IEEE P802.11  
Wireless LANs

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| Proposed Draft Text (PDT-PHY): Modulation Accuracy | | | | |
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Abstract

This submission proposed the draft text on modulation accuracy for TGbe D0.1.

This document is based on 27.3.19.4 Modulation accuracy of P802.11ax D6.1.

Added 320MHz, 4KQAM related discussion and values.

This draft is only for 20/40/80/160/320MHz transmission. Didn’t include 80+80/160+160MHz yet as there is some related discussion.

Yellow highlighted texts are TBD.

Revision 1: add visio files at the end of documents. Add more notes on 1024QAM EVM and more explanation for reference in step f).

Revision 2: revise the document based on Youhan Kim’s comments

Revision 3: editorial changes by Yujin Noh

Revision 4: feedback during conference call

Revision 5: Update MCS level (4K QAM) indices. MCS 7 for reference to TB PPDU power level.

Add LO requirements for BW320 TBD.

Add # of frames, # of symbols, # of PPDU for measurements from 11ax

Add reference to Motion 112, #SP20

802.11be supports -38 dB as the Tx EVM requirement for 802.11be 4096 QAM.

[Motion 112, #SP20, [13] and [32]]

Revision 6: add 80+80/160+160 MHz with TBD (highlighted)

xx.3.19.4 Modulation accuracy

xx.3.19.4.1 Introduction to modulation accuracy tests

Transmit modulation accuracy specifications are described in xx.3.19.4.2 (Transmit center frequency leakage) and xx.3.19.4.3 (Transmitter constellation error). The test method is described in xx.3.19.4.4 (Transmitter modulation accuracy (EVM) test).

xx.3.19.4.2 Transmit center frequency leakage

For an 80+80 MHz or 160+160 MHz transmission where the RF LO falls outside both frequency segments, the RF LO shall meet the spectral mask requirements as defined in xx.3.19.1 (Transmit spectral mask). For 20/40/80/160 MHz transmission, the power measured at the location of the RF LO using resolution BW 78.125 kHz shall not exceed the maximum of –32 dB relative to the total transmit power and –20 dBm, or equivalently max(P – 32, –20), where P is the transmit power per antenna in dBm. The transmit center frequency leakage is specified per antenna. The transmit center frequency leakage for 320 MHz transmission is TBD.

xx.3.19.4.3 Transmitter constellation error

The relative constellation RMS error in the test, calculated by first averaging over subcarriers, frequency segments, EHT PPDUs, and spatial streams (see Equation (xx-y1)) as described in xx.3.19.4.4 (Transmitter modulation accuracy (EVM) test) shall not exceed a data-rate dependent value according to Table xx-y1 (Allowed relative constellation error versus constellation size and coding rate). The number of spatial streams under test shall be equal to the number of utilized transmitting STA antenna (output) ports and also equal to the number of utilized testing instrumentation input ports. In the test, *NSS* = *NSTS* [(no STBC)] and no beamforming steering matrix shall be used. Each output port of the transmitting STA shall be connected through a cable to one input port of the testing instrumentation. The requirements shall apply to 20 MHz, 40 MHz, 80 MHz, 160 MHz, and 320 MHz contiguous transmissions as well as 80+80 MHz and 160+160 MHz transmissions.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Table xx-y1 - Allowed relative constellation error versus constellation size and coding rate | | | | | |
| Modulation | | Coding rate | Relative constellation error in an EHT MU PPDU (dB) | Relative constellation error in an EHT TB PPDU when transmit power is larger than the maximum power of EHT-MCS 7 (dB) | Relative constellation error in an EHT TB PPDU when transmit power is less than or equal to the maximum power of EHT-MCS 7 (dB) |
| Without DCM | With DCM |
| N/A | BPSK | 1/2 | –5 | –13 | –27 |
| BPSK | N/A | 1/2 | –5 | –13 | –27 |
| QPSK | N/A | 1/2 | –10 | –13 | –27 |
| QPSK | N/A | 3/4 | –13 | –13 | –27 |
| 16-QAM | N/A | 1/2 | –16 | –16 | –27 |
| 16-QAM | N/A | 3/4 | –19 | –19 | –27 |
| 64-QAM | N/A | 2/3 | –22 | –22 | –27 |
| 64-QAM | N/A | 3/4 | –25 | –25 | –27 |
| 64-QAM | N/A | 5/6 | –27 | –27 | –27 |
| 256-QAM | N/A | 3/4 | –30 | –30 | –30 |
| 256-QAM | N/A | 5/6 | –32 | –32 | –32 |
| 1024-QAM | N/A | 3/4 | [–35/–32] | [–35/–32] | [–35/–32] |
| 1024-QAM | N/A | 5/6 | [–35/–32] | [–35/–32] | [–35/–32] |
| 4096-QAM | N/A | 3/4 | –38 *(Motion 112, #SP20)* | –38 *(Motion 112, #SP20)* | –38 *(Motion 112, #SP20)* |
| 4096-QAM | N/A | 5/6 | –38 *(Motion 112, #SP20)* | –38 *(Motion 112, #SP20)* | –38 *(Motion 112, #SP20)* |
| NOTE—The maximum power of EHT-MCS 7 can be measured by setting the UL Target RSSI subfield as defined in Table 9-31i (UL Target RSSI subfield encoding) in the Trigger frame to 127 for the RU for which the EVM test is conducted. | | | | | |

