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Title	Correction to Rx SNR, Rx sensitivity, and Tx Relative Constellation Error for OFDM and OFDMA systems.	
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Re:	IEEE P80216_Cor1_D3	
Abstract	Correction to Rx SNR, Rx sensitivity, and Relative Constellation Error for OFDM and OFDMA systems.	
Purpose	The Rx SNR values in 802.16d are incorrect. As a result, relative constellation error (RCE) and Rx sensitivity are also in error. In addition, there are many inconsistencies throughout section 8.3, 8.4, and 12.4 specifying RCE 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 lower than it should be, so the required sensitivity is 3.4 dB higher (easier to meet) than it should be. We will correct these errors in SNR, and hence errors in Rx sensitivity.

There is also a problem with the Tx relative constellation error (RCE). The Tx RCE 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 RCE is tied to the receive SNR, then the errors in Rx SNR have also resulted in an error in required Tx RCE. We will correct required Tx RCE 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 RCE requirements. For example, table 264 (OFDM-PHY) specifies that the Tx RCE for 64-QAM-3/4 must be -31 dB. Table 336 (OFDMA-PHY) specifies that the RCE must be -31.4. Table 413 (minimum performance requirement for OFDMA in the Systems Profiles chapter) calls for a minimum RCE of -34.4 dB. As part of this submission, we will correct all of these inconsistencies.

Finally, in order to ensure that the Tx RCE is 10 dB below the Rx SNR, we have found that the required RCE is often impractical. For example, the Rx SNR for 64QAM-3/4 OFDMA is 20 dB. Adding in 5 dB implementation loss, this becomes 25 dB. We would like to have the Tx RCE 10 dB below this level, which would result in a required RCE of -35dB. This is impractical, and will result in significant cost and power implications. We are therefore proposing that the Tx RCE 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.

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. 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, this value becomes -76 dBm.

The transmitter relative constellation error (RCE) must also be changed as a result of this error correction. The Tx RCE is computed so that it is 10 dB below the Rx SNR (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. With the 5 dB implementation loss, this means that the Rx SNR needs to be 16.5 dB. Therefore, the required Tx RCE will be - (16.5 + 10) = - 26.5 dB, and the Tx RCE only degrades the overall SNR by 0.4 dB (the 16.5 dB SNR will be degraded to an SNR of 16.1 dB when the transmitted signal with a RCE of -26.5 dB is applied).

For higher order modulations, requiring the Tx RCE to be 10 dB above (Rx SNR + implementation loss) makes the RCE impractically high. For example, for 64QAM-3/4, this formula will require the RCE to be –(21+5+10) = -36 dB. This level is impractical, and will result in very high power consumption and cost. To address this issue, we would like to apply a cap to the RCE, and we are also proposing that we split the requirements for base stations and subscriber stations.

For subscriber stations, we are proposing that we use only an 8 dB delta between (Rx SNR + implementation loss) and Tx RCE. Furthermore, we would like to cap the RCE at -30 dB. Using a delta of 8 dB results in the transmitter degrading the overall SNR by 0.6 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 leave the delta at 10 dB, and put a cap on RCE at -31 dB. This will result in a worst case degradation of the SNR of 1.2 dB for 64QAM-3/4.

To summarize:

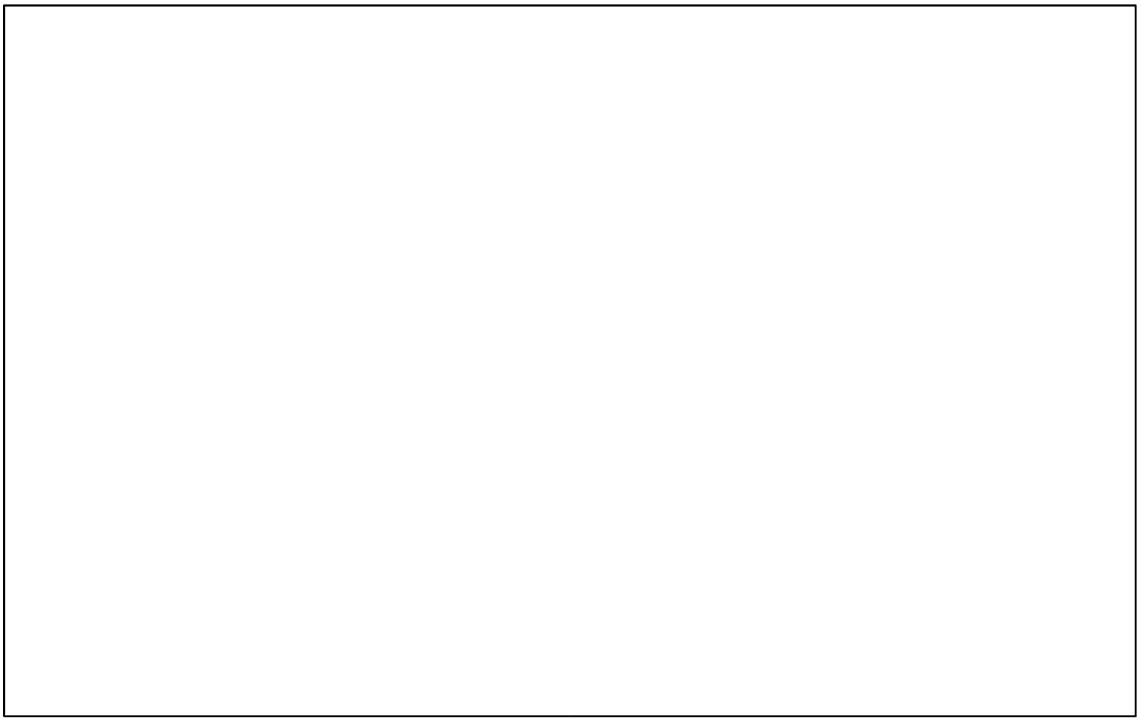
SS RCE = BS SNR + BS implementation loss + 8 dB = BS SNR+13 dB.
This is capped at -30 dB.

