Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee8O2.org/16>**
Title	OVERVIEW OF PHYSICAL LAYER PROPOSAL FOR IEEE 802.16.3
Date	2001-1-22
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Re:	In response to an Invitation to Contribute Phy Layer Proposal (2000-12-02)
Abstract	A brief summary of a physical layer proposal based on space-time coded OFDM with QPSK subcarrier modulation.
Purpose	Discussion and development of 802.16.3 BWA PHY.
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OVERVIEW OF PHYSICAL LAYER PROPOSAL FOR IEEE 802.16.3

Introduction

This document provides a summary description of the proposed physical layer (PHY) for the IEEE 802.16.3 Broadband Fixed Wireless Access standard under development for licensed frequency bands in the range from 2-11 GHz.

The key features of proposed PHY include the following:

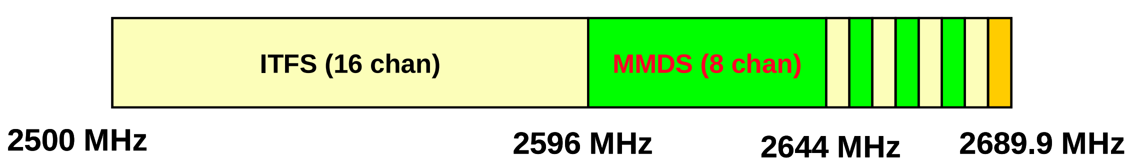
- OFDM + QPSK subcarrier modulation (8-PSK and QAM modulation can be introduced. Efficacy will depend on traffic distribution and rf channel conditions).
- TDD multiplexing for MMDS bands, FDD supported if permitted by band plan.
- Adaptive space-time channel codes exploiting MIMO transceivers
- Automatic repeat request (ARQ)

This set of innovative features meets the requirements of the 802.16.3 FRD. Whereas existing supercell concepts provide only line-of-sight (LOS) coverage with limited capacity and availability, and highly sectored solutions are impractical due to propagation environment and non-uniform subscriber distribution, the STC-OFDM approach provides high system capacity in non-LOS, multi-cellular environments through the use of combined coding and modulation that is robust with respect to fading and multipath interference. While other proposed schemes, such as VOFDM, utilize diversity as a mechanism to mitigate the effects of fading, STC-OFDM exploits the slow fading channel to achieve higher system capacity (bps/Hz/cell).

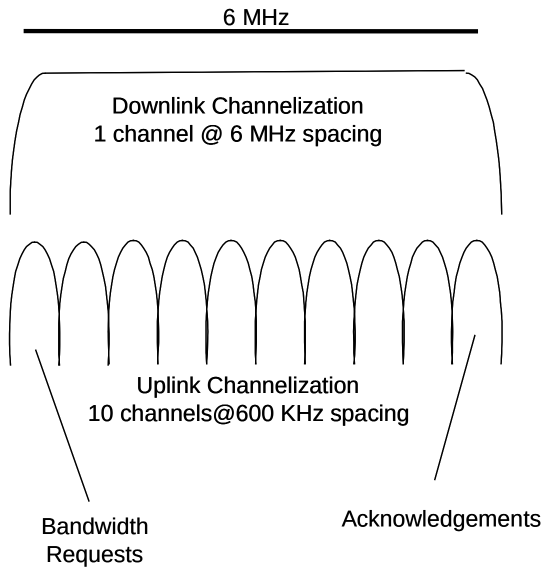
Although a specific STC-OFDM scheme is described in this submission, it is clear that the STCs themselves have broader appeal. STCs can provide the same sort of improvements (system capacity and fading robustness) for virtually any of the OFDM schemes presented to 802.16. At a minimum, the STC portion of this proposal should be considered independently as an adjunct or enhancement to any of the OFDM proposals.

Channelization

In the U.S., the band 2596 MHz - 2686 MHz is allocated for MMDS application, with the frequencies above 2644 MHz in this band interlaced with ITFS. Each of the MMDS and ITFS channels are 6 MHz wide.



