

Project	IEEE 802.16 Broadband Wireless Access Working Group < http://ieee802.org/16 >	
Title	Examples of uncoded BER performance for proposed 802.16.3 OFDM Phy layer in Multipath	
Date Submitted	2001-03-11	
Source(s)	[Dr. Robert M. Ward Jr] [SciCom, Inc.] [13863 Millards Ranch Lane] [Poway, Ca. 92064]	Voice: [858.513.4326] Fax: [858.513.4326] mailto:[drbmward@ieee.org]
Re:	IEEE802.16.3-01/8 document. Response to “CALL FOR IMPROVEMENTS AND MERGERS IEEE 802.16 TG 3, Session #12”	
Abstract	Simulated BER results in multiipath are provided. The performance shown is representative of capabilities expected of the proposed OFDM system for TG3. These results are contributed to the Task Group, to support evaluations as the Air Interface is developed.	
Purpose	Proposed PHY system technology is described for consideration by 802.16.3 Task group in the development of its standard.	
Notice	This document has been prepared to assist IEEE 802.16. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.	
Release	The contributor grants a free, irrevocable license to the IEEE to incorporate text contained in this contribution, and any modifications thereof, in the creation of an IEEE Standards publication; to copyright in the IEEE’s name any IEEE Standards publication even though it may include portions of this contribution; and at the IEEE’s sole discretion to permit others to reproduce in whole or in part the resulting IEEE Standards publication. The contributor also acknowledges and accepts that this contribution may be made public by IEEE 802.16.	
Patent Policy and Procedures	<p>The contributor is familiar with the IEEE 802.16 Patent Policy and Procedures (Version 1.0) <http://ieee802.org/16/ipr/patents/policy.html>, including the statement “IEEE standards may include the known use of patent(s), including patent applications, if there is technical justification in the opinion of the standards-developing committee and provided the IEEE receives assurance from the patent holder that it will license applicants under reasonable terms and conditions for the purpose of implementing the standard.”</p> <p>Early disclosure to the Working Group of patent information that might be relevant to the standard is essential to reduce the possibility for delays in the development process and increase the likelihood that the draft publication will be approved for publication. Please notify the Chair <mailto:r.b.marks@ieee.org> as early as possible, in written or electronic form, of any patents (granted or under application) that may cover technology that is under consideration by or has been approved by IEEE 802.16. The Chair will disclose this notification via the IEEE 802.16 web site <http://ieee802.org/16/ipr/patents/notices>.</p>	

SIMULATED BER RESULTS OF PROPOSED OFDM STRUCTURE IN MULTIPATH

Dr. Robert M. Ward Jr.

SciCom, Inc.

Introduction

A flexible OFDM system is under consideration by Task Group 3, Ref 2. FFT size, guard length and QAM modulation are three primary parameters to be considered relative to the multipath channels expected. This contribution describes a simulation in development for these trades and provides preliminary sample BER results for 16 and 64 QAM modulations in the presence of multipath. A 6 Mhz channel is used as reference for this discussion. A framing structure was not assumed. Rather the results presented are for preamble based transmission and burst demodulation.

Simulation overview

A simulation was developed to analyze and trade the effectiveness of suggested OFDM symbol structures versus multipath scenarios, Ref 1. Early results are provided herein. Key parameters included FFT size, guard length, QAM modulation. FFT sizes 64, 256, 512, 1024, and 2048 are supported. Guard lengths can be set as binary fractional ratios: $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, and $\frac{1}{64}$. Available QAM modulations include the expected set BPSK, QPSK, 16QAM, 64 QAM plus optional 32 and 128 QAM.

As shown in Figure 1, an OFDM modulated waveform is generated for a selected configuration. The channel consists of additive white gaussian noise (AWGN) and Multipath as specified in Ref 1. The OFDM demodulator synchronizes to the received waveform and decodes the OFDM constellations. BER comparisons are then made between the transmitted and received data streams.

