IEEE P802.11
Wireless LANs

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| CID 13  |
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Abstract

This submission proposes resolutions for the following comments from comment collection on P802.11me D0.0:

13

The baseline used in this document is D0.3.

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 an alternative version based on side discussions (option A / option B)

R2: Added new co-author

R3: Added goals and new option

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| --- | --- | --- | --- | --- |
| 13 | 2924.4 | 17.3.9.6 | The TX is permitted to have +-20 or +25ppm oscillator offset according to band. The TX EVM test is intended to limit the level of impairments within the TX that would not be accounted for by a minimal receiver. However, the language is unclear (or negative) towards one important impairment: residual sampling frequency offset due to the oscillator offset. This EVM test ambiguity (or deficiency) is made more acute by a) wider bandwidths, b) denser constellations, c) denser subcarriers, and (arguably) d) uplink multi-user transmissions. Specifically, a pedantic/naive reading of "estimate the phase from the pilot subcarriers, derotate the subcarrier values according to estimated phase" suggests that a single phase (i.e. CPE) is estimated and corrected, but no mitigation is provided for SFO aka increasing-over-time STO. Because an oscillator offset is permitted elsewhere, out of necessity test equipment does not count residual sampling frequency offset towards EVM, and so the 802.11 standard should align itself with industry reality. This comment applies to each OFDM-based PHY clause with an EVM test. (Clauses 17, 19, 21, 22, 23, and 11ax when it lands) | See 21/618 |

**Discussion**

See companion deck in 21/1569 (and also 21/618).

Furthermore, given the long-established nature of the EVM test, it is worthwhile to define the goals of any comment resolution as:

1. Legacy or imminent TX implementations should not become incompatible with the final REVme draft
2. New RX implementations should continue to have clarity on how legacy compliant TX devices might behave, so that the RX implementations can interoperate with legacy compliant TX devices
3. New TX implementations compliant with any defined EVM test need to be receiveable by legacy RX devices.
4. Implementations that require extreme or unapproachable receiver algorithms in order to experience the claimed TX EVM and thence achieve the performance anticipated by the standard should be discouraged

**Proposed Resolution: CID 13**

**Revised**.

**Note to Commenter:**

The commenters concerns are valid and are substantially addressed in 21/1570R<motionedRevision> under CID 13.

**Instruction to Editor:**

Implement the proposed text updates listed under CID 13 in 21/1570R<motionedRevision>

**Proposed Text Updates: CID 13 – Option 2 from 21/1569**

*Instruction to Editor: Update D0.3*

17.3.9.8 Transmit modulation accuracy test

The transmit modulation accuracy test shall be performed by instrumentation capable of converting the transmitted signal into a stream of complex samples at 20 Msample/s or more, with sufficient accuracy in terms of I/Q arm amplitude and phase balance, dc offsets, phase noise, etc. A possible embodiment of such a setup is converting the signal to a low IF 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 using the following steps or equivalent procedure:

a) Start of frame shall be detected.

b) Transition from short sequences to channel estimation sequences shall be detected, and fine timing (with one sample resolution) shall be established.

c) Coarse and fine carrier frequency offsets shall be estimated.

d) The PPDU shall be derotated according to estimated carrier frequency offset. Sampling offset drift of the PPDU shall be also compensated according to a single parameter estimated during the preamble of the PPDU (i.e., fields before the DATA field).

e) The complex channel response coefficients shall be estimated for each of the subcarriers.

f) For each of the data OFDM symbols: transform the symbol into subcarrier received values, estimate the phase (see NOTE) from the pilot subcarriers, derotate the subcarrier values to compensate the estimated phase, and divide each subcarrier value with a complex estimated channel response coefficient.

g) For each data-carrying subcarrier, find the closest constellation point and compute the Euclidean distance from it.

h) Compute the RMS average of all errors in a PPDU. It is given by

NOTE - This phase is commonly called the Common Phase Error (CPE).

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. Each transmit chain is connected directly through a cable to the setup input port. A possible embodiment of such a setup is converting the signals to a low intermediate 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 using the following steps or equivalent procedure:

a) Detect the start of frame.

b) Detect the transition from short sequences to channel estimation sequences, and establish fine timing (with one sample resolution).

c) Estimate the coarse and fine carrier frequency offsets.

d) Derotate the frame according to estimated carrier frequency offset. Sampling offset drift of the PPDU shall be also compensated according to a single parameter estimated during the preamble of the PPDU (i.e., fields before the Data field).

e) Estimate the complex channel response coefficients for each of the subcarriers and each of the transmit chains.

f) For each of the data OFDM symbols, transform the symbol into subcarrier received values, estimate the phase (see NOTE) from the pilot subcarriers in all spatial streams, derotate the subcarrier values to compensate the estimated phase, group the results from all of the receiver chains in each subcarrier to a vector, multiply the vector by a zero-forcing equalization matrix generated from the channel estimated during the channel estimation phase.

g) For each data-carrying subcarrier in each spatial stream, find the closest constellation point and compute the Euclidean distance from it.

h) Compute the average of the RMS of all errors in a frame. It is given by Equation (19-89).

