Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Selection Criteria pertinent to Modulation, Equalization, Coding for the for 2-11 GHz Fixed Broadband Wireless Systems**
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Re:	IEEE 802.16.3-00/07r1 document. Response to “802.16.3 Invitation for Contribute” on Evaluation Criteria for the list of Key Characteristics of the Sub-11 Air interface for Session #9.
Abstract	This document presents a list of evaluation criteria by which the Key characteristics that were Established by the 802.16.3 Task Group by the end of Session #8.
Purpose	This contribution will be presented and discussed within the Task Group in Session #9 for Possible adoption for technical assessment of various XXXX.
Notice	
Release	
Patent Policy and Procedures	

Evaluation Criteria pertinent to Modulation, Equalization, Coding for the for 2-11 GHz Fixed Broadband Wireless Systems

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1. Introduction

Key characteristics for the Fixed Broadband Wireless Systems envisioned by the 802.16.3 were stated by the Task Group in Session #8. Modulation, Equalization and Coding are inter-related characteristics in terms of desired performance and implementation complexity. Therefore system rather than independent assessments of these characteristics is needed. In order to facilitate a thorough evaluation of candidate 802.16.3 systems, the following criteria is proposed.

2. Background

A networked system comprising base stations and subscriber stations is envisioned by the 802.16.3 System Model, [Ref 1]. Capacity demand, superior performance, low system costs, operation across 2 – 11 Ghz frequencies, and coexistence/competition with similar and dissimilar systems highlight the challenges facing any successful effort to market this system. Some of these challenges are discussed as background herein to emphasize the interrelationships of the three characteristics, but also the importance of the subsequent criteria.

Figure 1 shows three basic elements for either the base or subscriber station. The Analog Front End (AFE) will provide the RF interface to the channel medium. Baseband Processing (BP) must provide reliable conversion between the waveform layer of the RF channel and information data layer. The MAC layer control will ensure adequate control to access the physical layer, jointly provided by the AFE and BP elements.

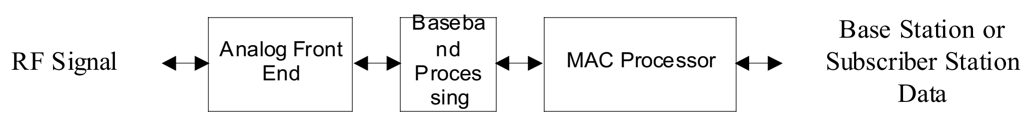

Figure 1: Simplied Processing Diagram

Modulation, Equalization and Coding requirements place direct requirements onto the AFE and BP. Indirectly the MAC layer is affected by phy layer error events on its ability to manage the phy layer efficiently and deliver data services to higher layers. From the perspective of the Mac layer therefore, it is primarily concerned with how reliable digital data can be relayed. Thus, impacts on the Mac Layer can not be totally ignored, however, subsequent discussion will focus on evaluation criteria that is more closely related to Phy layer operation and performance.

It is well understood that modulation, equalization and coding are related. A simple example demonstrates this. One of the specific challenges to successful system operation is the impact of the anticipated multipath environment. Two candidate modulation schemes to be evaluated within this environment are QAM and OFDM. QAM, which is a single carrier modulation technique and includes BPSK or QPSK as reduced constellations, utilizes time domain orthogonality for the independent transmission of data symbols. Because multipath exhibits delay spreads that can be on the order of N symbols, multiple symbols of the QAM waveform are affected jointly, thus compromising reliable demodulation. N symbols of multipath spread can be interpreted as long multipath. Within the QAM signal spectrum, multiple nulls and peaks result. This will introduce significant errors unless equalized. OFDM incorporates a cyclic prefix to provide orthogonal frequency signaling transmission. It has the important additional benefit of providing *inherent* to the waveform, multipath mitigation capability. The same multipath delay spread of N symbols, if less than the cyclic prefix, will not cause “long” multipath effects within the signal bandwidth. Rather the symbol decision device of the OFDM receiver would be confronted with “short” multipath. On the spectrum display, a single null or peak within the signal bandwidth would be exhibited. Short multipath may be considered to be less demanding than long multipath to compensate for. In either short or long multipath, as long as it is not too severe, the error effects can be controlled via equalization, coding or by both. However, by this simple argument, the system designer could expect the error control processing (using either equalization, coding or both) to be simpler in the OFDM case since the signal spectrum is less damaged. Thus, the system complexity/performance product typically favors the OFDM system over the QAM system.

CDMA is another potential modulation scheme. Not only does CDMA offer opportunities for multiple access, but its code division properties can also be exploited by jointly despreading to help mitigate multipath effects. Thus, less demand is again placed on the equalization and/or coding techniques to recover from the induced multipath errors. CDMA may also aid system planning by allocation of different codes to adjacent cells in the network. This would alleviate interference across cell boundaries. Neither the QAM or OFDM schemes have this inherent advantage

3. Criteria

Proposed criteria to support consideration of these three key characteristics are bulletized for expediency. Indented bullets are to help clarify the criteria of the prior bullet. It is expected that criteria listed below can be utilized as rows of a comparison matrix vs candidate system architectures, comprised of combined modulation, equalization,/coding techniques.

<u>Modulation</u>

- Multipath model
  - Delay spread
  - null depths
  - NLOS
- Inherent waveform multipath protection
  - signal robustess without equalization or coding
  - degree to which equalization and/or coding/interleaving is reduced
- Impact on Equalization technique
  - time vs frequency domain processing required
  - Added complexity required for waveform to mitigate multipath
- Impact on Coding/Interleaving
  - Inherent relationship such as with TCM
  - Soft vs Hard interface
  - Erasure capability
- Spectrum Utilization
  - bits/hz
  - rate flexibility
  - Occupied Bandwidth
  - Pulse shaping
  - Stop band requirements
- Synchronization

  - Frequency
  - Timing
  - Preamble vs blind
- Interference Resistance
  - Adjacent cells/zones/system
  - Coexistence
- Linearity
  - Backoff
  - Clipping
- Processing Complexity
  - Multiplies per unit time
  - Loop interaction/susceptibilities

Equalization

- Processing technique
  - Frequency or Time domain
- Modulation interface
  - Incorporation of decision slicer within equalizer architecture
- Coding Interface
  - Erasure support
  - Soft decisioning
- Latency
- Complexity expected
  - Architectures (FFE, DFE, Hybrid, block)
  - Acquisition algorithm
  - Tracking algorithm/rate
  - Span
  - Tap spacing
- Performance
  - Depth of nulls countered
  - Number of nulls

Coding/Interleaving

- Interleaving depth
- Architecture
  - Soft vs Hard interface with demodulator
  - Convolutional, Block, Turbo
  - Coding rates
  - Memory
- Programmability
- Performance
  - Latency

- Coding Gain
- Speed
- Bandwidth expansion

4. References

Ref 1: 802163-00_02r3, "Functional Requirements for the 802.16.3 Interoperability Standard"