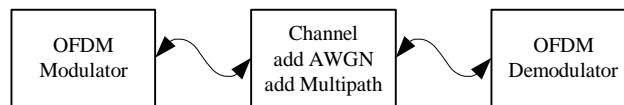


Figure 1: Simulation processes

Simulation Description

All simulations are uncoded at this point. Thus simulations of shorter length can be made and analyzed more quickly. Knowledge of input error rates vs desired output coded rates for the various FECs can be used to determine the operating point ranges for the simulations.

Elements of a standard modulator are shown in Figure 2. A random generator drives a grey coded QAM mapper to generate the 16 and 64 QAM symbols. Mapping of subcarriers is controlled by data and pilot masks to format the subcarriers for loading the IFFT. The IFFT outputs a time domain signal to which a guard of length

$\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, $\frac{1}{64}$ relative to the IFFT size is prepended. At this point, no tapering is performed on the time waveform. The preamble structure is similar to 802.11a, consisting of a short symbol sequence and a long symbol sequence. The short symbol structure can be modified to include more than the ten short symbols that 802.11a has. The long symbols are generated to match the length of the data symbols and the data/pilot masking.

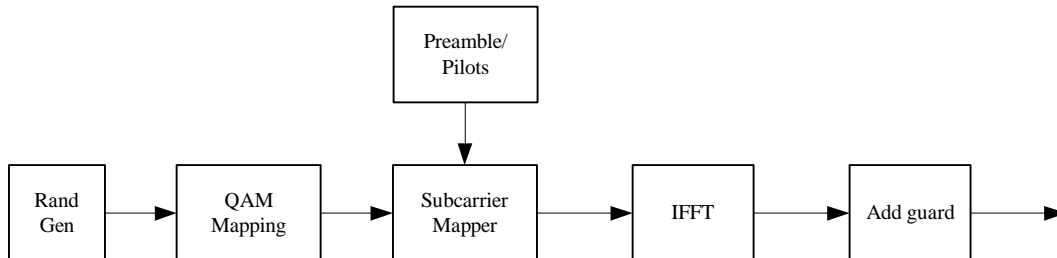


Figure 2: Modulation processes

The channel consists of a standard awgn source and a 3 tap FIR with randomly generated Doppler taps as prescribed by Ref 1. In this paper, only the SUI#1 model is used. For this contribution, a 6 Mhz channel is considered. The longest tap delay of 0.8 usec at the 6 Mhz sample rate is on the order of 4 to 5 taps. Higher sampling rates are used to equivalently represent fractional tap delays. Low pass filtered AWGN sources randomize each tap to match the Doppler rate of 0.4 hz specified. Frequency offsets are not introduced at this point.

Demodulation is a two step process, acquisition and tracking. As stated in the introduction, this simulation uses preamble based transmission and burst demodulation. Better performance can be envisioned if a framing structure, which facilitates tracking, rather than requiring independent burst synchronization, is utilized. Coarse timing is made on short symbols, identical in structure to 802.11a. For longer multipath than 802.11a expects, the number of short symbols can be increased. Frequency estimates can be made easily on the short symbols, but are not at this point since frequency offsets were not made. The long symbols are identified at the end of the short symbols and are normally used to refine the coarse timing and frequency estimates. A conservative approach used at this point, is to rely solely on the timing estimates derived from the short symbol. Later processing of the long symbols will only improve the results shown at this stage. The long symbols are used to provide the channel estimate. As mentioned earlier, the long symbols match the selected FFT size. Thus for the 64 point FFT, the long symbols are 64 points long, and so forth.

Tracking is not performed in this simulation. It has been demonstrated in 802.11a systems that tracking enhances performance considerably. Once again, the inclusion of the tracking processes will only enhance these results.

