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| Project | **IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>** | |
| Title | Correction to Rx SNR, Rx sensitivity, and Tx Relative Constellation Error for OFDM and OFDMA systems. | |
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| Source(s) | Darcy Poulin [SiGe Semiconductor], Paul Piggin [Cygnus Multimedia Communications], Ran Yaniv [Alvarion], Dov Andelman [Intel] | Voice: [613-820-9244 x274]<br>Fax: [Fax Number]<br>[dp@sige.com, ppiggin@cygnuscom.com] |
| Re: | IEEE P80216_Cor1_D4 | |
| Abstract | Correction to Rx SNR, Rx sensitivity, and Relative Constellation Error for OFDM and OFDMA systems. | |
| Purpose | The Rx SNR values in 802.16-2004 are incorrect. As a result, relative constellation error (EVM) and Rx sensitivity are also in error. In addition, there are many inconsistencies throughout section 8.3, 8.4, and 12.4 specifying EVM and Rx SNR. This submission attempts to resolve these inconsistencies. | |
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# Introduction

The current 802.16-2004 standard derives the Rx sensitivity based on the SNR of an ideal receiver needed to achieve a BER of 1e-6 in AWGN. It takes this ideal Rx SNR, then adds 5 dB for implementation loss and 7 dB for the receiver noise figure. Finally, it accounts for the channel bandwidth. The SNR of the ideal receiver is incorrect; it is approximately 3.4 dB higher than it should be, so the required sensitivity is 3.4 dB higher (easier to meet) than it should be. We wish to correct these errors in SNR, and hence errors in Rx sensitivity.

There is also a problem with the Tx relative constellation error (EVM). The Tx EVM was initially defined to be 10 dB lower than the Rx SNR so that the overall link SNR would not degrade more than 0.5 dB due to the transmitter. Since EVM is tied to the receive SNR, then the errors in Rx SNR have also resulted in an error in required Tx EVM. We wish to correct required Tx EVM so that it is consistent with the corrected Rx SNR.

In addition, there are a number of inconsistencies in the 802.16-2004 standard in specifying Tx EVM requirements. For example, table 264 (OFDM-PHY) specifies that the Tx EVM for 64-QAM-3/4 must be -31 dB. Table 336 (OFDMA-PHY) specifies that the EVM must be -31.4. Table 413 (minimum performance requirement for OFDMA in the Systems Profiles chapter) calls for a minimum EVM of -34.4 dB. As part of this submission, we will correct all of these inconsistencies.

Finally, we are therefore proposing that the Tx EVM be capped at -30 dB for subscriber stations, and -31 dB for base stations.

## 1.0 Discussion of Rx SNR and relative constellation Error for OFDM

The Rx SNR in the 802.16-2004 standard for OFDM is incorrect. The correct values for an ideal OFDM receiver, in order to decode OFDM with a BER of 1e-6 in AWGN can be found in an earlier submission by Tal Kaitz and Naftali Chayat in C80216d-03_44.The correct values are approximately 3.4 dB lower than they are in Table 266 of the current 802.16-2004 standard. This correction was also noted in 80216-03_18r12, comment 151. This comment was accepted, but the change to the Rx SNR table was not implemented due to an editorial error. To show this, note that P802_16d_D3 (Sept 3, 2003), table 212, shows the corrected Rx SNR values. The next version of the draft, P80216-REVd_D1.pdf (Sept 27, 2003) shows the incorrect values for Rx SNR again. The fact that this was simply an editorial error was discovered after tracking through the commentary files used to generate both versions of the draft standard.

As a result of this error, the Rx sensitivity is incorrect, since sensitivity is derived wholly from the required Rx SNR. The sensitivity is given by equation 98 in section 8.3.11.1. It is calculated assuming that there is a 5 dB implementation loss (which includes non-ideal receiver effects such as channel estimation errors, tracking errors, quantization errors, and phase noise) and a 7 dB noise figure. As a result of this error, the sensitivity will be about 3.4 dB lower (harder to achieve) when these corrections are applied. In order to partially offset the fact that the sensitivity is being made 3.4 dB harder to achieve, we are proposing that the allowed noise figure be increased from 7 dB to 8 dB. For example, the sensitivity for a 3.5MHz channel bandwidth with 64QAM-3/4 is currently -72.6 dBm. When the correct value for the receiver SNR is applied with an 8 dB noise figure, this value becomes -75 dBm.

