Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Evaluation Criteria for 802.16.3 Physical Layer**
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Re:	Response to document 802.16.3-00/09: Invitation to contribute on evaluation criteria.
Abstract	802.16.3 evaluation criteria and impairments models are presented.
Purpose	To aid in the evaluation of competing PHY layer proposals.
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Patent Policy and Procedures	

Evaluation Criteria for 802.16.3

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1. Introduction

In this contribution we propose several evaluation criteria and associated impairments models. The proposal is based, in part, on the parameters and models used by IEEE802.11 Task Group A in the process of selecting a PHY layer for the 5GHz band.

The proposed evaluation parameters can be categorized as follows:

- Overall System Performance: Bit rate, Spectral efficiency, PHY efficiency.
- MAC related parameters: Latency and data granularity, multirate support.
- Performance under noise and interference: Thermal noise, co channel interference adjacent channel interference and alternate channel interference.
- Performance under RF system impairments: Phase noise and power amplifier non-linearity.
- Performance in multipath conditions.

The proposed parameters consider both system performance and implementations issues. Thus, the proposed criteria are relevant to the following PHY characteristics: Modulation, RF propagation and diversity, coding and interleaving and equalization.

To allow a fair comparison of competing PHY proposals, it is recommended that all presented data would in respect to a common set of impairments models. Toward this end, a set of impairments model is proposed. The models are straightforward, simple to simulate and yet allow a realistic performance evaluation. The models support a single parameter evaluation (e.g. single scalar parameter for multipath). This allows an unambiguous comparison result. In addition, the proposed models have the advantage of being endorsed by an independent experts group, namely the 802.11 task group A.

This document serves only as an outline for the evaluation process. An exact definition of the simulation environment and conditions is required.

The evaluation criteria are presented in section 2. The impairments models are discussed in section 3.

2. Evaluation Criteria

2.1. Assumptions

For the rest of this document the following test conditions are assumed:

1. The operating threshold is at a bit error rate (BER) of 10^{-5} after FEC. While different applications may require higher or lower BER levels, the value of 10^{-5} is selected as common requirement.

2. The noise figure (NF) is set at 5dB.

3. The level of power amplifier backoff for which the test results were obtained is specified. See section 3.1 for details.

4. The level of phase noise test results were obtained is specified. See section 3.2 for details.

2.2. Overall Performance

This section provides basic performance and efficiency measures.

Specify the following parameters:

1. Data bit rate after FEC
2. Spectral efficiency in bit/s/Hz, where the occupied spectrum is the channel spacing.
3. PHY overheads per packet.

2.3. MAC related issues

In this section the applicability of the proposed PHY layer to diverse MAC protocol is evaluated.

Specify the following parameters:

1. Decoding latency: The decoding time between the end of arrival of a data fragment at the air interface to the complete decoding of the last bit of information.
2. Data granularity
3. Multirate support: the ability to dynamically change transmission rate in the PHY layer.

2.4. Performance under noise and interference

2.4.1. Performance under AWGN condition

Consider the system operating under additive white gaussian noise conditions.

1. Specify the required input power P_{in} in dBm.
2. Specify the normalized signal to noise ratio per bit E_b/N_0 given by:

$$E_b/N_0 = P_{in}\ [\text{dBm}] - NF\ [\text{dB}] - 10\log_{10}(\text{ bitrate [bit/s]}) + 174[\text{dBm}]$$

Where NF denotes the noise figure of the front end.

2.4.2. Performance under interference

2.4.2.1. Co channel interference

Consider the effect of a like-wise modulated signal at the same frequency channel as the wanted signal. Specify the ratio between the relative and the interfering signal that would cause a BER as specified in 2.1.

2.4.2.2. Adjacent channel interference

Consider the effect of a like-wise modulated signal at the adjacent frequency channel to the wanted signal. Specify the ratio between the relative and the interfering signal that would cause a BER as specified in 2.1.

2.4.2.3. Alternate channel interference

Consider the effect of a like-wise modulated signal at the next to adjacent frequency channel to the wanted signal. Specify the ratio between the relative and the interfering signal that would cause a BER as specified in 2.1.