For this frequency allocation, the following strawman frequency plan is proposed for TDD operation.



The narrower Uplink Channel reduces transmit power, but still provides sufficient data rate. Frequency slots on the uplink channel may be dedicated for bandwidth requests and / or acknowledgements.

Modulation

The proposed modulation scheme is conventional OFDM with QPSK subcarrier modulation. Pilot symbols are used to facilitate coherent demodulation.

Note that, while higher-order QAM could be supported on the subcarriers, space-time channel coding provides sufficiently high throughput with QPSK modulation. The choice of QPSK is advantageous since high-order modulation is more sensitive to multipath and other impairments. This simplifies design of the transmitter and receivers. If, on the other hand, higher-order QAM is required to meet customer needs, STCs can be designed to provide gains similar to those achieved with QPSK.

Space-Time Channel Codes

Space-time channel codes exploit the enhanced capacity of Multiple Input/Multiple Output (MIMO) communication systems over fading channels. In order to minimize system complexity, especially with regard to the CPE, the space-time channel coding scheme is selected for a relatively small number of transmit and receive antennas, which may be different at the user terminal and base station.

For reference, we assume 2 transmit/2 receive antennas at user terminal and 4 transmit/4 receive antennas at base station. The channel code is a rate 1/2 trellis-based space-time code (64-state) that provides the user terminal with effective diversity between 3 and 6. Space-time coding can be adaptive by trading diversity for throughput and is compatible as the inner code in a concatenated coding scheme (e.g. with a Reed-Solomon outer code).

Space-time codes have significant advantages when the information rate required is higher than the bandwidth. In Table 1, using four TX and two RX antennas, the ability to transmit 20 Mbps over 6 MHz in a Rayleigh fading channel at a C/I consistent with a reuse environment makes it the only viable solution for MMDS applications.

For these results, a frame size of 256 information bits was used, and the target word error rate was 1%. The STC+OFDM advantage is expected to increase for smaller frame error rates.

High efficiency, fast response and low end-to-end error rate achieved through fast acting ARQ with optimized frame size. Note that, in slow fading channels, ARQ should work

System	**Peak Downlink Information Rate (Mbps)**		
	5	***10***	***20***
Hughes STC+OFDM	2 dB	8 dB	13 dB
Conventional OFDM	6 dB	12 dB	24 dB

better for STC than conventional OFDM due to higher diversity levels.

Table 1: STC-OFDM Gain over OFDM-Only Implementation

Threaded STCs – Comparison to other MIMO Schemes (without OFDM)

The STC approach described in this proposal was developed by A. R. Hammons and Hesham El Gamal of Hughes Network Systems. These particular STCs compare favorably to other MIMO approaches for the slow-fading Rayleigh channel. In Figure 1, the absolute (non-comparative) SNR performance is given for 4 Tx antennas, 2 Rx antennas, QPSK modulation and an information throughput of 4 bits / symbol. At a typical FER performance threshold of 1%, the required CNR is 13.5 dB.

