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Re:	Response to the call for comments IEEE 802.16-2004/Cor1-D1 Corrigendum to IEEE 802.16-2004
Abstract	Correction of inconsistencies for 802.16-2004 OFDMA
Purpose	Resolving ambiguity in OFDMA PHY layer §8.4
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Correction of inconsistencies for 802.16-2004 OFDMA symbol clock frequency tolerance

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1 Statement of the problem

In section 8.4.14.1 "Center frequency and symbol clock frequency tolerance" of IEEE802.16-2004 it is stated that the symbol clock frequency of the subscriber station (SS) "shall be synchronized to the BS with a tolerance of maximum 2% of the subcarrier spacing". This specification is misleading.

The subcarrier spacing is defined as follows:

$$\Delta f = F_s / N_{FFT}$$

with $F_S = floor(n * BW / 8000) * 8000$

F_s = sampling frequency, n = sampling factor = $8/7$, BW = nominal channel bandwidth

and N_{FFT} = number of points for FFT

In the case of BW = 10 MHz, N_{FFT} = 1024, a subcarrier spacing of

$$\Delta f = floor(n * BW / 8000) * 8000 \div N_{FFT} = 11.156\,\text{kHz}$$

results. Two percent of this value corresponds to 223.1 Hz.

According to this tolerance the SS is allowed to transmit OFDMA symbols with differences in duration as shown in Figure 1 where a Cyclic Prefix (CP) time of 1/4 of the "useful" symbol time is assumed. The symbol time extension by the CP is 1024/4 = 256 samples. The whole symbol is equivalent to 1280 samples that correspond to Ts = 112.044 μsec nominal.

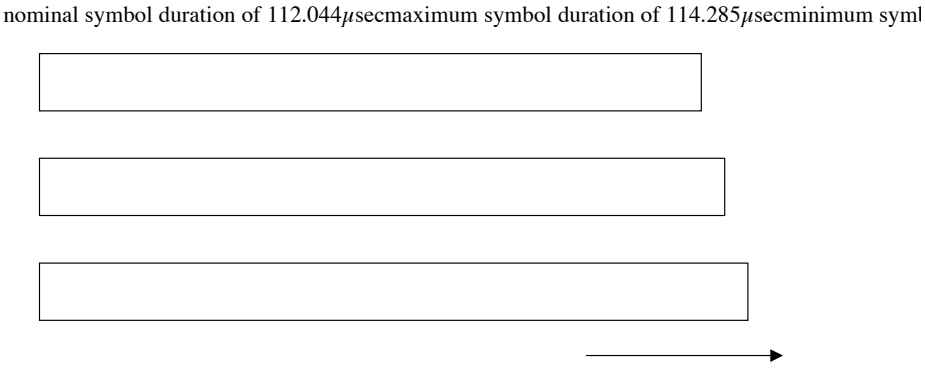

Figure 1: Possible differences in the OFDMA symbol duration

An UL OFDMA symbol with maximum symbol duration of 114.285μsec is 2.241 μsec longer than the expected 1280 samples with nominal 112.044μsec which corresponds to 25.6 samples. A performance degradation in the OFDMA receiver will result.

2 Estimation of the Required Frequency Accuracy

A mismatch of the sampling frequencies of different SSs causes interference between subcarriers due to different subcarrier spacings. Assuming that

- the frequency synchronization removes the frequency offset at the center frequency

- all subcarriers except the distorted one are interferers and have the same sampling frequency offset (worst case scenario)
- the distorted subcarrier is either that with the highest or that with the lowest frequency (worst case due to highest frequency offset at that positions)
- data on different subcarriers are uncorrelated

the worst case signal-to-interference ratio (SIR) due to this sampling frequency mismatch can in good correspondence with simulations be approximated by the expression

$$\mathrm{SIR} = 10\log\frac{24}{\pi^2\delta^2}\ \mathrm{dB}$$

where δ is the absolute sampling frequency error divided by the subcarrier spacing. This relationship is shown in Figure 2.

