IEEE P802.11
Wireless LANs

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| PDT PHY OFDM Modulation |
| Date: 2024-5-2 |
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Abstract

This document contains Proposed Draft Text (PDT) for 38.3.16.9 (OFDM modulation) and related texts of P802.11bn D0.2.

There are no relevant motions as 38.3.16.9 (OFDM modulation) is ‘basic’ equation describing the transmitted waveform.

NOTE – Set the Track Changes Viewing Option in the MS Word to “All Markup” to clearly see the proposed text edits.

**Revision History:**

R0: Initial version.

R1: Added further clarification on ELR Data field in 38.3.16.9.

R2: Fix windowing function duration.

## Proposed Text Updates

***Instruction to TGbn Editor: Add the following text to 11bn D0.2.***

***NOTE to TGbn Editor: The objective of this change is to add equation numbers to some equations in Clause 36 (EHT). MS Word Track Change is not enabled for this portion of changes because ‘underline’ needs to be added to the 11bn draft (and ‘underline’ is not visible if Track Change is enabled).***

**36. Extremely high throughput (EHT) PHY specification**

**36.3 EHT PHY**

**36.3.11 Mathematical description of signals**

**36.3.11.4 Transmitted signal**

***Add equation numbers to two equations after Table 36-26 as follows:***

 (36-11a)

 is a set of 20 MHz channels in which pre-EHT modulated fields are located. The set of 20 MHz channels contains one or more values in the range 0 to *N*20MHz – 1 for an EHT MU PPDU with preamble puncturing, or an EHT TB PPDU, and it contains all values in the range 0 to *N*20MHz – 1 for a EHT MU PPDU without preamble puncturing.

 is the cardinality of the set of 20 MHz channels .

 is the power deboosting factor of the corresponding pre-EHT modulated field relative to the L-SIG field defined as:

  (36-11b)

***NOTE to TGbn Editor: MS Word Track Change is enabled from here.***

 ***Instruction to TGbn Editor: Add the following subclause to 11bn D0.2.***

**37.19a Rules related to the PHY interface of an UHR STA**

**37.19a.1 POWER\_BOOST\_FACTOR**

For an OFDMA UHR MU PPDU, the POWER\_BOOST\_FACTOR parameter in the TXVECTOR for an occupied RU or MRU shall be in the range  if the Power Boost Factor Support subfield of the EHT PHY Capabilities Information field in the EHT Capabilities element from any recipient STA of the PPDU equals 0; otherwise, the POWER\_BOOST\_FACTOR shall be in the range [0.5, 2].

For a non-OFDMA UHR MU PPDU, the POWER\_BOOST\_FACTOR shall be set to 1.

NOTE — The POWER\_BOOST\_FACTOR is not present in the TXVECTOR in a UHR TB PPDU or a UHR ELR PPDU.

***Instruction to TGbn Editor: Add the following subclause 38.3.2.X before 38.3.2.1 of 11bn D0.2 as shown below.***

**38.3.2 Subcarrier and resource allocation**

**38.3.2.X Tone plan for RUs and MRUs**

Tone plan and RU locations for RUs and MRUs in a UHR PPDU are the same as those in an EHT PPDU. See 36.3.2 (Subcarrier and resounce allocation).

**38.3.2.1 Tone plan for DRUs**

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***Instruction to TGbn Editor: Update 38.3.13 of 11bn D0.2 as shown below.***

**38.3.13 Timing-related parameters**

Table 38-16 defines the timing-related parameters for UHR PPDU format.

