and spatial expansion. Below are provided the examples of spatial mapping methods and **Q** matrices examples that might be used in different cases:

1. *Direct mapping*, *NSTS* = *NTX*: spatial mapping matrix **Q** is a square diagonal complex values matrix of size *NTX* that might be defined as follows:
	1. , the identity matrix
	2. , exponential matrix
2. *Indirect mapping*, *NSTS* = *NTX*: spatial mapping matrix **Q** is a square matrix of size *NTX* composed of complex values that might be defined as follows:
	1. **Q** = **F**, the discrete Fourier matrix
	2. **Q** = **H**, the normalized Hadamard matrix
3. *Digital beamforming*, *NSTS* ≤ *NTX*: spatial mapping matrix **Q** is a rectangular matrix of size *NTX* by *NSTS* composed of complex values that might be defined based on some knowledge of the channel between beamformer and beamformee.
4. *Spatial expansion*, *NSTS* = 1 < *NTX*: the spatial expansion is performed by application of cyclic shift (CSD) over different transmit chains. The cyclic shift is applied to the number of consecutive fields in the PPDU. This allows duplication of the PPDU fields transmission over the *NTX* transmit chains and avoids unintentional beamforming existing with a coherent signal transmission. The spatial expansion technique is not applied to the TRN field which is transmitted using orthogonal sequence set.

**30.5.8.3 Non-EDMG duplicate PPDU transmission**

The SC non-EDMG duplicate PPDU waveform shall be defined at the SC chip rate equal to 1.76 GHz and include the following modulated fields:



where

*  is a duration of L-STF part of PPDU
*  is a total duration of L-STF and L-CEF parts of PPDU
*  is a total duration of L-STF, L-CEF, and L-Header parts of PPDU
*  is a total duration of L-STF, L-CEF, L-Header, and Data parts of PPDU

If not specified additionally, the chip index *n* is defined in the range [0, *NField*-1], where *NField* defines the total number of samples for given signal field.

The TRN field may be present in a 2.16 GHz PPDU transmission and shall not be present for 4.32 GHz, 6.48 GHz, and 8.64 GHz PPDU transmission.

The definition of L-STF, L-CEF, and L-Header fields is provided in 20.3.6.2, 20.3.6.3, and 20.6.3.1 accordingly.

In case of digital beamforming transmission, the non-EDMG PPDU waveform for the *iTX*-th transmit chain is defined as follows:



where

*  is a spatial mapping matrix
*  is a matrix element from *m*-th row and *n*-th column

In case of spatial expansion, the non-EDMG waveform for *iTX*-th transmit chain includes a cyclic shift  dependent on the particular transmit chain number. The time shift  is defined in SC chip units as (*iTX*-1)×*Nc*×*Tc*, where *Nc* is equal to 4 chips and *Tc* is a chip time duration.



where

* 

The non-EDMG waveform for *iTX*-th transmit chain is obtained by up-sampling and filtering and then appropriate carrier frequency shift of the  waveform if required. The up-sampling procedure is applied by a factor of *Nup*. The filtering procedure is performed with a pulse shaping filter  defined at the *Nup*×1.76 GHz sampling rate as follows:



where

*  is a length of  in samples



The non-EDMG waveform for the *iTX*-th transmit chain with transmission over 2.16 GHz channel shall be defined as follows:



The non-EDMG waveform for the *iTX*-th transmit chain with duplicate transmission over 4.32 GHz channel shall be defined as follows:



where

* ∆*F* defines sub-channel spacing equal to 2.16 GHz
* ∆*t1* and ∆*t2* are in the range [0, *Tc*]
* the primary channel shall have a zero delay

The non-EDMG waveform for the *iTX*-th transmit chain with duplicate transmission over 6.48 GHz channel shall be defined as follows:



where

* ∆*t1*, ∆*t2,* and ∆*t3* are in the range [0, *Tc*]
* the primary channel shall have a zero delay

The non-EDMG waveform for the *iTX*-th transmit chain with duplicate transmission over 8.64 GHz channel shall be defined as follows:



where

* ∆*t1*, ∆*t2*, ∆*t3,* and ∆*t4* are in the range [0, *Tc*]
* the primary channel shall have a zero delay

The pulse shaping filter impulse response  and *Nup* parameter definition is out of scope of this standard and is implementation specific.

**30.5.8.4 EDMG SU PPDU transmission**

**30.5.8.4.1 PPDU transmission over 2.16 GHz channel with *iSTS* = 1**

The SC mode EDMG SU PPDU transmitted over a 2.16 GHz channel with single space-time stream (*iSTS* = 1) is composed of pre-EDMG, data and TRN field. The total number of transmit chains *NTX* shall be constant over the different fields of EDMG SU PPDU.