[For 1024-QAM, the relative constellation error shall meet one of the following requirements:

* The relative constellation error shall less than or equal to –35 dB if amplitude drift compensation is disabled in the test equipment
* The relative constellation error shall be less than or equal to –35 dB with amplitude drift compensation enabled in the test equipment, and the relative constellation error shall be less than or equal to –32 dB with amplitude drift compensation disabled in the test equipment

For all other constellations the relative constellation error shall be less than or equal to the values in Table 27-49 (Allowed relative constellation error versus constellation size and coding rate) whether or not amplitude drift compensation is enabled in the test equipment.]

xx.3.19.4.3 Transmitter modulation accuracy (EVM) test

The transmit modulation accuracy test shall be performed by instrumentation capable of converting the transmitted signals into a stream of complex samples at sampling rate greater than or equal to the bandwidth of the signal being transmitted except that for a noncontiguous transmissions each frequency segment may be tested independently.

In this case, transmit modulation accuracy of each segment shall meet the required value in Table xx-y1 (Allowed relative constellation error versus constellation size and coding rate) using only the occupied data subcarriers within the corresponding segment. For EHT TB PPDU transmission, two sets of EVM requirements are defined in Table xx-y1 (Allowed relative constellation error versus constellation size and coding rate) for different transmission power levels to assist AP in better managing the interference among multiple STAs responding to a Trigger frame.

LO leakage that can potentially show up at the center frequency of the EHT PPDU tone plan and within ±3 neighboring subcarriers shall be excluded from the computation of the transmitter modulation accuracy test. The potential LO leakage subcarriers for 20 MHz operating devices are the center of primary 20 MHz of the EHT PPDU tone plan and ±3 subcarriers of it. The potential LO leakage subcarriers for 40 MHz operating devices are the center of the primary 40 MHz of the PPDU tone plan and ±3 subcarriers. The potential LO leakage subcarriers for 80 MHz operating devices are the center of the primary 80 MHz of the PPDU tone plan and ±3 subcarriers of it. The potential LO leakage tones for 160 MHz operating devices are the center of the primary 160 MHz of the PPDU tone plan and ±3 subcarriers of it. The potential LO leakage tones for 320 MHz operating devices are the center of the 320 MHz of the PPDU tone plan and ±3 subcarriers of it. The potential LO leakage tones for 80+80 MHz or 160+160 MHz operating devices exist outside the PPDU bandwidth and should not affect the transmitter modulation accuracy test. For 40 MHz operating devices that transmits 20 MHz, the potential LO leakage subcarriers exist outside the PPDU bandwidth and should not affect the transmitter modulation accuracy test. For 80 MHz operating devices that transmits 20 MHz or 40 MHz PPDU, the potential LO leakage subcarriers exist outside the PPDU bandwidth and should not affect the transmitter modulation accuracy test. For 160 or 80+80 MHz operating devices that transmits 20 MHz or 40 MHz PPDU or 80 MHz PPDU, the potential LO leakage subcarriers exist outside the PPDU bandwidth and should not affect the transmitter modulation accuracy test. For 320 or 160+160 MHz operating devices that transmits 20 MHz or 40 MHz PPDU or 80 MHz PPDU or 160 MHz PPDU, the potential LO leakage subcarriers exist outside the PPDU bandwidth and should not affect the transmitter modulation accuracy test.