The transmitter relative constellation error (EVM) must also be changed as a result of this error correction. The Tx EVM is computed so that it is 10 dB below the Rx SNR (not including implementation loss). This is done to ensure that the transmitter has minimal effect on the overall link. For example, for 16QAM-1/2, the Rx SNR is 11.5 dB. Therefore, the required Tx EVM will be - (11.5 + 10) = - 21.5 dB, and the Tx EVM only degrades the overall SNR by 0.4 dB (the 11.5 dB SNR will be degraded to an SNR of 11.1 dB when the transmitted signal with a EVM of -21.5 dB is applied).

For subscriber stations, we are also proposing that we cap the EVM at -30 dB. Applying a cap at -30 dB means that for the worst case 64QAM-3/4 modulation, the transmitter will degrade the overall SNR by 1.5 dB.

For base stations, we will not put a cap on EVM, so it remains at -31 dB. This will result in a worst case degradation of the SNR of 1.2 dB for 64QAM-3/4.
To summarize:

SS EVM = BS SNR + 10 dB.
This is capped at -30 dB.

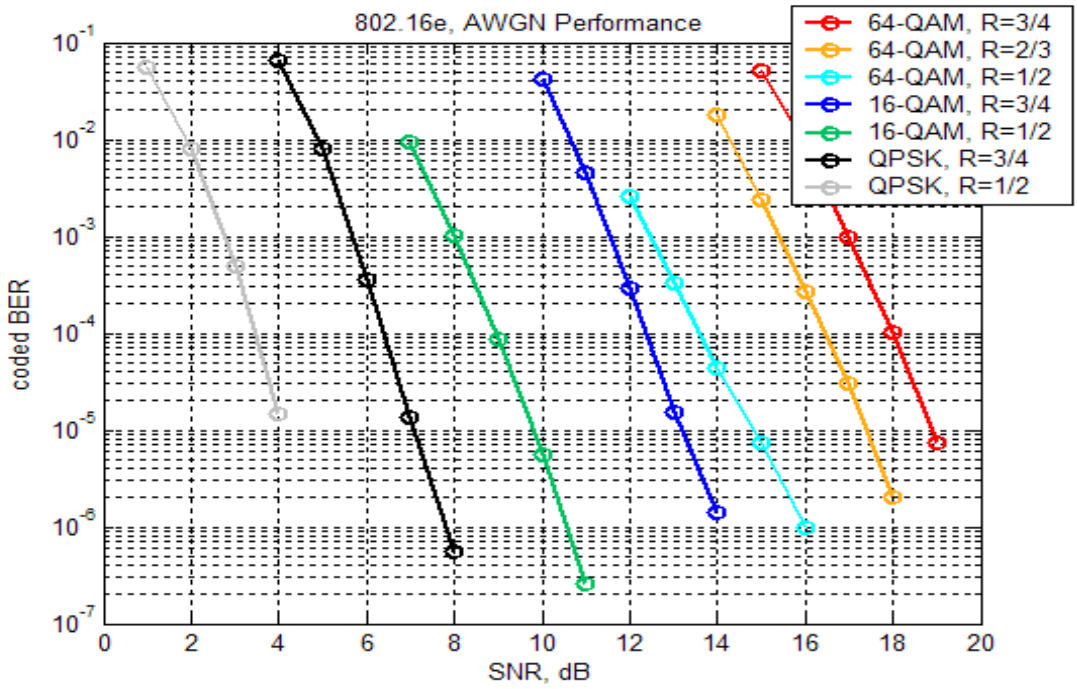
BS EVM = SS SNR + 10 dB

By capping the SS EVM at -30 dB, this will allow SS radios to use lower cost, and less complex radios and

amplifiers. We also note that a 5 dB implementation loss is very conservative. We anticipate that SS and BS vendors will achieve implementation losses significantly better than this, and this will improve the overall link SNR.