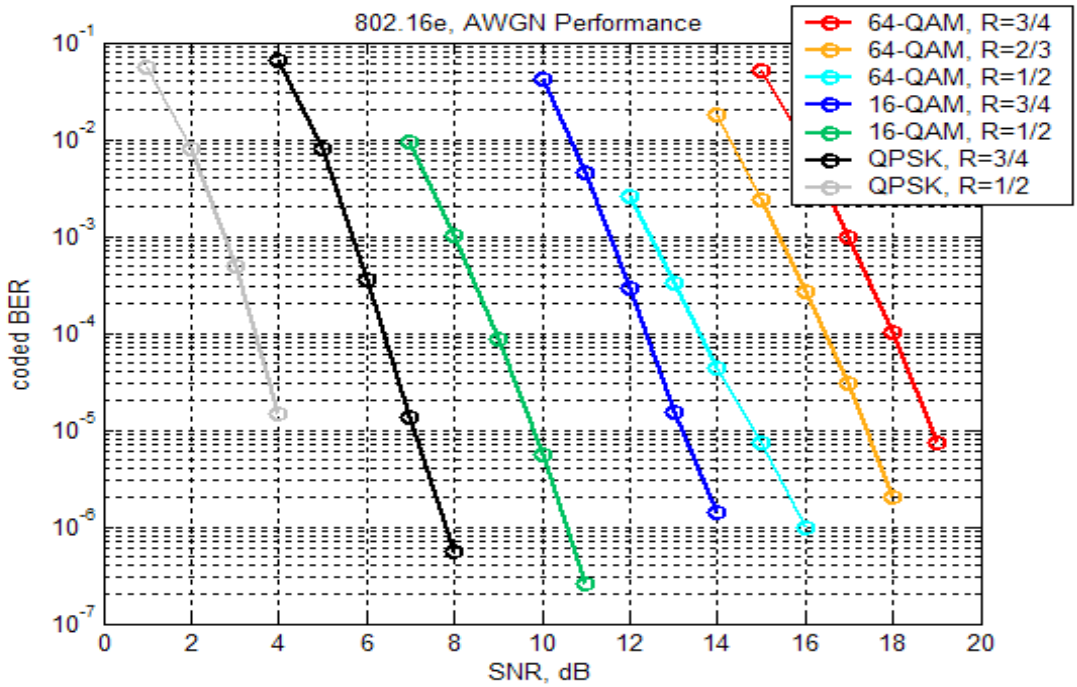
BS RCE = SS SNR + SS implementation loss + 10 dB = SS SNR + 15 dB.
This is capped at -31 dB.
By capping the SS RCE at -30 dB, and by using an 8 dB delta, this will allow SS radios to use lower cost, and less complex radios and amplifiers. We also note that a 5 dB implementation loss, while reasonable for a SS, is very conservative for a BS. We anticipate that BS vendors will achieve implementation losses of 3 dB or less,

and this will improve the overall link SNR to negate the effect of an 8 dB delta.

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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at the required Tx RCE
by 0.4 dB (the 15.5 dB
f -25.5 dB is applied).

For higher order modulations, requiring the Tx RCE to be 10 dB above (Rx SNR + implementation loss) makes the RCE impractically high. For example, for 64QAM-3/4, this formula will require the RCE to be –(20+5+10) = -35 dB. This level is impractical, and will result in very high power consumption and cost. To address this issue, we would like to apply a cap to the RCE, and we are also proposing that we split the requirements for base stations and subscriber stations.

For subscriber stations, we are proposing that we use only an 8 dB delta between (Rx SNR + implementation loss) and Tx RCE. Furthermore, we would like to cap the RCE at -30 dB. Using a delta of 8 dB results in the transmitter degrading the overall SNR by 0.6 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 1.2 dB.