The transmitter modulation accuracy test procedure for the occupied subcarriers of the PPDU is similar as in steps of the transmit modulation accuracy test procedure defined in 27.3.19.4.4 (Transmitter modulation accuracy (EVM) test) as follows.

* Start of PPDU shall be detected.
* Transition from L-STF to L-LTF shall be detected and fine timing shall be established.
* Coarse and fine frequency offsets shall be estimated.
* Symbols in a PPDU shall be derotated according to estimated frequency offset. Sampling offset drift shall be also compensated.
* For each EHT-LTF symbol, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, and derotate the subcarrier values according to the estimated phase.
* Estimate the complex channel response coefficient for each of the subcarriers and each of the transmit streams.
* For each of the data OFDM symbols: transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, and compensate the subcarrier values according to the estimated phase, group the results from all of the receiver chains in each subcarrier to a vector, and multiply the vector by a zero-forcing equalization matrix generated from the estimated channel.
* For each data-carrying subcarrier in each spatial stream of RU under test, find the closest constellation point and compute the Euclidean distance from it.
* Compute the average across PPDUs of the RMS of all errors per PPDU as given by Equation (xx-y1).

(xx-y1)

where

*I0*(*if*, *is*, *iss*, *isc*) *Q0*(*if*, *is*, *iss*, *isc*) denotes the ideal symbol point in the complex plane in data subcarrier *isc* of the RU under test, spatial stream *iss*, and OFDM symbol *is* of frame *if*

*Ie*(*if*, *is*, *iss*, *isc*) *Qe*(*if*, *is*, *iss*, *isc*) denotes the equalized observed symbol point in the complex plane of the data subcarrier *isc* of the RU under test, spatial stream *iss*, and OFDM symbol *is* of frame *if*

*P0* is the average power of constellation

*Nf* is the number of tested frames

*NSD* is the number of data tones of the occupied RU. For an 80+80 or 160+160 MHz transmission, *NSD* is the total number of data subcarriers in all 80 MHz frequency segments.

*NSS* is the number of spatial streams of the data

*NSYM* is the number of data OFDM symbols

The test shall be performed over at least 20 PPDUs (*Nf* as defined in Equation (xx-y1)). If the occupied RU has 26 tones, the PPDUs under test shall be at least 32 data OFDM symbols long. For occupied RUs that have more than 26 tones, the PPDUs under test shall be at least 16 data OFDM symbols long. Random data shall be used for the symbols.

For an EHT TB PPDU with an RU or MRU smaller than a 4x996-tone RU, additional transmit modulation accuracy test for the unoccupied subcarriers of the PPDU shall be performed. There are two cases, one with a single RU or a continuous MRU and the other with a non-continuous MRU.

In case of a single RU or a continuous MRU, the transmit modulation accuracy test procedure for the unoccupied subcarriers of the PPDU is similar as in steps of the transmit modulation accuracy test procedure for the unoccupied subcarriers of the PPDU defined in 27.3.19.4.4 (Transmitter modulation accuracy (EVM) test) as follows.

* Start of PPDU shall be detected.
* Transition from L-STF to L-LTF shall be detected and fine timing shall be established.
* Coarse and fine frequency offsets shall be estimated.
* Symbols in a PPDU shall be derotated according to estimated frequency offset. Sampling offset drift shall be also compensated.
* For each of the data OFDM symbols, transform the symbol into subcarrier received values and estimate the power of each subcarrier.
* Compute the average unoccupied subcarrier error vector magnitude for each unoccupied 26-tone RU and average across PPDUs of the RMS of all errors per PPDU as given by Equation (xx-y2)

