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| 30.6.8 OFDM PPDU Transmission |
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Abstract

This document proposes specification text for subclauses 30.6.2 and 30.6.8 of the spec describing OFDM transmitter block diagram and PPDU transmission, [1], [2].

**30.6.2 Transmitter block diagram**

*Editor: add new subclause 30.6.2, shift the rest of the clauses by one*

**30.6.2.1 General**

EDMG OFDM PPDU transmissions can be generated using a transmitter consisting of the following blocks:

1. Scrambler scrambles the data to reduce the probability of long sequences of 0s and 1s; see 20.3.9 (Scrambler).
2. Stream parser divides the output of scrambler into the groups of bits that are sent to different LDPC encoders and mapping devices. The sequence of the bits sent to different encoder is called a spatial stream; see 30.6.7.3 (Encoding).
3. LDPC encoder encodes the data to enable error correction. It makes bits padding to get an integer number of codewords and OFDM symbols; see 30.6.7.3 (Encoding).
4. Constellation mapper maps the sequence of bits in each stream to constellation points (complex numbers); see 30.6.7.4 (Modulation mapping).
5. Interleaver performs interleaving inside an OFDM symbol; see (30.6.7.4.4 Block interleaver)
6. STBC encoder spreads constellation points from *NSS* spatial streams into *NSTS* space-time streams using a space-time block code. OFDM mode defines single STBC scheme with *NSS* = 1 and *NSTS* = 2; see 30.6.7.4.3 (Space-time block coding).
7. Preamble builder builds symbols of EDMG-STF and EDMG-CEF fields in frequency domain; see 30.6.3 (EDMG-STF definition) and 30.6.4 (EDMG-CEF definition).
8. TRN builder builds symbols of TRN field; see 30.9.2.2.5 (TRN field definition).
9. Spatial mapper maps space-time streams to transmit chains. The spatial mapping is applied per subcarrier basis and may include one of the followings; see 30.6.8.2 (Spatial mapping):
	1. Direct mapping: constellation points from each space-time stream are mapped directly into the transmit chains.
	2. Indirect mapping: constellation points from each space-time stream are mapped to each transmit chain.
	3. Digital beamforming: each vector of constellation points from all of the space-time streams is multiplied by a matrix of steering vectors to produce the input to the transmit chains.
10. Cyclic shift (CSD) insertion prevents the transmission from unintentional beamforming. A cyclic shift is specified per transmitter chain for pre-EDMG portion of PPDU transmission; see 30.5.3.3.1 (Pre-EDMG fields of PPDU transmission).
11. IDFT applies Inverse Discrete Fourier Transform to the input block of subcarriers.
12. GI insertion and windowing prepends the OFDM symbol with guard interval defined as a cyclic extension of the OFDM symbol in time domain and applies window function; see 30.6.7.2 (OFDM modulation).

**30.6.2.2 EDMG PPDU transmission**

**30.6.2.2.1 Pre-EDMG portion of PPDU transmission**

See 30.5.3.3.1.

**30.6.2.2.2 EDMG portion of SU PPDU transmission**

Figure 1 shows the transmitter blocks used to generate the EDMG portion of SU PPDU. The EDMG-STF, and EDMG-CEF fields are generated using the Preamble builder, IDFT, and GI insertion blocks. The TRN field is generated using the TRN builder, IDFT, and GI insertion blocks. The data part of PPDU is generated using the scrambler, LDPC encoder, constellation mapper, interleaver, IDFT, and GI insertion blocks. If STBC encoder is applied, then a single spatial stream is mapped to two space-time streams as defined in 30.6.7.1. The *NSTS* space-time streams are further mapped to *NTX* transmit chains, where *NSTS* ≤ *NTX*.



Figure 1: Transmitter block diagram for EDMG portion of SU PPDU transmission.

NOTE – Interleaver is applied to 16-QAM and 64-QAM modulations only.

**30.6.2.2.3 EDMG portion of MU PPDU transmission**

Figure 2 shows the transmitter blocks used to generate the EDMG portion of MU PPDU. The EDMG-STF, and EDMG-CEF fields are generated using the preamble builder, IDFT, and GI insertion blocks. The TRN field is generated using the TRN builder, IDFT, and GI insertion blocks. The EDMG-Header-B and data part of PPDU are generated using scrambler, LDPC encoder, constellation mapper, interleaver, IDFT, and GI insertion blocks. The PPDU encoding uses the seed value defined in the EDMG-Header-B and has independent flow per user. However, transmitter keeps the common space-time streams numeration over all users. If STBC encoder is applied, then a single spatial stream is mapped to two space-time streams as defined in 30.6.7.1. The *NSTS* space-time streams are further mapped to *NTX* transmit chains, where *NSTS* ≤ *NTX*.



Figure 2: Transmitter block diagram for EDMG portion of MU PPDU transmission.

NOTE – Interleaver is applied to 16-QAM and 64-QAM modulations only.

**30.6.8 OFDM PPDU transmission**

*Editor: add new subclause 30.6.8, shift the rest of the clauses by one*

**30.6.8.1 General**

This subclause defines a waveform for OFDM 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 30.6.8.2. The EDMG SU PPDU transmission shall be as defined in 30.6.8.3. The EDMG MU PPDU transmission shall be as defined in 30.6.8.4.