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| Table 38-16 – Timing-related constants  |
| Parameter | Value | Description |
| Δ*F*,Pre-UHR | 312.5 kHz | Subcarrier frequency spacing for the pre-UHR modulated fields |
| Δ*F*,UHR | 78.125 kHz | Subcarrier frequency spacing for the UHR modulated fields |
| *TDFT*,Pre-UHR | 3.2 µs | IDFT/DFT period for the pre-UHR modulated fields |
| *TDFT*,UHR | 12.8 µs | IDFT/DFT period for the UHR modulated fields |
| *TGI*,Pre-UHR | 0.8 µs | Guard interval duration for the pre-UHR modulated fields excluding the L-LTF field |
| *TGI*,L-LTF | 1.6 µs | Guard interval duration for the L-LTF field |
| *TGI*,ELR-MARK | 0.8 µs | Guard interval duration for the ELR-MARK field |
| *TGI*1,Data | 0.8 µs | Base guard interval duration for the Data field |
| *TGI*2,Data | 1.6 µs | Double guard interval duration for the Data field |
| *TGI*4,Data | 3.2 µs | Quadruple guard interval duration for the Data field |
| *TGI*,Data | *TGI1*,Data, *TGI2*,Data or *TGI4*,Data depending on the GI used for the Data field | Guard interval duration for the Data field in UHR MU PPDUs and UHR TB PPDUs |
| *TGI*,UHR-LTF | *TGI*,Data | Guard interval duration for the UHR-LTF field, same as *TGI*,Data |
| *TGI*,UHR-LTF,ELR | 1.6 µs | Guard interval duration for the UHR-LTF field in UHR ELR PPDU |
| *TGI*, ELR-SIG | 1.6 µs | Guard interval duration for the ELR-SIG field |
| *TGI*,Data,ELR | 1.6 µs | Guard interval duration for the Data field in UHR ELR PPDU |
| *T*UHR-LTF,ELR | 6.4 µs | Duration of each UHR-LTF OFDM symbol without GI in UHR ELR PPDU |
| *TSYM*, ELR-MARK | 4 µs = *TDFT*,Pre-UHR + *TGI*,ELR-MARK | OFDM symbol duration for ELR-MARK field |
| *TSYM*, UHR-LTF,ELR | 8 µs = *T*UHR-LTF,ELR+ *TGI*,UHR-LTF,ELR | OFDM symbol duration for UHR-LTF field including GI in UHR ELR PPDU |
| *TSYM*, ELR-SIG | 14.4 µs = *TDFT*,UHR+ *TGI*,Data,ELR *=* 1.125 ´ *TDFT*,UHR | OFDM symbol duration for ELR-SIG field including GI |
| *TSYM*, Data,ELR | 14.4 µs = *TDFT*,UHR+ *TGI*,Data,ELR *=* 1.125 ´ *TDFT*,UHR | OFDM symbol duration for ELR-Data field including GI in UHR ELR PPDU |
| *TSYM*1 | 13.6 µs = *TDFT*,UHR+ *TGI*1,Data *=* 1.0625 ´ *TDFT*,UHR | OFDM symbol duration with base GI |
| *TSYM*2 | 14.4 µs = *TDFT*,UHR+ *TGI*2,Data *=* 1.125 ´ *TDFT*,UHR | OFDM symbol duration with double GI |
| *TSYM*4 | 16 µs = *TDFT*,UHR+ *TGI*4,Data *=* 1.25 ´ *TDFT*,UHR | OFDM symbol duration with quadruple GI |
| *TSYM* | *TSYM*1, *TSYM*2, or *TSYM*4 depending on the GI used for UHR Data fields | OFDM symbol interval for UHR Data fields in UHR MU PPDUs and UHR TB PPDUs |
| *T*L-STF | 8 µs = 10 ´ *TDFT*,Pre-UHR / 4 | Non-HT Short Training field duration |
| *T*L-LTF | 8 µs = 2 ´ *TDFT*,Pre-UHR + *TGI*,L-LTF | Non-HT Long Training field duration |
| *T*L-SIG | 4 µs | Non-HT SIGNAL field duration |
| *T*RL-SIG | 4 µs | Repeated non-HT SIGNAL field duration |
| *T*U-SIG | 8 µs = 2 ´ 4 µs | U-SIG field duration in an UHR PPDU |
| *T*UHR-SIG | 4 µs = *TDFT*,Pre-UHR + *TGI*,Pre-UHR | Duration of each OFDM symbol in the UHR-SIG field |
| *T*ELR-MARK | 8 µs = 2 ´ *TSYM*, ELR-MARK | ELR-MARK field duration |
| *T*UHR-STF-T | 8 µs = 5 × 1.6 µs | UHR-STF field duration for an UHR TB PPDU |
| *T*UHR-STF-NT | 4 µs = 5 × 0.8 µs | UHR-STF field duration for an UHR MU PPDU and an UHR ELR PPDU |
| *T*UHR-LTF-1X | 3.2 µs | Duration of each 1´ UHR-LTF OFDM symbol without GI |
| *T*UHR-LTF-2X | 6.4 µs | Duration of each 2´ UHR-LTF OFDM symbol without GI |
| *T*UHR-LTF-4X | 12.8 µs | Duration of each 4´ UHR-LTF OFDM symbol without GI |
| *T*UHR-LTF | *T*UHR-LTF-1X, *T*UHR-LTF-2X or *T*UHR-LTF-4X depending upon the UHR-LTF duration used | Duration of each OFDM symbol without GI in the UHR-LTF field |
| *T*UHR-LTF-SYM | *T*UHR-LTF + *T*GI,UHR-LTF | Duration of each OFDM symbol including GI in the UHR-LTF field |
| *T*UHR-LTF, ELR | 16 µs = *TSYM*, UHR-LTF,ELR ´ 2 | ELR-LTF field duration in UHR ELR PPDU |
| *T*ELR-SIG | 28.8 µs= *TSYM*, ELR-SIG ´ 2 | ELR-SIG field duration |
| *TSYML* | 4 µs | OFDM symbol duration including GI in the pre-UHR modulated fields |
| *TPE* | 0, 4 μs, 8 μs, 12 μs, 16 μs or 20 μs depending on the actual packet extension duration used | Duration of the PE field |