(xx-y2)

where

 denotes unequalized observed symbol point in the complex plane in subcarrier *isc* of the unoccupied 26-tone RU and OFDM symbol *is* of frame *if*

Ω*k* is a set of subcarriers for *k*-th 26-tone RU as defined in Table xx-z1 (Data and pilot subcarrier indices for RUs in a 20 MHz EHT PPDU and in a non-OFDMA 20 MHz EHT PPDU), Table xx-z2 (Data and pilot subcarrier indices for RUs in a 40 MHz EHT PPDU and in a non-OFDMA 40 MHz EHT PPDU) , Table xx-z3 (Data and pilot subcarrier indices for RUs in an 80 MHz EHT PPDU and in a non-OFDMA 80 MHz EHT PPDU) , Table xx-z4 (Data and pilot subcarrier indices for RUs in an 160 MHz EHT PPDU and in a non-OFDMA 160 MHz EHT PPDU), and Table xx-z5 (Data and pilot subcarrier indices for RUs in an 320 MHz EHT PPDU and in a non-OFDMA 320 MHz EHT PPDU)

*PS* is the average data subcarrier power of the occupied RU under test and is given by Equation (xx-y3)

 (xx-y3)

where

*Nf* is the number of tested frames

*NSYM* is the number of data OFDM symbols

*NSD* is the number of data subcarriers in the occupied RU

* For all EHT-MCSs, for an occupied RU bandwidth of *r* in units of a 26-tone RU as defined by Equation (xx-y4)

  (xx-y4)

The average unused subcarrier error vector magnitude for each unoccupied 26-tone RU as calculated in step f) shall meet the staircase mask requirement in Equation (xx-y5) and Equation (xx-y6), where *m* defines the gap in the units of 26-tone RU to the occupied RU from either side with *m* = ±1 being the adjacent 26-tone RUs.

 (xx-y5)

The valid range for *m* for Equation (xx-y5) is as follows:

 for a 20 MHz, 40 MHz, 80 MHz , 160 MHz or 320MHz PPDU

for an 80+80 MHz PPDU and

for an 80+80 MHz PPDU and

for an 160+160 MHz PPDU and

for an 160+160 MHz PPDU and

 (xx-y6)

The valid range for *m* for Equation (xx-y6) is as follows:

 for a 20 MHz, 40 MHz, 80 MHz , 160 MHz or 320MHz PPDU

for an 80+80 MHz PPDU and

for an 80+80 MHz PPDU and

for an 80+80 MHz PPDU and

for an 80+80 MHz PPDU and

where *iRU26,start* is equal to *iRU* if the occupied RU is a 26-tone RU, and is defined in Table xx-y2 (***iRU26,start*** for RUs other than a 26-tone RU) for other RU sizes