Results

16/64 QAM vs SUI#1

The configuration of the simulation is as follows

- 64 or 256 point FFT
- 6 Mhz channel
- $\frac{1}{4}$ guard length
- 0.4 doppler of SUI channel
 - K factor = 4
 - 0.4 μ sec tap, -15 db
 - 0.8 μ sec tap, -20 db

Figure one shows the time profile of the zeroth or main tap of the multipath filter. As expected for 0.4 hz Doppler the tap varies slowly. Thus, each preamble detection of the transmitted packet, the multipath was varied typically as shown.

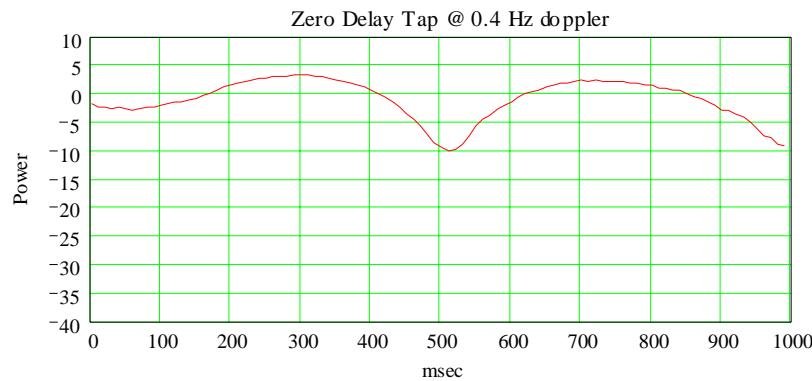


Figure 3: Example doppler

Figure 4 and Figure 5 are BER results of 16 and 64 QAM respectively vs Theory. Good results of approximately 1 db from theory are obtained. Thus a 10^{-3} to 10^{-4} BER operating point can be easily achieved at the output of the QAM decoding. This is sufficient for a concatenated convolutional – Reed Solomon decoding technique to achieve 10^{-6} or better coded output error rate.

It is interesting to note that either the 64 or 256 point FFT performs adequately. This should be expected as the maximum delay of this multipath channel is 0.8 μ sec, which is within either the $\frac{1}{4}$ guard of the 64 or 256 point FFT

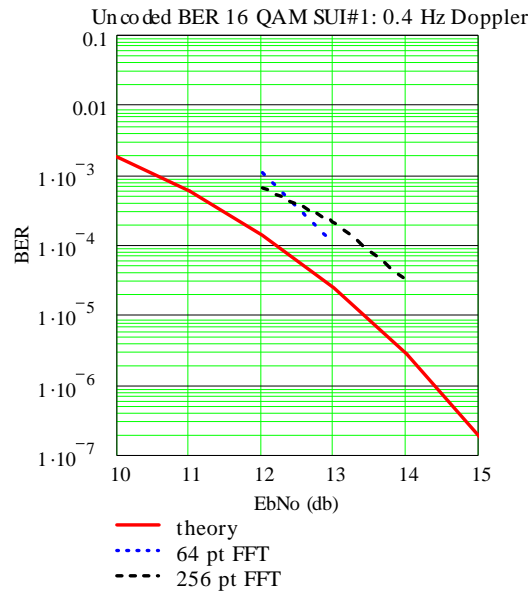


Figure 4: Effect of 64 and 256 point FFT for **16 QAM** vs SUI#1

Results for 64 QAM is shown in Figure 5. Note again that both the 64 and 256 point FFT perform similarly. Figure 6 demonstrates that the guard for the 256 FFT system could be reduced to 1/8 without significant difference in multipath performance in this scenario. An advantage would be reduced overhead.

