IEEE P802.11
Wireless LANs

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| Performance Requirements for the EDMG SC Mode |
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Abstract

This document proposes specification text for subclause 30.5.11 (Performance requirements) defining the performance requirements for the EDMG and non-EDMG SC PPDUs. The proposed text addresses CIDs 1323, 1620, 1888, 1917, and 2090.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **CID** | **Clause** | **Page** | **Comment** | **Proposed change** |
| 1323 | 30.5.11 | 328.20 | SC performance requirements are missing | Add performance requirements |
| 1620 | 30.5.11 | 328.19 | Sensitivity and EVM values need to be defined | Please add. Some may be taken from 11ad spec, for new modulations it needs to be defined. |
| 1888 | 30.5.8 | 291.01 | new MCS is defined in table 57 in page 291 but the EVM table is not updated in the draft 1.0. MCS6 is a new data rate that is not available in 11ad and thus its EVM requirement needs to be specified. | add EVM requirement table, especially new data rate, MCS6, in appropriate location |
| 1917 | 30.5.11 | 328.19 | No text in section. | Either add text or remove section |
| 2090 | 30.5.11 | 328.20 | Text is missing | There are no performance requirements listed in the section. Complete the section |

**Proposed resolution**: Revised

**Background:** Examples of the use of “sufficient accuracy” in 802.11-2016:

**19.3.18.7.4 Transmitter modulation accuracy (EVM) test**

The transmit modulation accuracy test shall be performed by instrumentation capable of converting the transmitted signals into a streams of complex samples at 40 Msample/s or more, with sufficient accuracy in terms of I/Q arm amplitude and phase balance, dc offsets, phase noise, and analog-to-digital quantization noise.

**20.4.4.1.2 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.

**20.5.4.1.2 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.

**20.6.4.1.1 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.

**21.3.17.4.4 Transmitter modulation accuracy (EVM) test**

The instrument shall have sufficient accuracy in terms of I/Q arm amplitude and phase balance, DC offsets, phase noise, and analog to digital quantization noise. A possible embodiment of such a setup is converting the signals to a low IF frequency with a microwave synthesizer, sampling the signal with a digital oscilloscope and decomposing it digitally into quadrature components. The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or equivalent procedure:

**Modification:** Include the text propose below in subclause 30.5.11 (Performance requirements).

**30.5.11 Performance requirements**

**30.5.11.1 Transmit requirements**

**30.5.11.1.1 Transmit modulation accuracy (EVM) test and requirements**

This subclause specifies the EVM test and corresponding requirements for:

* PPDUs transmitted with the TXVECTOR parameter EDMG\_MODULATION equal to EDMG\_SC\_MODE and with TXVECTOR parameter CH\_BANDWIDTH equal to CBW216, CBW432, CBW648, CBW864, CBW216+216, and CBW432+432; and
* PPDUs transmitted with the TXVECTOR parameter NON\_EDMG\_MODULATION equal to NON\_EDMG\_DUP\_SC\_MODE and with TXVECTOR parameter CH\_BANDWIDTH equal to CBW432, CBW648, CBW864, CBW216+216, and CBW432+432

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 SC chip rate; except that

* If the TXVECTOR parameter NON\_EDMG\_MODULATION is set to NON\_EDMG\_DUP\_SC\_MODE, the transmission in the two or more 2.16 GHz channels may be tested independently, and
* If the TXVECTOR parameter CH\_BANDWIDTH is set to either CBW216+216 or CBW432+432, the transmission in the two (adjacent or non-adjacent) 2.16 GHz channels (for CBW216+216) or 4.32 GHz channels (for CBW432+432) may be tested independently.

In the two cases indicated above, transmit modulation accuracy of each 2.16 GHz channel (when NON\_EDMG\_MODULATION is set to NON\_EDMG\_DUP\_SC\_MODE or when CH\_BANDWIDTH is set to CBW216+216) or of each 4.32 GHz channel (when CH\_BANDWIDTH is set to CBW432+432) shall meet the required value in Tables 1-4 using only the signal within the corresponding channel.