**Table xx-y2 - *iRU26,start* for RUs other than a 26-tone RU**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***iRU*** | **52-tone RU** | **78-tone RU** | **106-tone RU** | **132-tone RU** | **242-tone RU** | **484-tone RU** | **484-tone RU + 242-tone RU** | **996-tone RU** | **996-tone RU + 484-tone RU** | **2×996-tone RU** | **2×996-tone RU + 484-tone RU** | **3×996-tone RU** | **3×996-tone RU + 484-tone RU** |
| 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2 | 3 | 3 | 6 | 14 | 10 | 19 | 10 | 37 | 19 | 73 | 37 | 37 | 19 |
| 3 | 6 | 6 | 10 | 19 | 19 | 37 | 37 | 73 | 73 |  |  |  |  |
| 4 | 8 | 11 | 15 | 32 | 28 | 55 | 46 | 109 | 91 |  |  |  |  |
| 5 | 10 | 12 | 19 | 37 | 37 | 73 | 73 |  |  |  |  |  |  |
| 6 | 12 | 15 | 24 | 50 | 46 | 91 | 82 |  |  |  |  |  |  |
| 7 | 15 | 20 | 28 | 55 | 55 | 109 | 109 |  |  |  |  |  |  |
| 8 | 17 | 21 | 33 | 68 | 64 | 127 | 118 |  |  |  |  |  |  |
| 9 | 19 | 24 | 37 | 73 | 73 |  |  |  |  |  |  |  |  |
| 10 | 21 | 29 | 42 | 86 | 82 |  |  |  |  |  |  |  |  |
| 11 | 24 | 30 | 46 | 91 | 91 |  |  |  |  |  |  |  |  |
| 12 | 26 | 33 | 51 | 104 | 100 |  |  |  |  |  |  |  |  |
| 13 | 28 | 38 | 55 | 109 | 109 |  |  |  |  |  |  |  |  |
| 14 | 30 | 39 | 60 | 122 | 118 |  |  |  |  |  |  |  |  |
| 15 | 33 | 42 | 64 | 127 | 127 |  |  |  |  |  |  |  |  |
| 16 | 35 | 47 | 69 | 140 | 136 |  |  |  |  |  |  |  |  |
| 17 | 37 | 48 | 73 |  |  |  |  |  |  |  |  |  |  |
| 18 | 39 | 51 | 78 |  |  |  |  |  |  |  |  |  |  |
| 19 | 42 | 56 | 82 |  |  |  |  |  |  |  |  |  |  |
| 20 | 44 | 57 | 87 |  |  |  |  |  |  |  |  |  |  |
| 21 | 46 | 60 | 91 |  |  |  |  |  |  |  |  |  |  |
| 22 | 48 | 65 | 96 |  |  |  |  |  |  |  |  |  |  |
| 23 | 51 | 66 | 100 |  |  |  |  |  |  |  |  |  |  |
| 24 | 53 | 69 | 105 |  |  |  |  |  |  |  |  |  |  |
| 25 | 55 | 74 | 109 |  |  |  |  |  |  |  |  |  |  |
| 26 | 57 | 75 | 114 |  |  |  |  |  |  |  |  |  |  |
| 27 | 60 | 78 | 118 |  |  |  |  |  |  |  |  |  |  |
| 28 | 62 | 83 | 123 |  |  |  |  |  |  |  |  |  |  |
| 29 | 64 | 84 | 127 |  |  |  |  |  |  |  |  |  |  |
| 30 | 66 | 87 | 132 |  |  |  |  |  |  |  |  |  |  |
| 31 | 69 | 92 | 136 |  |  |  |  |  |  |  |  |  |  |
| 32 | 71 | 93 | 141 |  |  |  |  |  |  |  |  |  |  |
| 33 | 73 | 96 |  |  |  |  |  |  |  |  |  |  |  |
| 34 | 75 | 101 |  |  |  |  |  |  |  |  |  |  |  |
| 35 | 78 | 102 |  |  |  |  |  |  |  |  |  |  |  |
| 36 | 80 | 105 |  |  |  |  |  |  |  |  |  |  |  |
| 37 | 82 | 110 |  |  |  |  |  |  |  |  |  |  |  |
| 38 | 84 | 111 |  |  |  |  |  |  |  |  |  |  |  |
| 39 | 87 | 114 |  |  |  |  |  |  |  |  |  |  |  |
| 40 | 89 | 119 |  |  |  |  |  |  |  |  |  |  |  |
| 41 | 91 | 120 |  |  |  |  |  |  |  |  |  |  |  |
| 42 | 93 | 123 |  |  |  |  |  |  |  |  |  |  |  |
| 43 | 96 | 128 |  |  |  |  |  |  |  |  |  |  |  |
| 44 | 98 | 129 |  |  |  |  |  |  |  |  |  |  |  |
| 45 | 100 | 132 |  |  |  |  |  |  |  |  |  |  |  |
| 46 | 102 | 137 |  |  |  |  |  |  |  |  |  |  |  |
| 47 | 105 | 138 |  |  |  |  |  |  |  |  |  |  |  |
| 48 | 107 | 141 |  |  |  |  |  |  |  |  |  |  |  |
| 49 | 109 |  |  |  |  |  |  |  |  |  |  |  |  |
| 50 | 111 |  |  |  |  |  |  |  |  |  |  |  |  |
| 51 | 114 |  |  |  |  |  |  |  |  |  |  |  |  |
| 52 | 116 |  |  |  |  |  |  |  |  |  |  |  |  |
| 53 | 118 |  |  |  |  |  |  |  |  |  |  |  |  |
| 54 | 120 |  |  |  |  |  |  |  |  |  |  |  |  |
| 55 | 123 |  |  |  |  |  |  |  |  |  |  |  |  |
| 56 | 125 |  |  |  |  |  |  |  |  |  |  |  |  |
| 57 | 127 |  |  |  |  |  |  |  |  |  |  |  |  |
| 58 | 129 |  |  |  |  |  |  |  |  |  |  |  |  |
| 59 | 132 |  |  |  |  |  |  |  |  |  |  |  |  |
| 60 | 134 |  |  |  |  |  |  |  |  |  |  |  |  |
| 61 | 136 |  |  |  |  |  |  |  |  |  |  |  |  |
| 62 | 138 |  |  |  |  |  |  |  |  |  |  |  |  |
| 63 | 141 |  |  |  |  |  |  |  |  |  |  |  |  |
| 64 | 143 |  |  |  |  |  |  |  |  |  |  |  |  |