The pre-EDMG and data part includes the following modulated fields:



where

*  is a duration of L-STF field of PPDU
*  is a total duration of L-STF and L-CEF fields of PPDU
*  is a total duration of L-STF, L-CEF, and L-Header fields of PPDU
*  is a total duration of L-STF, L-CEF, L-Header, and EDMG-Header-A fields of PPDU

The definition of L-STF, L-CEF, and L-Header fields is provided in 20.3.6.2, 20.3.6.3, and 20.6.3.1 accordingly.

In case of digital beamforming the pre-EDMG and data part waveform for *iTX*-th transmit chain shall be defined as follows:



where

*  is a spatial mapping matrix
*  is a matrix element from *m*-th row and *n*-th column

In case of spatial expansion, the pre-EDMG and data part waveform for *iTX*-th transmit chain includes a cyclic shift  dependent on the particular transmit chain number. The time shift  is defined in SC chip units as (*iTX*-1)×*Nc*×*Tc*, where *Nc* is equal to 4 chips and *Tc* is a chip time duration.



where

* 

The TRN field  shall be defined at the SC chip rate equal to 1.76 GHz per *iTX*-th transmit chain as defined in 30.9.2.2.5.

The SU PPDU for 2.16 GHz channel and single space-time stream (*iSTS* = 1) waveform for *iTX*-th transmit chain concatenates the preamble and data part with TRN field and shall be defined as follows:



where

*  is a total duration of L-STF, L-CEF, L-Header, EDMG-Header-A, and Data fields of PPDU

The filtering procedure is performed with a pulse shaping filter  defined at the *Nup*×1.76 GHz sampling rate as follows:



where

*  is a length of  in samples
* 

The pulse shaping filter impulse response  and *Nup* parameter definition is out of scope of this standard and is implementation specific.

**30.5.8.4.2 PPDU transmission over 2.16 GHz with *iSTS* > 1 and 4.32 GHz, 6.48 GHz, 8.64 GHz channel with *iSTS* ≥ 1**

The SC mode EDMG SU PPDU transmitted over a 2.16 GHz channel with multiple streams (*iSTS* > 1) and 4.32 GHz, 6.48 GHz, and 8.64 GHz channels with single and multiple space-time streams (*iSTS* ≥ 1) is composed of pre-EDMG, EDMG preamble, data part and TRN field. The total number of transmit chains *NTX* shall be constant over the different fields of EDMG SU PPDU.

**30.5.8.4.2.1 Pre-EDMG part of PPDU transmission**

The pre-EDMG part of PPDU includes the following modulated fields:



where

*  is a duration of L-STF field of PPDU
*  is a total duration of L-STF and L-CEF fields of PPDU
*  is a total duration of L-STF, L-CEF, and L-Header fields of PPDU

In case of digital beamforming the pre-EDMG part of PPDU waveform for *iTX*-th transmit chain shall be defined as follows:



where

*  is a spatial mapping matrix
*  is a matrix element from *m*-th row and *n*-th column

In case of spatial expansion, the pre-EDMG part of PPDU waveform is transmitted for *iTX*-th transmit chain including a cyclic shift  dependent on the particular transmit chain number. The time shift  is defined in SC chip units as (*iTX*-1)×*Nc*×*Tc*, where *Nc* is equal to 4 chips and *Tc* is a chip time duration.



where

* 

The pre-EDMG waveform for *iTX*-th transmit chain is obtained by up-sampling and filtering and then appropriate carrier frequency shift of the  waveform if required. The up-sampling procedure is applied by a factor of *Nup*. The filtering procedure is performed with a pulse shaping filter  defined at the *Nup*×1.76 GHz sampling rate as follows:



where

*  is a length of  in samples



The pre-EDMG waveform for the *iTX*-th transmit chain with transmission over 2.16 GHz channel shall be defined as follows:



The pre-EDMG waveform for the *iTX*-th transmit chain with duplicate transmission over 4.32 GHz channel shall be defined as follows:



where

* ∆*F* defines sub-channel spacing equal to 2.16 GHz
* ∆*t1* and ∆*t2* are in the range [0, *Tc*]
* the primary channel shall have a zero delay

The pre-EDMG waveform for the *iTX*-th transmit chain with duplicate transmission over 6.48 GHz channel shall be defined as follows:



where

* ∆*t1*, ∆*t2,* and ∆*t3* are in the range [0, *Tc*]
* the primary channel shall have a zero delay

The pre-EDMG waveform for the *iTX*-th transmit chain with duplicate transmission over 8.64 GHz channel shall be defined as follows:



where

* ∆*t1*, ∆*t2*, ∆*t3,* and ∆*t4* are in the range [0, *Tc*]
* the primary channel shall have a zero delay

The pulse shaping filter impulse response  and *Nup* parameter definition is out of scope of this standard and is implementation specific.