If the TXVECTOR parameter EDMG\_MODULATION is set to EDMG\_SC\_MODE, the TXVECTOR parameters NUM\_STS and NUM\_TX\_CHAINS shall be equal, and the value of both parameters shall be equal to the number of utilized testing instrumentation input ports. In the test, $N\_{SS}=N\_{STS}$ (no STBC) shall be used. If the TXVECTOR parameter NUM\_STS is set to a value greater than 1, the two or more space-time streams shall have the same modulation type. Each transmit chain of the transmitting STA shall be connected through a cable to one input port of the testing instrumentation.

The instrumentation used in the transmit EVM accuracy test shall have sufficient accuracy in terms of I/Q arm amplitude and phase balance, DC offsets, phase noise, and analog-to-digital quantization noise. A possible embodiment of such a setup is converting the signals to a low IF frequency with a microwave synthesizer, sampling the signal with a digital oscilloscope and decomposing it digitally into quadrature components. The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or equivalent procedure:

1. Detect the start of the PPDU.
2. Establish fine timing.
3. Estimate the coarse and fine frequency offsets.
4. De-rotate the frame according to the estimated frequency offset.
5. Estimate the complex channel impulse response for each of the transmit chains using the EDMG-CEF field, if present. If not, channel estimation is performed using the L-CEF field.
6. For each SC symbol block, estimate time-dependent phase variations using guard interval symbols (for example, by interpolating the phase between the prefix and postfix GI samples), and de-rotate the corresponding symbol samples accordingly.
7. For each SC symbol block, perform demodulation and apply a minimum mean square error equalization matrix generated from the channel estimate. Group the demodulated symbols from each SC symbol block, and combine the demodulated data from each spatial stream into a vector.
8. For each element of the vector, find the closest constellation point and compute the Euclidian distance from it.
9. Compute the average relative constellation RMS error (EVM) across PPDUs according to the formula:

$$EVM=20log\_{10}\left(\frac{1}{N\_{f}}\sum\_{f=1}^{N\_{f}}\sqrt{\frac{\sum\_{n=0}^{N\_{BLKS}-1}\sum\_{j=1}^{N\_{ss}}\sum\_{k=0}^{N\_{SPB}-1}\left(I\left(f,n,j,k\right)-I^{\*}\left(f,n,j,k\right)-I\_{0}\left(f,j\right)\right)^{2}+\left(Q\left(f,n,j,k\right)-Q^{\*}\left(f,n,j,k\right)-Q\_{0}\left(f,j\right)\right)^{2}}{N\_{BLKS}×N\_{SS}×N\_{SPB}×P\_{0}}}\right)$$

where

* $N\_{f}$ is the number of frames for the measurement
*  is the number of SC symbol blocks within each frame
*  is the number of spatial streams of each frame
*  is the number of data modulated symbols per SC symbol block
*  is the average power of the constellation
* $I\left(f,n,j,k\right)$ and $Q\left(f,n,j,k\right)$ denote the observed symbol point in the complex plane for the *k*-th symbol of the *n*-th SC symbol block and *j*-th spatial stream within the *f*-th frame
* $I^{\*}\left(f,n,j,k\right)$ and $Q^{\*}\left(f,n,j,k\right)$ denote the ideal symbol point in the complex plane for the *k*-th symbol of the *n*-th SC symbol block and *j*-th spatial stream within the *f*-th frame
* $I\_{0}\left(f,j\right)$ and $Q\_{0}\left(f,j\right)$ is the complex DC term chosen to minimize the EVM, which may be dependent on the frame index (*f*) and spatial stream index (*j*)

The total number of symbols used in the test, which is equal to $N\_{f}×N\_{BLKS}×N\_{SS}×N\_{SPB}$, shall be at least 1000.