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| Table 38-18 – Frequently used parameters  |
| Symbol | Explanation |
| *NRU* | For pre-UHR modulated fields, *NRU* = 1*.*For UHR modulated fields, *NRU* represents the number of occupied RU(s) or MRU(s) in the transmission. |
| *Nuser,r* | For pre-UHR modulated fields, *Nuser* = 1.For UHR modulated fields, *Nuser,r* represents the total number of users in the *r*-th occupied RU or MRU of the transmission. |
| *Nuser,total* | Total number of users in all occupied RU(s) or MRU(s) of a UHR transmission, i.e., . |
| *NCPBS,u* | Number of coded bits per OFDM symbol for user *u*, *u* = 0, 1, … , *Nuser,total* ˗ 1. |
| *NCPBS,m,u* | Number of coded bits per OFDM symbol over the *m*-th spatial stream for user *u*, *m* = 1, 2, … , *Nss,r,u* in OFDMA transmission, *u* = 0, 1, … , *Nuser,total* ˗ 1. |
| *NSD* | Effective number of data tones carrying unique data.NOTE—The *NSD* value with DCM (when applicable) is half of the *NSD* value without DCM, for each RU or MRU size. |
| *NSD,u* | Effective number of data tones carrying unique data for user *u*, *u* = 0, 1, … , *Nuser,total* ˗ 1. |
| *NCBPSS,u* | Number of coded bits per OFDM symbol per spatial stream for user *u*,*u* = 0, 1, … , *Nuser,total* ˗ 1. |
| *NCBPSS,l,u* | Number of coded bits per OFDM symbol per spatial stream for user *u* in the *l*-th 80 MHz frequency block, *u* = 0, 1, … , *Nuser,total* ˗ 1 and *l* = 0, 1, … , *L* ˗ 1. *L* is the number of 80 MHz frequency subblocks. |
| *NDBPS,u* | Number of data bits per OFDM symbol for user *u*, *u* = 0, 1, … , *Nuser,total* ˗ 1.NOTE—For LDPC, *NDBPS,u* is derived from *NDBPS,u* using *Ru*, rather than the effective LDPC code rate, which may vary depending on shortening/puncturing/repetition performed during LDPC encoding. |
| *NBPSCS,u* | Number of coded bits per subcarrier per spatial stream for user *u*,*u* = 0, 1, … , *Nuser,total* ˗ 1. |
| *NBPSCS,m,u* | Number of coded bits per subcarrier over the *m*-th spatial stream for user *u*, *m* = 1, 2, … , *Nss,r,u* in OFDMA transmission, *u* = 0, 1, … , *Nuser,total* ˗ 1. |
| *NBPSCS,l,u* | Number of coded bits per subcarrier per spatial stream for user *u* in the *l*-th 80 MHz frequency block, *u* = 0, 1, … , *Nuser,total* ˗ 1 and *l* = 0, 1, … , *L* ˗ 1. *L* is the number of 80 MHz frequency subblocks. |
| *NRX* | Number of receive chains. |
| *NSS,r,u*, *NSS,u*, *NSS* | Number of spatial streams. For the Data field, *NSS,r,u* is the number of spatial streams at *r*-th RU or MRU for user *u*, *u* = 0, 1, … , *Nuser,total* ˗ 1, and *NSS,u* is the number of spatial streams for user *u*, *u* = 0, 1, … , *Nuser,total* ˗ 1.For the Data field of a UHR PPDU, . |
| *NSS,r,total* | For UHR modulated fields, *NSS,r,total* is the total number of spatial streams at r-th RU or MRU in a PPDU: .For pre-UHR modulated fields, *NSS,r,total* is undefined. |
| *NTX* | Number of transmit chains. |
| *NUHR-LTF* | The number of OFDM symbols in the UHR-LTF field (see 38.3.15.11) |
| *NUHR-SIG* | The number of OFDM symbols in the UHR-SIG field (see 38.3.15.9) |
| *Mr,u* | The sum of the number of spatial streams of users prior to user *u* in RU or MRU *r*.For pre-UHR modulated fields, *Mr,u* = 0.For UHR modulated fields, *Mr,u* = 0 for *u* = 0 and , for *u* = 1, 2, …, *Nuser,r* – 1. |