A tolerance for the sampling clock will be transformed to a symbol clock accuracy. The relation between sampling frequency and OFDM symbol clock ($1/T_s$) is given by the following formula depending on the applied FFT size:

$$\frac{1}{T_S} = \frac{1}{(1+G)\cdot N_{FFT}}\cdot F_S$$

The specified cyclic prefix values G are 1/4, 1/8, 1/16 and 1/32. Worst case for this consideration is the maximum CP duration (G= 1/4) resulting in:

$$\frac{1}{T_S} = \frac{1}{1.25\cdot N_{FFT}}\cdot F_S = \frac{0.8}{N_{FFT}}\cdot F_S$$

As an indication Figure 2 shows the resulting SIR values in function of the tolerance for the sampling clock frequency for a range of values, that still would leave some margin to the SNR requirement of 24.4 dB for 64 QAM.

A symbol clock frequency tolerance of 2 % of the subcarrier spacing on the other hand, as currently required in 802.16-REVd/D5, results due to the above relation between the symbol clock and the sampling clock frequency in a much higher tolerance for the sampling clock frequency. Therefore this requirement on the symbol clock frequency is not sufficient.

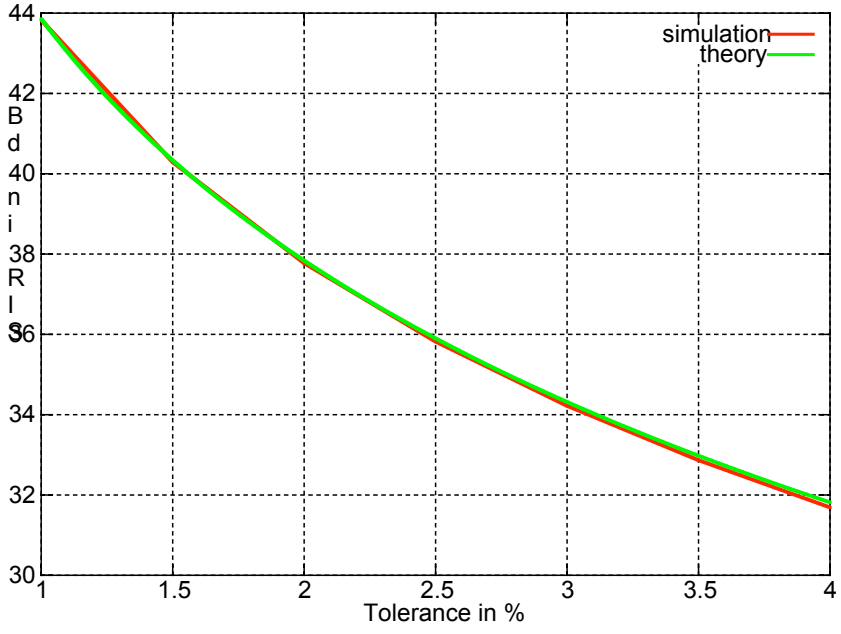

Figure 2: Signal-to-interference ratio (SIR) as a function of the absolute tolerance of the sampling clock F_S in percent of the subcarrier spacing Δf

Even though a tolerance of the symbol clock frequency accuracy derived from the range of values for the sampling clock frequency shown in Figure 2 could be sufficient, there is a more direct means to guarantee a still higher accuracy exploiting the requirement that the symbol clock frequency and the center frequency are derived from a single reference at the BS and thus have a fixed and predefined ratio within the system.

3 Proposed solution

The above inconsistencies could be solved and a sufficient accuracy for the symbol clock frequency at the SS could be achieved by explicitly stating that the accuracy of the symbol clock frequency at the SS is guaranteed by its locking to center frequency at the SS, thereby exploiting the fact that through the requirement, that the symbol clock frequency and the center frequency are derived from a single reference at the BS, they have a fixed and predefined ratio.

4 Specific text changes

8.4.14.1 Center frequency and symbol clock frequency tolerance

add the following text in [1], starting page 119, line 45:

Change the second paragraph in §8.4.14.1 as follows:

At the SS, the transmitted center frequency ~~and the symbol clock frequency~~ shall be synchronized to the BS with a tolerance of maximum 2% of the subcarrier spacing. Additionally the symbol clock frequency at the SS shall be locked to the center frequency at the SS which guarantees a relative tolerance for the symbol clock frequency at the SS of maximum 0.02*(subcarrier spacing)/(center frequency).

5 Reference

[1] working document IEEE 802.16-2004/Cor1-D1, 2005-02-11