For base stations, we will leave the delta at 10 dB, and put a cap on RCE at -31 dB. Applying a cap at -31 dB means that for the worst case 64QAM-3/4 modulation, the transmitter will degrade the overall SNR by 1.0 dB.

To summarize:
SS RCE = BS SNR + BS implementation loss + 8 dB = BS SNR+13 dB.
This is capped at -30 dB.

BS RCE = SS SNR + SS implementation loss + 10 dB = SS SNR + 15 dB.
This is capped at -31 dB.

By capping the SS RCE to -30 dB, and by using an 8 dB delta, this will allow SS radios to use lower cost, and less complex radios and amplifiers. We also note that a 5 dB implementation loss, while reasonable for a SS, is very conservative for a BS. We anticipate that BS vendors will achieve implementation losses of 3 dB or less, and this will improve the overall link SNR to negate the effect of an 8 dB delta.

Suggested Corrections to 802.16-2004:

8.3.10.1.2

Replace the paragraph from the beginning of section 8.3.10.1.2 to the end of table 264 with the following text:

To ensure that the receiver SNR does not degrade 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. These values are calculated as follows:

SS RCE = BS SNR + BS implementation loss + 8 dB = BS SNR + 13 dB [eqn xxx]
This value is capped at -30 dB.

BS RCE = SS SNR + SS implementation loss + 10 dB = SS SNR + 15 dB [eqn xxy]
This value is capped at -31 dB.

Table 264- Allowed relative constellation error versus data rate

Modulation	Relative Constellation Error for SS (dB)	Relative Constellation Error for BS (dB)
BPSK-1/2	-16	-18
QPSK-1/2	-19	-21
QPSK-3/4	-21.5	-23.5
16QAM-1/2	-24.5	-26.5
16QAM-3/4	-28	-30
64QAM-2/3	-30	-31
64QAM-3/4	-30	-31

8.3.11.1

Replace table 266 with the table below:

Table 266-Receiver SNR assumptions

Modulation	Receiver SNR (dB)
BPSK-1/2	3
QPSK-1/2	6
QPSK-3/4	8.5
16QAM-1/2	11.5
16QAM-3/4	15
64QAM-2/3	19
64QAM-3/4	21

12.3.2

Remove the Tx relative constellation error row in table 266, and replace it with the following row (note that an extra column is added, since we have split BS and SS requirements):

Tx relative constellation error:	SS	BS
BPSK-1/2	≤ -16	≤ -18
QPSK-1/2	≤ -19	≤ -21
QPSK-3/4	≤ -21.5	≤ -23.5
16QAM-1/2	≤ -24.5	≤ -26.5
16QAM-3/4	≤ -28	≤ -30
64QAM-2/3	≤ -30	≤ -31
64QAM-3/4	≤ -30	≤ -31

8.4.12.3:

Replace the text and table from the beginning of this section to the end of table 336 with:

To ensure that the receiver SNR does not degrade 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. These values are calculated as follows

SS RCE = BS SNR + BS implementation loss + 8 dB = BS SNR+13dB [eqn yyy]
This value is capped at -30 dB.

BS RCE = SS SNR + SS implementation loss + 10 dB = SS SNR + 15 dB [eqn yyz]
This value is capped at -31 dB.

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	-18	-20
QPSK-3/4	-21	-23
16QAM-1/2	-23.5	-25.5
16QAM-3/4	-27	-29
64QAM-1/2	-29	-31
64QAM-2/3	-30	-31
64QAM-3/4	-30	-31

8.4.13.1

Replace the text from the beginning of section 8.4.13.1 to the end of Table 338 with the following text:

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

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

$R_{SS} = -114 + SNR_{Rx} - 10*\log10(R) + 10\log10(F_S*N_{used}/N_{FFT}) + ImpLoss + NF$ (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 7 dB.

Table 338-Receiver SNR assumptions

Modulation	**Receiver SNR (dB)**
QPSK-1/2	5
QPSK-3/4	8
16QAM-1/2	10.5
16QAM-3/4	14
64QAM-1/2	16
64QAM-2/3	18
64QAM-3/4	20

12.4.3.1.5

Replace the row describing Tx relative constellation error in table 413 with:

Tx relative constellation error:	SS	BS
QPSK-1/2	≤ -18	≤ -20
QPSK-3/4	≤ -21	≤ -23
16QAM-1/2	≤ -23.5	≤ -25.5
16QAM-3/4	≤ -27	≤ -29
64QAM-1/2	≤ -29	≤ -31
64QAM-2/3	≤ -30	≤ -31
64QAM-3/4	≤ -30	≤ -31

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 RCE, so removing the RCE requirement here makes the table consistent with all other profiles.
Therefore, remove the row specifying Tx relative constellation error in table 414.