Table 38-17 defines subcarrier allocation related parameters for a UHR ELR PPDU. Subcarrier allocation related parameters for the UHR modulated fields in a nonpunctured non-OFDMA UHR PPDU that is not a UHR ELR PPDU is the same as those for EHT modulated fields in a non-unctured non-OFDMA EHT PPDU – see Table 36-19 (Subcarrier allocation related constants for the EHT-modulated fields in a nonpunctured non-OFDMA EHT PPDU).

Table 38-17 – Subcarrier allocation related constants for the UHR ELR PPDU

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| **Parameter** | **ELR PPDU** | **Description** |
| NSD,total | 234 | Total number of data subcarriers |
| NSP | 16 | Number of pilot subcarriers |
| NST | 208 | Total number of subcarriers |
| NSR | 121 | Highest data subcarriers index |
| NDC | 3 | Number of null subcarriers at DC |
| NGuard,Left | 6 | Number of low frequency guard subcarriers |
| NGuard,Right | 5 | Number of high frequency guard subcarriers |

**38.3.14.4 Transmitted signal**

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***Instruction to TGbn Editor: Add the following text at the end of 38.3.14.4 of 11bn D0.2.***

For notational simplicity, the parameter bandwidth is omitted from some bandwidth dependent terms.

In Equation (38-2) and Equation (38-3), the following notations are used:

 is a windowing function. An example function for  is given in 17.3.2.5 (Mathematical conventions in the signal descriptions). *T*Subfield is *T*L-STF for L-STF, *T*L-LTF for L-LTF, *TSYML* for L-SIG, RL-SIG, U-SIG, UHR-SIG and ELR-MARK, *T*UHR-STF-NT for UHR-STF of UHR MU PPDU and UHR ELR PPDU, *T*UHR-STF-T for UHR-STF of UHR TB PPDU, *T*UHR-LTF-SYM for UHR-LTF of UHR MU PPDU and UHR TB PPDU, *TSYM,*UHR-LTF,ELR for UHR-LTF of UHR ELR PPDU, *T SYM,*ELR-SIG for ELR-SIG, *TSYM* for UHR-Data for UHR MU PPDU and UHR TB PPDU, and *TSYM*,Data,ELR for UHR-Data.

*NRU* is defined in Table 38-18 (Frequently used parameters).