2.5. Performance under implementation impairments

2.5.1. Power amplifier backoff

Assume the model given in 3.1

2.5.1.1. Effect on in-band distortion

Consider the system operating under AWGN conditions, as described in section 2.4.1. Decrease backoff level (i.e. increase power relative to saturation point) until the BER level is increased to 10^{-4}.

2.5.1.2. Effect on out-of-band distortion

1. Specify the amount of backoff required to meet all relevant regulatory requirements.
2. Specify the amount of out of band distortion for various backoff levels. Out-of-band region is defined as the spectral region where the linear power spectral density drops below 30dB relative to maximum.

2.5.2. Phase Noise

Consider the system operating under AWGN conditions, as described in section 2.4.1. Assume the model given in 3.2. Increase the amount of integrated phase noise until BER level is increased to 10^{-4}.

2.6. Performance under multipath conditions

Consider the channel model given in 3.3.

2.6.1. Ultimate multipath limit

In ideal conditions increase the RMS delay spread until the BER rate reaches 10^{-5}.

2.6.2. Multipath and Noise

1. For a delay spread of 100nSec measure the BER rate vs. E_b/N_0
2. Repeat item 1 for delay spread of 250nSec and 500nSec

3. Impairments models

3.1. Power amplifier non-linearity

The power amplifier model is based on the well-known Rapp's model ([2]) with knee parameter P=2. Besides its simplicity, the model well represents typical power amplifiers at the sub 10GHz range.

Consider using a complex baseband notation. Denote by v_{IN} and v_{OUT} the input and output complex signals, respectively. Let $P_{SAT} = |v_{SAT}|^2$ denote let the saturated power of the amplifier be $P_{SAT} = |v_{SAT}|^2$. Then the relation between v_{IN} and v_{OUT} is given by:

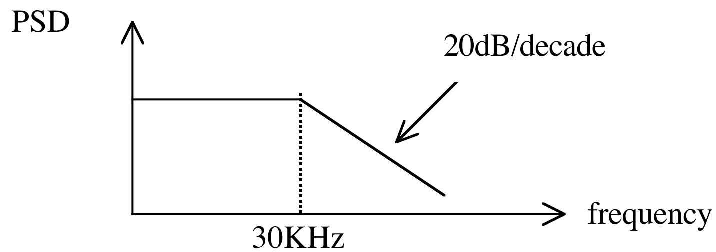
$$v_{OUT} = v_{IN} \Big/ \left(1 + \left(|v_{IN}| / v_{SAT}\right)^{2P}\right)^{1/(2P)}, P = 2 \ .$$

3.2. Phase noise

For the phase noise simplified phase noise model is selected. While maintaining a simple description the model adequately represent the behavior of typical microwave phase-locked loop oscillator.

The phase noise is presented as white gaussian noise process for which is driven through a single pole low pass filter. The 3dB corner of the low-pass should be set at 30KHz, which is a typical value for large step oscillators.

The model ignores the contribution of the oscillator phase noise, which can be easily tracked and the effects of phase noise PSD flattening in high frequencies.



3.3. Multipath

The multipath model is selected to be a Rayleigh fading model with an exponentially decaying power profile. The channel is specified by the RMS of the tap weights. For an exact definition see [1] or [3].

The selected model is simple to analyze and simulate. With a proper choice of delay spread values it represents realistic conditions.

4. References

[1] IEEE802.11a 802.11-98/156r2 "Updated submission template for Tga –revision 2."

[2] Rapp, C. “Effects of HPA non-linearity on 4-DPSK/OFDM Signal for Digital Sound Broadcasting System” *Proceedings of the Second European Conference on Satellite Communications*, Liege Belgium pp.179-184, Oct 22-24 1991.

[3] C. Tellambura, Y.J. Guo and S.K, Barton: Equalizer Performance for HiperLAN Indoor channels”, *Wireless Personal Comuunications vol*. 3, pp. 397-410 Feb. 1996.