## 2.0 Discussion of Rx SNR and Tx Relative Constellation Error for OFDMA

The Rx SNR in the 802.16-2004 standard for OFDMA is incorrect. The correct values for an ideal OFDMA receiver, in order to decode OFDMA with a BER of 1e-6 , can be derived from Figure 1.

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To summarize:
SS EVM = BS SNR 10 dB
BS EVM = SS SNR + 10 dB

## Suggested Corrections to 802.16-2004:

8.3.10.1.2

To ensure that the receiver SNR does not degrade ~~more than 0.5 dB~~ significantly due to the transmitter SNR, the relative constellation RMS error, averaged over subcarriers, OFDM frames, and packets, shall not exceed a burst profile dependent value according to table 264.

Table 264- Allowed relative constellation error versus data rate

| ~~Burst Type~~ Modulation | Relative Constellation Error for SS (dB) | Relative Constellation Error for BS (dB) |
|---|---|---|
| BPSK-1/2 | -13 | -13 |
| QPSK-1/2 | -16 | -16 |
| QPSK-3/4 | -18.5 | -18.5 |
| 16QAM-1/2 | -21.5 | -21.5 |
| 16QAM-3/4 | -25 | -25 |
| 64QAM-2/3 | -29 | -29 |
| 64QAM-3/4 | ~~-31~~ -30 | -31 |

8.3.11.1 Receiver sensitivity

The BER measured after FEC shall be less than $10^{-6}$ at the power levels given by Equation (98) for standard message and test conditions. If the implemented bandwidth is not listed, then the values for the nearest smaller listed bandwidth shall apply. The minimum input levels are measured as follows:

— Using the defined standardized message packet formats, and

— Using an AWGN channel.

The receiver minimum input level sensitivity ($R_{SS}$) shall be (assuming 5 dB implementation margin and ~~7~~ 8 dB Noise Figure):

$R_{SS}$= ~~-102~~ -101 + $SNR_{RX}$+10log ($F_S$*$N_{used}$/$N_{FFT}$ * $N_{subchannels}$/16)

where

$SNR_{RX}$ the receiver SNR as per Table 267 in dB

$F_S$ sampling frequency in MHz as defined in 8.3.2.2

$N_{subchannels}$ the number of allocated subchannels (default 16 if no subchannelization is used)

Table 266: Receiver SNR assumptions

| Modulation | Receiver SNR (dB) |
|---|---|
| BPSK-1/2 | ~~6.4~~ 3 |
| QPSK-1/2 | ~~9.4~~ 6 |
| QPSK-3/4 | ~~11.2~~ 8.5 |
| 16QAM-1/2 | ~~16.4~~ 11.5 |
| 16QAM-3/4 | ~~18.2~~ 15 |
| 64QAM-2/3 | ~~22.7~~ 19 |
| 64QAM-3/4 | ~~24.4~~ 21 |

Note that these SNR values are derived in an AWGN environment, and assume that Reed-Solomon convolutional coding (RS-CC) is used.

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12.3.2

Remove the Tx relative constellation error row in table 404, and replace it with the following row (note that an extra column is added, since we have split BS and SS requirements):

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| Tx relative constellation error: | SS | BS |
|---|---|---|
| BPSK-1/2 | ≤ -13 | ≤ -13 |
| QPSK-1/2 | ≤ -16 | ≤ -16 |
| QPSK-3/4 | ≤ -18.5 | ≤ -18.5 |
| 16QAM-1/2 | ≤ -21.5 | ≤ -21.5 |
| 16QAM-3/4 | ≤ -25 | ≤ -25 |
| 64QAM-2/3 | ≤ -29 | ≤ -29 |
| 64QAM-3/4 | ≤ -30 | ≤ -31 |

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8.4.12.3: **Transmitter constellation error and test method**

To ensure that the receiver SNR does not degrade ~~more than 0.5 dB~~ significantly due to the transmitter SNR, the relative constellation RMS error, averaged over subcarriers, OFDMA frames, and packets, shall not exceed a burst profile dependent value according to table 336.