*NNorm,r* For pre-UHR modulated fields, *NNorm,r* = *NTX*. For UHR modulated fields, *NNorm,r* = *NSS,r,total* for a UHR MU PPDU, *NNorm,r* = *NSS,r,u* for an UHR TB PPDU, and *NNorm,r* = 1 for an UHR ELR PPDU where *NSS,r,total* and *NSS,r,u* are given in Table 38-18 (Frequently used parameters).

 is the power boost factor of the *r*-th occupied RU or MRU in a UHR MU PPDU as defined in 37.19a.1 (POWER\_BOOST\_FACTOR) and is set to the value of POWER\_BOOST\_FACTOR parameter in the TXVECTOR.  in a UHR ELR PPDU.

*Kr* For pre-UHR modulated fields, *Kr* is the set of subcarriers indices for all the tones in the corresponding 20 MHz channels where UHR modulated fields are located for the *r*-th occupied RU, MRU or DRU. For UHR modulated fields in a nonpunctured non-OFDMA UHR PPDU that is not a UHR ELR PPDU, *Kr* is the set of subcarriers indices from –*NSR* to *NSR* excluding DC subcarriers as defined in 38.3.13 (Timing-related parameters) and null subcarriers as defined in 38.3.2.2 (Null subcarriers) if present. For UHR modulated fields in a punctured non-OFDMA UHR PPDU and an OFDMA UHR PPDU, *Kr* is the set of subcarriers indices for the tones in the *r*-th RU, MRU or DRU. For UHR modulated fields in a UHR ELR PPDU, *Kr* is the set of subcarriers indices for the tones in the *r*-th 52-tone RU where *r* = 0, 1, 2, 3. Data and pilot subcarrier indices for an RU, MRU or DRU are defined in 38.3.2.X (Tone plan for RUs and MRUs).

 is the cardinality of the set .

 is the power normalization factor of the corresponding field in the *r*-th occupied RU, MRU or DRU and is defined in Equation (36-11) with pre-EHT modulated fields and EHT modulated fields replaced with pre-UHR modulated fields and UHR modulated fields, respectively.

 is the number of tones in the corresponding field.  for UHR PPDUs is the same as that for EHT PPDUs specified in Table 36-26 (Number of modulated subcarriers and guard interval duration values for EHT PPDU fields) with EHT PPDU, EHT-SIG, *TGI*,Pre-EHT replaced with UHR PPDU, UHR-SIG and *TGI*,Pre-UHR, respectively.  for a UHR ELR PPDU is the same as  for 20 MHz bandwidth, with  for ELR-MARK having the same value as that for U-SIG.

 is defined in Equation (36-11a).

 is the set of 20 MHz channels in which pre-UHR modulated fields are located. The set of 20 MHz channels contains one or more values in the range 0 to *N*20MHz – 1 for a UHR MU PPDU with preamble puncturing, or a UHR TB PPDU, and it contains all values in the range 0 to *N*20MHz – 1 for a UHR MU PPDU without preamble puncturing.  contains only one value 0 for a UHR ELR PPDU.

 is the power deboosting factor of the corresponding pre-UHR modulated field relative to the L-SIG field.  is defined in Equation (36-11b).

 equals the number of modulated subcarriers within *Kr* (see Table 38-18 (Frequently used parameters)) for the UHR-STF and Data fields. For the UHR-LTF field,  is defined as below to ensure per tone power are the same for both UHR-LTF and Data fields, regardless of 1×, 2×, or 4× UHR-LTF.

 

*Qk,u* is the spatial mapping matrix for user *u* on subcarrier *k*. For UHR modulated fields, *Qk,u* is a matrix with *NTX* rows and *NSS,r,u* columns. For pre-UHR modulated fields, *Qk,u* is a column vector with *NTX* elements, with element *iTX* being , where  represents the cyclic shift for the transmitter chain whose value is defined in 38.3.15.2.1 (Cyclic shift for pre-UHR modulated fields).

Δ*F*,Field is the subcarrier frequency spacing of the corresponding field. Δ*F*,Field is equal to Δ*F*,Pre-UHR and Δ*F*,UHR for pre-UHR modulated fields and UHR modulated fields, respectively, where Δ*F*,Pre-UHR and Δ*F*,UHR are given in Table 38-16 (Timing-related constants).