*iRU26,end* is equal to *iRU26,start* + *r* – 1

*iRU* is the index of the occupied RU

*NRU26* is the maximum number of 26-tone RUs for the given bandwidth of the EHT TB PPDU.

** is the relative constellation error requirement for an occupied RU of an EHT TB PPDU as defined in Table xx-y1 (Allowed relative constellation error versus constellation size and coding rate)

NOTE—For an 80+80 MHz PPDU the unused subcarrier error is measured only in the 80 MHz segment in which the occupied RU is located. This leads to the different valid range for *m* in Equation (xx-y5) and Equation (xx-y6) for the 80+80 MHz PPDU.

NOTE—For an 160+160 MHz PPDU the unused subcarrier error is measured only in the 160 MHz segment in which the occupied RU is located. This leads to the different valid range for *m* in Equation (xx-y5) and Equation (xx-y6) for the 160+160 MHz PPDU.

The test shall be performed over at least 20 PPDUs (*Nf* as defined in Equation (xx-y1)). The PPDUs under test shall be at least 16 data OFDM symbols long. The unequalized observed symbol of potential LO leakage subcarrier locations shall be treated as zero during unoccupied subcarriers transmit modulation accuracy test. Random data shall be used for the symbols.

In case of a non-continuous MRU, how to perform the transmit modulation accuracy test for the unoccupied subcarriers of the PPDU is TBD.

-------------------------------- End of text -------------------------------------------------

Visio files



Following portion is not for the spec. This is for discussion.

----Appendix---

In case of a non-continuous MRU, the transmit modulation accuracy test procedure for the unoccupied subcarriers of the PPDU is performed by constructing the overall relative constellation error staircase mask in the following manner. First, each non-continuous MRU consists of two portions where each portion has an RU or multiple RUs. Figure xx-y1 shows an example of non-continuous MRU of 2×RU996+RU484 where the lower portion and upper portion have 2×RU996 and RU484, respectively.



**Figure xx-y1 - Example of MRU of 2×RU996+RU484**

Then, the portion interim relative constellation error mask is placed on each of the portions based on the relative constellation error staircase masks of both portions. For each frequency at which both of the portion interim relative constellation error masks have values greater than –38 dB and less than max(ε-2, -38) dB, the sum of the two interim relative constellation error mask values (summed in linear domain) shall be taken as the overall interim relative constellation error mask value. Next, for each frequency at which neither of the two portions interim masks have values greater than max(ε-2, -38) dB, the higher value of the two interim masks shall be taken as the overall interim relative constellation error mask value. Finally, for any frequency region where the overall interim relative constellation error mask value has not been defined yet, linear interpolation (in dB domain) between the nearest two 26-tone RU points with the overall interim relative constellation error mask value defined shall be used to define the overall interim relative constellation error mask value. Figure xx-y2 (Example of relative constellation error mask for a MRU of 2×RU996+RU484) shows an example of a relative constellation error mask for a MRU of 2×RU996+RU484 with RU484 hole between two portions where the lower portion and upper portion have 2×RU996 and RU484, respectively.



Figure xx-y2- **Example of relative constellation error mask for a MRU of 2×RU996+RU484**