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

The transmit pulse shaping filter impulse response is implementation specific.

The EVM shall not exceed an MCS dependent value provided in Table 1 - Table 4.

Transmit requirements of PPDUs transmitted with TXVECTOR parameter NON\_EDMG\_MODULATION equal to SC\_MODE are defined in 20.6.4.

Table 1: EDMG-MCSs for the EDMG SC mode

|  |  |  |  |
| --- | --- | --- | --- |
| **MCS** | **Modulation** | **Code rate** | **EVM value [dB]** |
| 1 | π/2-BPSK | 1/2, ρ=2 | -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-BPSK | 7/8 | -13 |
| 7 | π/2-QPSK | 1/2 | -11 |
| 8 | π/2-QPSK | 5/8 | -12 |
| 9 | π/2-QPSK | 3/4 | -13 |
| 10 | π/2-QPSK | 13/16 | -15 |
| 11 | π/2-QPSK | 7/8 | -16 |
| 12 | π/2-16-QAM | 1/2 | -19 |
| 13 | π/2-16-QAM | 5/8 | -20 |
| 14 | π/2-16-QAM | 3/4 | -21 |
| 15 | π/2-16-QAM | 13/16 | -22 |
| 16 | π/2-16-QAM | 7/8 | -23 |
| 17 | π/2-64-QAM | 1/2 | -24 |
| 18 | π/2-64-QAM | 5/8 | -25 |
| 19 | π/2-64-QAM | 3/4 | -27 |
| 20 | π/2-64-QAM | 13/16 | -28 |
| 21 | π/2-64-QAM | 7/8 | -29 |

Table 2: EDMG-MCSs 12 and 13 for the EDMG SC mode if the π/2-8-PSK Applied field is 1

|  |  |  |  |
| --- | --- | --- | --- |
| **MCS** | **Modulation** | **Code rate** | **EVM value [dB]** |
| 12 | π/2-8-PSK | 2/3 | -17 |
| 13 | π/2-8-PSK | 5/6 | -20 |

Table 3: EDMG-MCSs 17 - 21 for the EDMG SC mode if the π/2-64-NUC Applied field is 1

|  |  |  |  |
| --- | --- | --- | --- |
| **MCS** | **Modulation** | **Code rate** | **EVM value [dB]** |
| 17 | π/2-64-NUC | 1/2 | -24 |
| 18 | π/2-64-NUC | 5/8 | -25 |
| 19 | π/2-64-NUC | 3/4 | -27 |
| 20 | π/2-64-NUC | 13/16 | -28 |
| 21 | π/2-64-NUC | 7/8 | -29 |

Table 4: EDMG-MCSs 2 - 6 for the EDMG SC mode if the DCM π/2-BPSK Applied field is 1

|  |  |  |  |
| --- | --- | --- | --- |
| **MCS** | **Modulation** | **Code rate** | **EVM value [dB]** |
| 2 | DCM π/2-BPSK | 1/2  | TBD |
| 3 | DCM π/2-BPSK | 5/8 | TBD |
| 4 | DCM π/2-BPSK | 3/4 | TBD |
| 5 | DCM π/2-BPSK | 13/16 | TBD |
| 6 | DCM π/2-BPSK | 7/8 | TBD |

**30.5.11.1.2 Time of Departure accuracy**

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

* MULTICHANNEL\_SAMPLING\_RATE is set to 1760×106 sample/s.
* FIRST\_TRANSITION\_FIELD is L-STF of the waveform transmitted in the primary channel.
* SECOND\_TRANSITION\_FIELD is L-CEF of the waveform transmitted in the primary channel.
* TRAINING\_FIELD is L-CEF of the waveform transmitted in the primary channel.
* TIME\_OF\_DEPARTURE\_ACCURACY\_TEST\_THRESH is 80 ns.

**30.5.11.2 Receive requirements**

**30.5.11.2.1 CCA**

CCA sensitivity requirements are defined in 30.3.8.