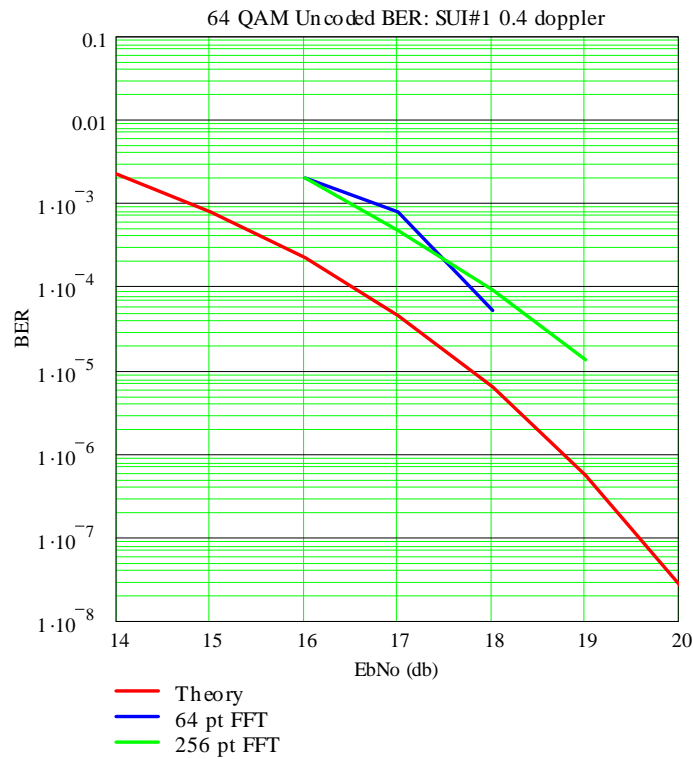


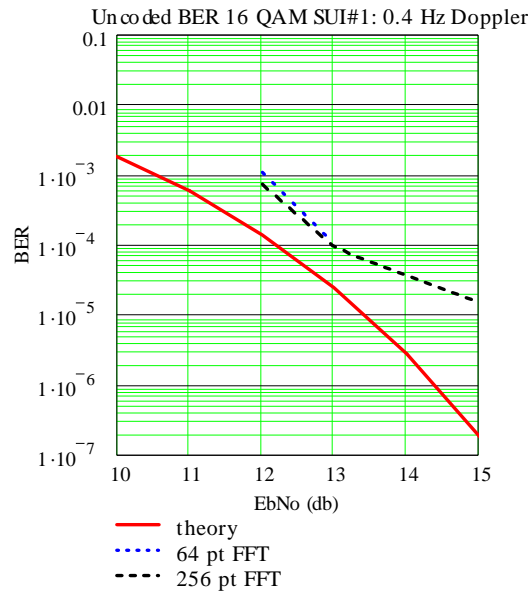
Figure 5: Effect of 64 and 256 point FFT for **64 QAM** vs SUI#1

Figure 6: Reduced guard for 256 point FFT

Other SUI models

Further results will be supplied during the presentation.

Summary

Initial BER results are provided as examples of OFDM performance.

References

Ref 1: 802163c-01_29r1, Channel Models for Fixed Wireless Applications (*final IEEE 802.16 TG3 ad hoc version*); 2001-02-23

Ref 2: IEEE 802.16.3 OFDM PHY proposal for the 802.16.3 PHY layer, March 2001; (Contribution #33)

Use of IEEE-Copyrighted Conference and Journal Papers

802.16 has obtained permission to post IEEE-copyrighted material from IEEE conferences and publications when received in an official contribution to the Working Group. IEEE requires two conditions:

- 1) A full copyright and credit notice must be posted at the top of the paper in the following format:

Copyright ©2000 Institute of Electrical and Electronics Engineers, Inc. Reprinted, with permission, from [all relevant journal info].

This material is posted here with permission of the IEEE. Internal or personal use of this material is permitted. However, permission to reprint/republish this material for advertising or promotional purposes or for creating new collective works for resale or redistribution must be obtained from the IEEE (contact pubs-permissions@ieee.org).

By choosing to view this document, you agree to all provisions of the copyright laws protecting it.

- 2) If the author is not the submitter of the contribution, the author's written approval for the reuse of the material must be attached.