NOTE - This phase is commonly called the Common Phase Error (CPE).

21.3.17.4.4 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 non-HT duplicate transmissions, each 20 MHz subchannel may be tested independently while all subchannels are being transmitted and

— For noncontiguous transmissions, each frequency segment may be tested independently while both segments are being transmitted.

In this case, transmit modulation accuracy of each segment shall meet the required value in Table 21-24 (Allowed relative constellation error versus constellation size and coding rate) using only the subcarriers within the corresponding segment.

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 using the following steps or equivalent procedure:

a) Start of PPDU shall be detected.

b) Transition from L-STF to L-LTF shall be detected and fine timing shall be established.

c) Coarse and fine carrier frequency offsets shall be estimated.

d) Symbols in a PPDU shall be derotated according to estimated carrier frequency offset. Sampling offset drift of the PPDU shall be also compensated according to a single parameter estimated during the preamble of the PPDU (i.e., fields before the VHT-SIG-B field).

e) For each VHT-LTF symbol, transform the symbol into subcarrier received values, estimate the phase (see NOTE) from the pilot subcarriers, and derotate the subcarrier values to compensate the estimated phase.

f) Estimate the complex channel response coefficient for each of the subcarriers and each of the transmit streams.

g) For each of the data OFDM symbols: transform the symbol into subcarrier received values, estimate the phase (see NOTE) from the pilot subcarriers, derotate the subcarrier values to compensate 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.

h) For each data-carrying subcarrier in each spatial stream, find the closest constellation point and compute the Euclidean distance from it.

i) Compute the average across PPDUs of the RMS of all errors per PPDU as given by Equation (19-89).

NOTE - This phase is commonly called the Common Phase Error (CPE).

27.3.19.4.4 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 a 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 27-49 (Allowed relative constellation error versus constellation size and coding rate(11ax)) using only the occupied data subcarriers within the corresponding segment. For HE TB PPDU transmission, two sets of EVM requirements are defined in Table 27-49 (Allowed relative constellation error versus constellation size and coding rate(11ax)) 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 HE 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 HE 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 160 MHz of the PPDU tone plan and ± 3 subcarriers of it. The potential LO leakage tones for 80+80 MHz operating devices exist outside the PPDU bandwidth and should not affect the transmitter modulation accuracy test. For 40 MHz capable devices that transmit 20 MHz, the potential LO leakage subcarriers exist outside the PPDU bandwidth and should not affect the transmitter modulation accuracy test. For 80 MHz capable devices that transmit 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 capable devices that transmit 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.

The instrument shall have sufficient accuracy in terms of I/Q branch 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 using the following or equivalent procedure:

a) Start of PPDU shall be detected.

b) Transition from L-STF to L-LTF shall be detected, and fine timing shall be established.

c) Coarse and fine carrier frequency offsets shall be estimated.

d) Symbols in a PPDU shall be derotated according to estimated carrier frequency offset. Sampling offset drift of the PPDU shall be also compensated according to a single parameter estimated during the preamble of the PPDU (i.e., fields before the Data field).

e) For each HE-LTF symbol, transform the symbol into subcarrier received values, estimate the phase (see NOTE) from the pilot subcarriers, and derotate the subcarrier values to compensate the estimated phase.

f) Estimate the complex channel response coefficient for each of the subcarriers and each of the transmit streams. If midambles are present in the Data field of the PPDU, the channel response coefficients shall be based upon the most recently received midamble symbols.

g) For each of the data OFDM symbols, transform the symbol into subcarrier received values, estimate the phase (see NOTE) from the pilot subcarriers, derotate the subcarrier values to compensate 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.

h) 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. If midambles are present in the Data field of the PPDU, the midamble symbols shall not be used to compute the Euclidean distance.

i) Compute the average across PPDUs of the RMS of all errors per PPDU as given by Equation (27-127).

NOTE - This phase is commonly called the Common Phase Error (CPE).