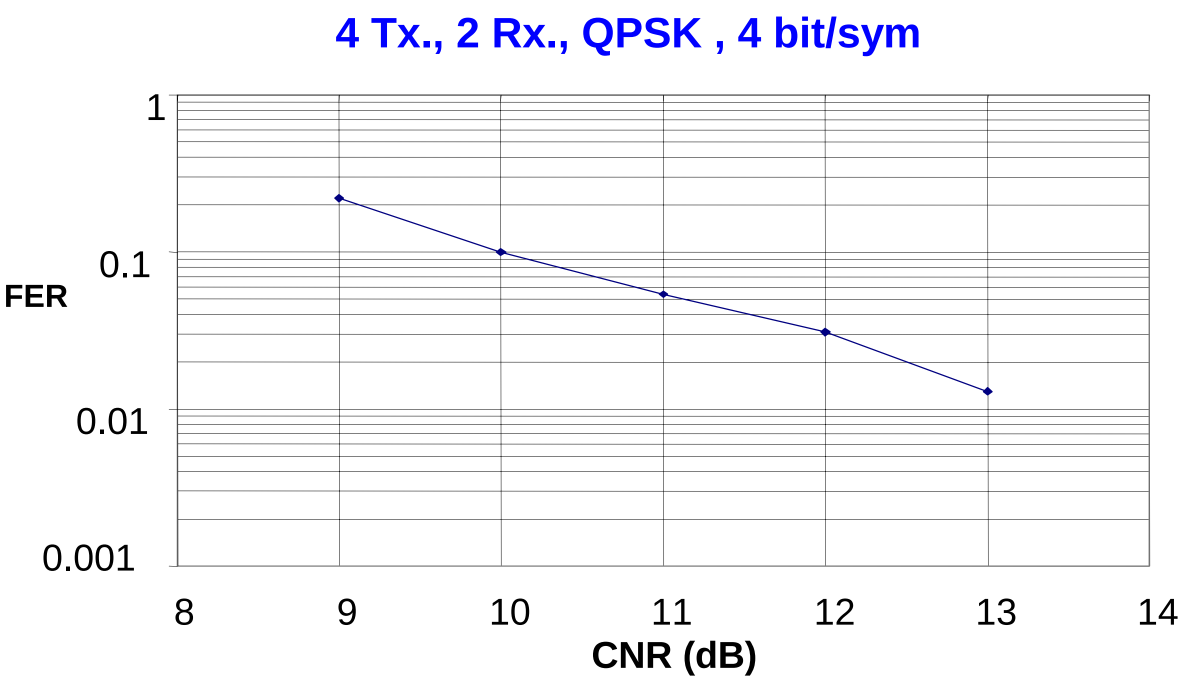


Figure 1: Hughes STC Performance

In the following figures, Hughes STCs are compared to AT&T's Group Suppression scheme. In Figure 2, the FER performance is depicted for a fixed throughput of 4 bits/symbol. The Hughes STC has a 4 dB advantage over AT&T's group suppression. An equal performance comparison is shown in Figure 3. Although these two approaches have about the same FER performance, the Hughes scheme provides 50% more throughput.

