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Title	Problems with Measurement of Transmitter Constellation Error in OFDM and a Solution
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Re:	Supporting document for Comment to 802.16maint (LB17).
Abstract	Changes required in to resolve ambiguities and errors in methods for calculating CINR for OFDM PHY modes.
Purpose	The document is intended for consideration within the comments resolution process.
Notice	
Release	
Patent Policy and Procedures	

Problems with Measurement of Transmitter Constellation Error in OFDM and a Solution

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References

1. IEEE, "IEEE Standard for Local and metropolitan area networks Part 16: Air Interface for Fixed Broadband Wireless Access Systems," IEEE Std 802.16-2004.
2. IEEE, "IEEE Draft Standard for Local and metropolitan area networks Part 16: Air Interface for Fixed Broadband Wireless Access Systems," IEEE P802.16-REVd/D5-2004.
3. IEEE, "Corrigendum to IEEE Standard for Local and metropolitan area networks Part 16: Air Interface for Fixed Broadband Wireless Access Systems," P802.16-2004/Cor1/D1, 2005-02-11.
4. Yuval Lomnitz , Intel, comment 544, 80216maint-04/04r10.
5. Yuval Lomnitz, Intel, "Missing definitions for CINR in OFDMA PHY," www.wirelessman.org/maint/contrib/C80216maint-04_46r1.pdf

Introduction

The changes proposed in this document are to correct errors in the description of the calculation of transmitter constellation error, and in particular the lack of detailed specification for its calculation on sub-channelised transmissions for the OFDM PHY mode, as described in IEEE 802.16-2004 [1, 2].

Description of Problem

In the 802.16-2004 standard [1] there is a description of the method by which the CINR shall be calculated.
I have the following observation to make on this procedure, which for convenience, I copy below.
(1) In step (f), the instruction is to derive the phase from the pilots and then de-rotate according to the estimated phase. I presume this is because of common phase correction. The sub-carrier values are then divided by a complex estimated channel response coefficient. This is, according to step (e), estimated for every subcarrier. This means that the estimation process will accommodate any group delay variations across the band (provided they are less than the cyclic prefix), but it is ambiguous as (in the downlink and full bandwidth uplink) the phase estimates from preambles are only available on every alternate tone. I am presuming that channel estimates are derived from the 128x2 preamble because of the statement at point (b): *"Transition from short sequences to channel estimation sequences shall be detected."* The phase on intermediate tones will require interpolation. The method and bandwidths of any interpolation/smoothing is not specified. This latter issue is NOT addressed in this contribution.
(2) The formula only applies to the downlink: there is no "*transition from short sequences*" in the case of an uplink transmission.
(3) The formula states it computes RMS error, but shows mean square error.
(4) For narrow subchannels, the sum is over N_{used}. This is not the active set of sub-carriers but rather all possible sub-carriers in the OFDM waveform. The result is that the noise is counted for all sub-carriers, while the signal is calculated on the active tones. This is something that has been addressed in the OFDMA physical layer in a comment from Yuval Lomnitz at Intel [4, 5]. The changes suggested there need addressing in the OFDM PHY also; otherwise there will be a 12 dB penalty for following the standard rigorously while measuring the narrowest subchannels.
(5) I am unsure of the use of brackets: are they meant to imply floor and ceiling operations for numerator and denominator respectively (underestimating noise and overestimating signal power), or were they meant to be [and]?

In the following changes, I make explicit that sums only run over the active tones, allowing deletion of the final sentence of points (f) and (g).

The following is a copy of the original equation 97:

$$\text{Error}_{RMS} = \frac{1}{N_f}\sum_{i=1}^{N_f}\frac{\sum_{j=1}^{L_P}\left[\sum_{\substack{k=-N_{used}/2 \\ k\neq 0}}^{N_{used}/2}\left\{(I(i,j,k)-I_0(i,j,k))^2+(Q(i,j,k)-Q_0(i,j,k))^2\right\}\right]}{\sum_{j=1}^{L_P}\left[\sum_{\substack{k=-N_{used}/2 \\ k\neq 0}}^{N_{used}/2}\left\{I_0(i,j,k)^2+Q_0(i,j,k)^2\right\}\right]} \quad (97)$$

Text Changes

At page 43, Line 42, include the following text:

8.3.10.1.2 Transmitter constellation error and test method

[Modify the second paragraph as indicated, replacing equation 97:]

The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or an equivalent procedure [B29]:

a) Start of frame shall be detected (or start of burst for uplink transmissions).

b) For downlinks, t~~T~~ransition 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 packet shall be de-rotated 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, de-rotate the subcarrier values according to estimated phase, and divide each subcarrier value with a complex estimated channel response coefficient. ~~In the case of subchannelization transmission, the estimated channel coefficient of the nearest allocated subcarrier shall be used for those subcarriers not part of the allocated subchannels.~~

g) For each data-carrying subcarrier, find the closest constellation point and compute the Euclidean distance from it. ~~In the case of subchannelization transmission, for data-carrying subcarriers not part of the allocated subchannels, the Euclidean distance shall be computed relative to 0+0j.~~

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

$$\text{Error}_{RMS} = \sqrt{\frac{1}{N_f}\sum_{i=1}^{N_f}\frac{\sum_{j=1}^{L_P}\left[\sum_{k\in A_{SCI}}\left\{(I(i,j,k)-I_0(i,j,k))^2+(Q(i,j,k)-Q_0(i,j,k))^2\right\}\right]}{\sum_{j=1}^{L_P}\left[\sum_{k\in A_{SCI}}\left\{I_0(i,j,k)^2+Q_0(i,j,k)^2\right\}\right]}} \quad (97)$$

where

L_P is the length of the packet;

N_f is the number of frames for the measurement;

$(I_0(i,j,k), Q_0(i,j,k))$ denotes the ideal symbol point of the i^{th} frame, j^{th} OFDM symbol of the frame, k^{th} subcarrier of the OFDM symbol in the complex plane;

$(I(i,j,k), Q(i,j,k))$ denotes the observed point of the i^{th} frame, j^{th} OFDM symbol of the frame, k^{th} subcarrier of the OFDM symbol in the complex plane;

A_{SCI} is the set of active carriers for the selected subchannel index as specified in Table 213.