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* |
|  | OFDM sampling rate equal to *NCB*×2.64 GHz |
|  | OFDM sample time duration, equal to 1/*Fs* |
|  | Number of contiguous 2.16 GHz channels used for PPDU transmission, 1 ≤ *NCB* ≤ 4 |
|  | Spatial mapping matrix of size *NTX* by *NSTS*, defined for *k*-th subcarrier |
|  | Up-sampling parameter |

**30.6.8.2 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 **Qk** of size *NTX* by *NSTS* defined per subcarrier basis or Cyclic Shift Diversity (CSD).

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 **Qk** matrices examples that might be used in different cases:

1. *Direct mapping*, *NSTS* = *NTX*: spatial mapping matrix **Qk** is a square diagonal complex 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 **Qk** is a square matrix of size *NTX* composed of complex values that might be defined as follows:
	1. **Qk** = **F**, the discrete Fourier matrix
	2. **Qk** = **H**, the normalized Hadamard matrix
3. *Digital beamforming*, *NSTS* ≤ *NTX*: spatial mapping matrix **Qk** 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.

**30.6.8.3 EDMG SU PPDU transmission**

The OFDM mode EDMG SU PPDU transmitted over a 2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz channels with single and multiple space-time streams (1 ≤ *iSTS* ≤ *NSTS*) is composed of pre-EDMG, EDMG preamble, data part and TRN field.

The pre-EDMG part of PPDU includes L-STF, L-CEF, L-Header, and EDMG-Header-A and transmitted using SC modulation as defined in 30.5.9.4.2.2. The EDMG-STF, EDMG-CEF, data part, and TRN field are transmitted using OFDM modulation as defined in 30.6.3, 30.6.4, 30.6.7.2, and 30.9.2.2.5 accordingly. The total number of transmit chains *NTX* shall be constant over the different fields of EDMG SU PPDU.

*Editor: add subclause defining OFDM TRN subfield*

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

See 30.5.9.4.2.2.

To align sampling rate over the SC and OFDM modulated fields, the pre-EDMG part of the preamble for OFDM PPDU shall be defined at the *Nup*×1.76 GHz sampling rate, where *Nup* = (3/2)×*NCB*, 1 ≤ *NCB* ≤ 4. The *NCB* parameter defines the total number of contiguous 2.16 GHz channels used in channel bonding transmission.

**30.6.8.3.2 EDMG preamble, data part and TRN field transmission**

The EDMG preamble, data part and TRN field of SU PPDU is defined for *iTX*-th transmit chain at the *Fs* = *NCB*×2.64 GHz sampling rate, sample time duration *Ts* = 1/*Fs* 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 Data fields of PPDU

The EDMG-STF, EDMG-CEF, and TRN field shall be as defined in 30.6.3, 30.6.4, and 30.9.2.2.5 accordingly.

The data part of SU PPDU shall be modulated using  OFDM symbols as defined in 30.6.7.2.

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



where

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

The pulse shaping filter impulse response  definition used for pre-EDMG fields’ transmission is out of scope of this standard and is implementation specific.

**30.6.8.4 EDMG MU PPDU transmission**

The OFDM mode EDMG MU PPDU transmitted over a 2.16 GHz, 4.32 GHz, 6.48 GHz, and 8.64 GHz channels with single and multiple space-time streams (1 ≤ *iSTS* ≤ *NSTS*) is composed of pre-EDMG, EDMG preamble, data part and TRN field.

The pre-EDMG part of PPDU includes L-STF, L-CEF, L-Header, and EDMG-Header-A and transmitted using SC modulation as defined in 30.5.9.4.2.2. The EDMG-STF, EDMG-CEF, EDMG-Header-B, data part, and TRN field are transmitted using OFDM modulation as defined in 30.6.3, 30.6.4, 30.6.5, 30.6.7.2, and 30.9.2.2.5 accordingly. The total number of transmit chains *NTX* shall be constant over the different fields of EDMG MU PPDU.

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

See 30.5.9.4.2.2.

To align sampling rate over the SC and OFDM modulated fields, the pre-EDMG part of the preamble for OFDM PPDU shall be defined at the *Nup*×1.76 GHz sampling rate, where *Nup* = (3/2)×*NCB*, 1 ≤ *NCB* ≤ 4. The *NCB* parameter defines the total number of contiguous 2.16 GHz channels used in channel bonding transmission.

**30.6.8.4.2 EDMG preamble, data part and TRN transmission**

The EDMG preamble, data part and TRN field of MU PPDU is defined for *iTX*-th transmit chain at the *Fs* = *NCB*×2.64 GHz sampling rate, sample time duration *Ts* = 1/*Fs* 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
*  is a total duration of EDMG-STF, EDMG-CEF, EDMG-Header-B, and Data fields of PPDU

The EDMG-STF, EDMG-CEF, EDMG-Header-B, and TRN field shall be as defined in 30.6.3, 30.6.4, 30.6.5, and 30.9.2.2.5 accordingly.

The data part of MU PPDU shall be modulated using  OFDM symbols for *iuser*-th user as defined in 30.6.7.2.

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



where

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

The pulse shaping filter impulse response  definition used for pre-EDMG fields’ transmission is out of scope of this standard and is implementation specific.

**SP:**

Do you agree to define the OFDM PHY PPDU transmission as defined in (11-17-1568-00-00ay 30 6 8 OFDM PPDU Transmission)?

**References:**

1. Draft P802.11ay\_D0.5
2. IEEE802.11-2016