**Proposed Text Updates: CID 13 – Option 3 from 21/1569**

*Instruction to Editor: Update D0.3*

17.3.9.8 Transmit modulation accuracy test

The transmit modulation accuracy test shall be performed by instrumentation capable of converting the transmitted signal into a stream of complex samples at 20 Msample/s or more, with sufficient accuracy in terms of I/Q arm amplitude and phase balance, dc offsets, phase noise, etc. A possible embodiment of such a setup is converting the signal to a low IF 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 an equivalent procedure:

a) Start of frame shall be detected.

b) Transition from short sequences to channel estimation sequences shall be detected, and fine timing (with one sample resolution) shall be established.

c) Coarse and fine carrier frequency offsets shall be estimated.

d) The PPDU shall be derotated according to estimated carrier frequency offset. Sampling offset drift of the PPDU shall be also compensated according to a single parameter estimated using any feature(s) in the PPDU.

e) The complex channel response coefficients shall be estimated for each of the subcarriers.

f) For each of the data OFDM symbols: transform the symbol into subcarrier received values, estimate the phase (see NOTE) from the pilot subcarriers, derotate the subcarrier values to compensate the estimated phase, and divide each subcarrier value with a complex estimated channel response coefficient.

g) For each data-carrying subcarrier, find the closest constellation point and compute the Euclidean distance from it.

h) Compute the RMS average of all errors in a PPDU. It is given by

NOTE - This phase is commonly called the Common Phase Error (CPE).

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. Each transmit chain is connected directly through a cable to the setup input port. A possible embodiment of such a setup is converting the signals to a low intermediate 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 an equivalent procedure:

a) Detect the start of frame.

b) Detect the transition from short sequences to channel estimation sequences, and establish fine timing (with one sample resolution).

c) Estimate the coarse and fine carrier frequency offsets.

d) Derotate the frame according to estimated carrier frequency offset. Sampling offset drift of the PPDU shall be also compensated according to a single parameter estimated using any feature(s) in the PPDU.

e) Estimate the complex channel response coefficients for each of the subcarriers and each of the transmit chains.

f) For each of the data OFDM symbols, transform the symbol into subcarrier received values, estimate the phase (see NOTE) from the pilot subcarriers in all spatial streams, derotate the subcarrier values to compensate the estimated phase, group the results from all of the receiver chains in each subcarrier to a vector, multiply the vector by a zero-forcing equalization matrix generated from the channel estimated during the channel estimation phase.

g) For each data-carrying subcarrier in each spatial stream, find the closest constellation point and compute the Euclidean distance from it.

h) Compute the average of the RMS of all errors in a frame. It is given by Equation (19-89).

NOTE - This phase is commonly called the Common Phase Error (CPE).

21.3.17.4.4 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

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In this case, transmit modulation accuracy of each segment shall meet the required value in Table 21-24 (Allowed relative constellation error versus constellation size and coding rate) using only the subcarriers within the corresponding segment.

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:

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d) Symbols in a PPDU shall be derotated according to estimated carrier frequency offset. Sampling offset drift of the PPDU shall be also compensated according to a single parameter estimated using any feature(s) in the PPDU.

e) For each VHT-LTF symbol, transform the symbol into subcarrier received values, estimate the phase (see NOTE) from the pilot subcarriers, and derotate the subcarrier values to compensate the estimated phase.

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h) For each data-carrying subcarrier in each spatial stream, find the closest constellation point and compute the Euclidean distance from it.

i) Compute the average across PPDUs of the RMS of all errors per PPDU as given by Equation (19-89).

NOTE - This phase is commonly called the Common Phase Error (CPE).

27.3.19.4.4 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 a 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 27-49 (Allowed relative constellation error versus constellation size and coding rate(11ax)) using only the occupied data subcarriers within the corresponding segment. For HE TB PPDU transmission, two sets of EVM requirements are defined in Table 27-49 (Allowed relative constellation error versus constellation size and coding rate(11ax)) 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 HE 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 HE 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 160 MHz of the PPDU tone plan and ± 3 subcarriers of it. The potential LO leakage tones for 80+80 MHz operating devices exist outside the PPDU bandwidth and should not affect the transmitter modulation accuracy test. For 40 MHz capable devices that transmit 20 MHz, the potential LO leakage subcarriers exist outside the PPDU bandwidth and should not affect the transmitter modulation accuracy test. For 80 MHz capable devices that transmit 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 capable devices that transmit 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.