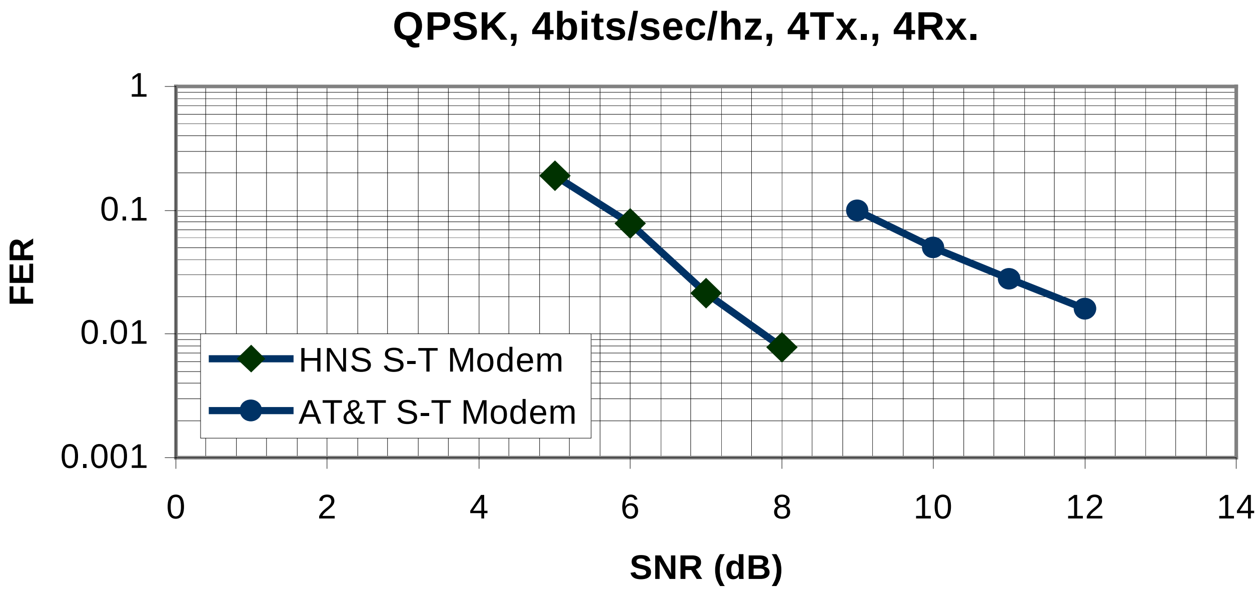


Figure 2: Equal Throughput Comparison – Hughes STC vs. AT&T Group Supression

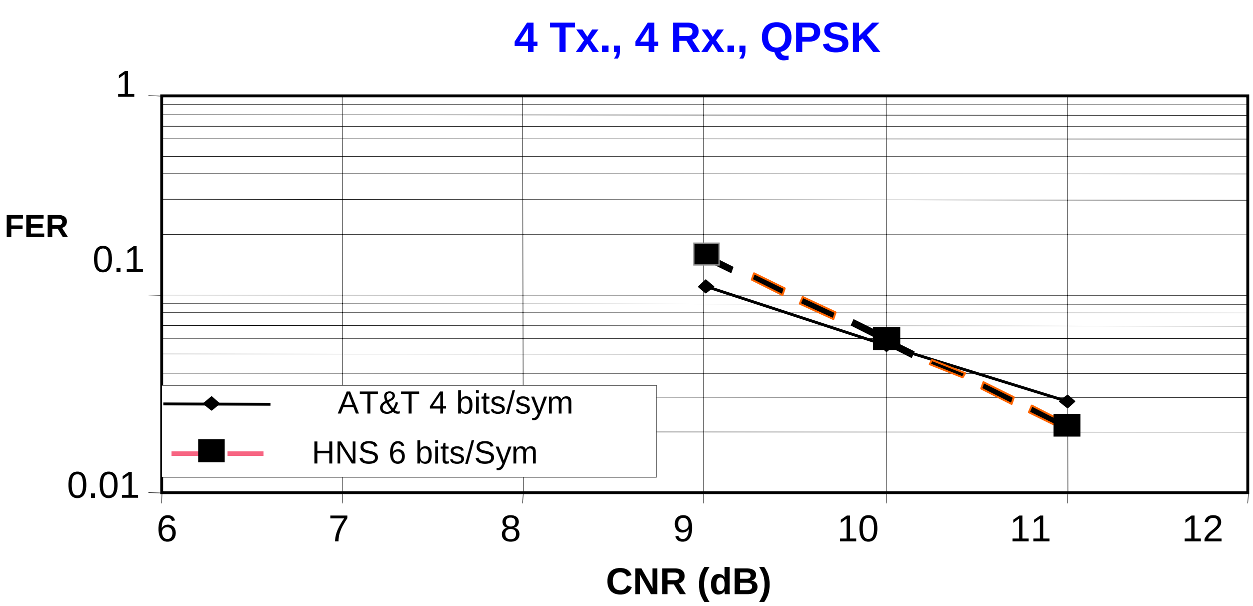


Figure 3: Equal Performance Comparison – Hughes STC vs. ATT Group Supression

Capacity

Per-cell capacity depends on Uplink / Downlink multiplexing / allocation, and the sectorization / reuse plan.

A conventional 1x3 reuse pattern is supportable with practical subscriber unit antennas. In this case, a 3:1 allocation of capacity between downlink and uplink in the TDD mode achieves 2.5 bps/Hz/cell. Tighter reuse pattern using dual polarization and 4-sectors/cell requires only two 6 MHz frequencies.

In an FDD mode, the per-cell capacity for the downlink is even higher (3.3 bps/Hz/cell for 3:1 reuse, 6.7 bps/Hz/cell for dual polarization, 4 sector/cell).