*Mr,u* is given in Table 38-18 (Frequently used parameters).

 is the frequency-domain symbol assigned for subcarrier *k* of user *u* in the *r*-th RU, MRU or DRU for the *m*-th spatial stream. Some of the  within –*NSR* ≤ *k* ≤ *NSR* have a value of zero. Examples of such cases include the DC tones, guard tones on each side of the transmit spectrum, the null subcarriers in an UHR OFDMA PPDU, as well as the unmodulated tones of L-STF, UHR-STF, and UHR-LTF fields.

*TGI*,Field is the guard interval duration used for each OFDM symbol in the corresponding field. The value of guard interval duration for each UHR PPDU field is defined in Table 38-16 (Timing-related constants).

*TCS*,UHR(*l*) For pre-UHR modulated fields, *TCS*,UHR(*l*) = 0. For UHR modulated fields, *TCS*,UHR(*l*) represents the cyclic shift per spatial stream, whose value is defined in 38.3.15.2.2 (Cyclic shift for UHR modulated fields).

γ*k,BW* is used to represent a phase rotation applied to the *k*-th subcarrier for a given bandwidth *BW*. For UHR modulated fields, γ*k,BW* = 1 for all subcarriers. For pre-UHR modulated fields, γ*k,BW* is the same as γ*k,BW* for pre-EHT modulated fields defined in 36.3.11.4 (Transmitted signal).

*Instruction to TGbn Editor: Update 38.3.16.9 of 11bn D0.2 P214L3 as shown below:*

**38.3.16.9 OFDM modulation**

Variables used in this subclause are defined in 38.3.13 (Timing-related parameters) and 38.3.14 (Mathematical description of signals) unless specified otherwise.

The time domain waveform for transmit chain *iTX* , 1  *iTX*  *NTX*, of the Data field of a UHR MU PPDU and UHR TB PPDU (for user *u* in the *r*-th RU, MRU or DRU) are defined in [Equation (38-X1)](#_bookmark247) and [Equation (38-X2)](#_bookmark247), respectively.

  (38-X1)

  (38-X2)

where

*pn* is defined in 17.3.5.10 (OFDM modulation)

 is defined based on RU, MRU or DRU size. The value is defined in 36.3.13.11 (Pilot subcarriers) for RU and MRU, and in 38.3.16.8 (Pilot subcarriers) for DRU.

 represents the cyclic shift for spatial stream  as defined in 38.3.15.2.2 (Cyclic shift for UHR modulated fields).

 is the transmitted constellation for user *u* in the *r*-th RU, MRU or DRU at subcarrier *k*, spatial stream *m*, and Data field OFDM symbol *n* in a UHR MU PPDU or a UHR TB PPDU, and is defined in Equation (38-X3).

 (38-X3)

where

*KPilot* is the set of pilot subcarrier indices for the Data field OFDM symbols as defined in 38.3.16.8 (Pilot subcarriers)



*Kr*,min is the minimum value of the set *Kr*.

 is the cardinality of the set .

NOTE – *Zr*(*k*) translates a subcarrier index (*k* ϵ *Kr*) into the index of data symbols in a transmission over RU or MRU *r*, (0 ≤ *Zr*(*k*) ≤ *NSD,total* – 1). The subcarrier index *k* for the data subcarrier is first offset by the minimum value of subcarrier index *Kr*,min (for the lower edge subcarrier) in this RU or MRU and number of the unoccupied tones, and then subtracted by the number of pilot subcarriers falling in between the data subcarrier and the edge subcarrier.

The time domain waveform for transmit chain *iTX* , 1  *iTX*  *NTX*, of the Data field of a UHR ELR PPDU is defined in [Equation](#_bookmark247) (38-X4).

  (38-X4)

where

 is the data and pilot subcarrier indices set for the *r*-th 52-tone RU in a 20 MHz PPDU and is defined in Table 27-8 (Data and pilot subcarrier indices for RUs in a 20 MHz HE PPDU and in a non-OFDMA 20 MHz HE PPDU).

 is the transmitted constellation at subcarrier *k* in the *r*-th 52-tone RU of the *n*-th OFDM symbol and is defined in 38.3.15.12.3 (Encoding and modulation).

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