The instrument shall have sufficient accuracy in terms of I/Q branch 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 using the following or equivalent procedure:

a) Start of PPDU shall be detected.

b) Transition from L-STF to L-LTF shall be detected, and fine timing shall be established.

c) Coarse and fine carrier frequency offsets shall be estimated.

d) Symbols in a PPDU shall be derotated according to estimated carrier frequency offset. Sampling offset drift of the PPDU shall be also compensated according to a single parameter estimated using any feature(s) in the PPDU.

e) For each HE-LTF symbol, transform the symbol into subcarrier received values, estimate the phase (see NOTE) from the pilot subcarriers, and derotate the subcarrier values to compensate the estimated phase.

f) Estimate the complex channel response coefficient for each of the subcarriers and each of the transmit streams. If midambles are present in the Data field of the PPDU, the channel response coefficients shall be based upon the most recently received midamble symbols.

g) For each of the data OFDM symbols, transform the symbol into subcarrier received values, estimate the phase (see NOTE) from the pilot subcarriers, derotate the subcarrier values to compensate 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.

h) 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. If midambles are present in the Data field of the PPDU, the midamble symbols shall not be used to compute the Euclidean distance.

i) Compute the average across PPDUs of the RMS of all errors per PPDU as given by Equation (27-127).

NOTE - This phase is commonly called the Common Phase Error (CPE).

**Proposed Text Updates: CID 13 – Options “5-2 and 5-3”**

*Instruction to Editor: Update D0.3*

17.3.9.8 Transmit modulation accuracy test

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The following test procedure is deprecated and shall not be used in designs using new components.

The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or an equivalent procedure:

a) Start of frame shall be detected.

b) Transition from short sequences to channel estimation sequences shall be detected, and fine timing (with one sample resolution) shall be established.

c) Coarse and fine frequency offsets shall be estimated.

d) The PPDU shall be derotated according to estimated frequency offset.

e) The complex channel response coefficients shall be estimated for each of the subcarriers.

f) For each of the data OFDM symbols: transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, derotate the subcarrier values according to estimated phase, and divide each subcarrier value with a complex estimated channel response coefficient.

g) For each data-carrying subcarrier, find the closest constellation point and compute the Euclidean distance from it.

h) Compute the RMS average of all errors in a PPDU. It is given by equation (17-28).

NOTE – The derotation in step f) might include correction of sampling drift offset. An equivalent procedure might perform a time domain correction of sampling drift offset according to a single parameter estimated using any feature(s) in the PPDU.

***<Now insert option 2 or option 3 here>***

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. Each transmit chain is connected directly through a cable to the setup input port. A possible embodiment of such a setup is converting the signals to a low intermediate frequency with a microwave synthesizer, sampling the signal with a digital oscilloscope, and decomposing it digitally into quadrature components.

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c) Estimate the coarse and fine frequency offsets.

d) Derotate the frame according to estimated frequency offset.

e) Estimate the complex channel response coefficients for each of the subcarriers and each of the transmit chains.

f) For each of the data OFDM symbols, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers in all spatial streams, derotate the subcarrier values according to estimated phase, group the results from all of the receiver chains in each subcarrier to a vector, multiply the vector by a zero-forcing equalization matrix generated from the channel estimated during the channel estimation phase.

g) For each data-carrying subcarrier in each spatial stream, find the closest constellation point and compute the Euclidean distance from it.

h) Compute the average of the RMS of all errors in a frame. It is given by Equation (19-89).

NOTE – The derotation in step f) might include correction of sampling drift offset. An equivalent procedure might perform a time domain correction of sampling drift offset according to a single parameter estimated using any feature(s) in the PPDU.

***<Now insert option 2 or option 3 here>***

21.3.17.4.4 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 non-HT duplicate transmissions, each 20 MHz subchannel may be tested independently while all subchannels are being transmitted and

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The following test procedure is deprecated and shall not be used in designs using new components.

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b) Transition from L-STF to L-LTF shall be detected and fine timing shall be established.

c) Coarse and fine frequency offsets shall be estimated.

d) Symbols in a PPDU shall be derotated according to estimated frequency offset.

e) For each VHT-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.

f) Estimate the complex channel response coefficient for each of the subcarriers and each of the transmit streams.

g) For each of the data OFDM symbols: transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, derotate 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.

h) For each data-carrying subcarrier in each spatial stream, find the closest constellation point and compute the Euclidean distance from it.

i) Compute the average across PPDUs of the RMS of all errors per PPDU as given by Equation (19-89).

NOTE – The derotation in steps e) and g) might include correction of sampling drift offset. An equivalent procedure might perform a time domain correction of sampling drift offset according to a single parameter estimated using any feature(s) in the PPDU.

***<Now insert option 2 or option 3 here>***

27.3.19.4.4 Transmitter modulation accuracy (EVM) test

***<Follow option 2 or option 3 here>***