Table 336-Allowed relative constellation error versus data rate

| Modulation | Relative Constellation Error for SS (dB) | Relative Constellation Error for BS (dB) |
|---|---|---|
| QPSK-1/2 | ~~-16.4~~ -15 | -15 |
| QPSK-3/4 | ~~-18.2~~ -18 | -18 |
| 16QAM-1/2 | ~~-23.4~~ -20.5 | -20.5 |
| 16QAM-3/4 | ~~-25.2~~ -24 | -24 |
| 64QAM-1/2 | -26 | -26 |
| 64QAM-2/3 | ~~-29.7~~ -28 | -28 |
| 64QAM-3/4 | ~~-31.4~~ -30 | -30 |

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8.4.13.1: **Receiver sensitivity**

The BER measured after FEC shall be less than $10^{-6}$ at the power levels given by Equation (xx) for standard message and test conditions. The minimum input levels are measured as follows:

-Using the defined standardized message formats, and

-Using an AWGN channel

(Remove table 335)

~~Table 335 (as well as Table 334) are derived assuming 5 dB implementation loss, a Noise Figure of 7 dB and receiver SNR and Eb/N0 values as listed in Table 336.~~

The receiver minimum sensitivity level, $R_{SS}$, is derived according to the following equation:

$$R_{SS} = -114 + SNR_{Rx} - 10*\log10(R) + 10\log10(F_S*N_{used}/N_{FFT}) + ImpLoss + NF \quad \text{(eq. xx)}$$

Where:

$SNR_{Rx}$ = the receiver SNR as per table 338

R = repetition factor, as described in section 8.4.9

Fs = sampling frequency in MHz as defined in section 8.4.2.4

ImpLoss = implementation loss, which includes non-ideal receiver effects such as channel estimation errors, tracking errors, quantization errors, and phase noise. The assumed value is 5 dB.

NF = receiver noise figure, referenced to the antenna port. The assumed value is 8 dB.

Table 338-Receiver SNR assumptions

| Modulation | ~~Eb/No~~ | Receiver SNR (dB) |
|---|---|---|
| QPSK-1/2 | ~~10.5~~ | ~~9.4~~ 5 |
| QPSK-3/4 | ~~10.5~~ | ~~11.2~~ 8 |
| 16QAM-1/2 | ~~14.5~~ | ~~16.4~~ 10.5 |
| 16QAM-3/4 | ~~14.5~~ | ~~18.2~~ 14 |
| 64QAM-1/2 | ~~19~~ | 16 |
| 64QAM-2/3 | ~~19~~ | ~~22.7~~ 18 |
| 64QAM-3/4 | ~~19~~ | ~~24.4~~ 20 |

Note that these SNR values are derived in an AWGN environment, and assume that a tail-biting convolutional code (CC) is used.

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12.4.3.1.5

Replace the row describing Tx relative constellation error in table 413 with the data below. Note that an extra column is added, since we have split BS and SS requirements:

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| Tx relative constellation error: | SS | BS |
|---|---|---|
| QPSK-1/2 | ≤ -15 | ≤ -15 |
| QPSK-3/4 | ≤ -18 | ≤ -18 |
| 16QAM-1/2 | ≤ -20.5 | ≤ -20.5 |
| 16QAM-3/4 | ≤ -24 | ≤ -24 |
| 64QAM-1/2 | ≤ -26 | ≤ -26 |
| 64QAM-2/3 | ≤ -28 | ≤ -28 |
| 64QAM-3/4 | ≤ -30 | ≤ -30 |

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12.4.3.2

In table 414, requirements of Tx relative constellation error are listed. These requirements are covered in table 413, and should be removed in table 414. Note that none of the other profiles includes EVM, so removing the EVM requirement here makes the table consistent with all other profiles.
Therefore, remove the row specifying Tx relative constellation error in table 414.