**30.5.8.4.2.2 EDMG preamble and data part of PPDU transmission**

The EDMG preamble and part of SU PPDU is defined for *iSTS*-th space-time stream at the *NCB* × 1.76 GHz, 1 ≤ *NCB* ≤ 4, chip rate and includes the following modulated fields:



where

*  is a duration of EDMG-STF field of PPDU
*  is a total duration of EDMG-STF and EDMG-CEF fields of PPDU

In case of direct mapping, indirect mapping, and digital beamforming the EDMG preamble and data part waveform for *iTX*-th transmit chain shall be defined as follows:



where

*  is a spatial mapping matrix
*  is a matrix element from *m*-th row and *n*-th column

In case of spatial expansion (*iSTS* = 1), the EDMG preamble and data part waveform for *iTX*-th transmit chain includes a cyclic shift  dependent on the particular transmit chain number. The time shift  is defined in SC chip units as (*iTX*-1)×*Nc*×*Tc*, where *Nc* is equal to 4 chips and *Tc* is a chip time duration.



where

* 

**30.5.8.4.2.3 TRN field transmission**

The TRN field  shall be defined at the SC chip rate equal to *NCB* × 1.76 GHz per *iTX*-th transmit chain as defined in 30.9.2.2.5.

**30.5.8.4.2.4 Filtering procedure**

The EDMG preamble, data part, and TRN field for *iTX*-th transmit chain are defined as follows:



where

*  is a total duration of EDMG-STF, EDMG-CEF, and data fields of PPDU

The EDMG preamble, data, and TRN field is filtered and resampled with conversion rate ratio *Nup*/*NCB*.

For example, the resampling procedure for the ratio *Nup*/*NCB* = 3/2, can be defined as follows:



where

*  is a length of  in samples
* 

The SC mode EDMG SU PPDU waveform for *iTX*-th transmit chain concatenates the pre-EDMG and EDMG preamble, data, and TRN field and shall be defined as follows:



where

*  is a total duration of L-STF, L-CEF, L-Header, EDMG-Header-A, EDMG-STF, EDMG-CEF, and data fields of PPDU

The pulse shaping filter impulse response  and *Nup* parameter definition is out of scope of this standard and is implementation specific.

**30.5.8.5 EDMG MU PPDU transmission**

**30.5.8.5.1 EDMG MU non-FDMA PPDU transmission**

The SC mode EDMG MU non-FDMA PPDU transmitted over a 2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz with multiple space-time streams (*iSTS* > 1) for two or more users (*iuser* > 1) is composed of pre-EDMG, EDMG preamble, EDMG-Header-B, data part and TRN field. The total number of transmit chains *NTX* shall be constant over the different fields of EDMG MU non-FDMA PPDU.

**30.5.8.5.1.1 Pre-EDMG part of PPDU transmission**

The pre-EDMG part of PPDU shall be as defined in 30.5.8.4.2.1.

**30.5.8.5.1.2 EDMG preamble, EDMG-Header-B and data part of PPDU transmission**

The EDMG preamble, EDMG-Header-B and part of MU PPDU is defined for *iSTS*-th space-time stream at the *NCB* × 1.76 GHz, 1 ≤ *NCB* ≤ 4, chip rate and includes the following modulated fields:



where

*  is a duration of EDMG-STF field of PPDU
*  is a total duration of EDMG-STF and EDMG-CEF fields of PPDU
*  is a total duration of EDMG-STF, EDMG-CEF, and EDMG-Header-B fields of PPDU

In case of direct mapping, indirect mapping, and digital beamforming the EDMG preamble, EDMG-Header-B and data part waveform for *iTX*-th transmit chain shall be defined as follows:



where

*  is a spatial mapping matrix
*  is a matrix element from *m*-th row and *n*-th column

**30.5.8.5.1.3 TRN field transmission**

The TRN field  shall be defined at the SC chip rate equal to *NCB* × 1.76 GHz per *iTX*-th transmit chain as defined in 30.9.2.2.5.

**30.5.8.5.1.4 Filtering procedure**

The EDMG preamble, EDMG-Header-B, data part, and TRN field for *iTX*-th transmit chain are defined as follows:



where

*  is a total duration of EDMG-STF, EDMG-CEF, EDMG-Header-B, and data fields of PPDU

The EDMG preamble, EDMG-Header-B, data, and TRN field is filtered and resampled with conversion rate ratio *Nup*/*NCB*.

For example, the resampling procedure for the ratio *Nup*/*NCB* = 3/2, can be defined as follows:



where

*  is a length of  in samples
* 

The SC mode EDMG SU PPDU waveform for *iTX*-th transmit chain concatenates the pre-EDMG and EDMG preamble, EDMG-Header-B, data, and TRN field and shall be defined as follows:



where

*  is a total duration of L-STF, L-CEF, L-Header, EDMG-Header-A, EDMG-STF, EDMG-CEF, EDMG-Header-B, and data fields of PPDU

The pulse shaping filter impulse response  and *Nup* parameter definition is out of scope of this standard and is implementation specific.

**30.5.8.5.2 EDMG MU FDMA PPDU transmission**

TBD

**SP:**

Do you agree to define the SC PHY PPDU transmission as defined in (11-17-1043-00-00ay 30 5 8 Single Carrier PPDU Transmission)?

**References:**

1. Draft P802.11ay\_D0.35
2. IEEE802.11-2016