Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Comparison of QPSK/QAM OFDM and Spread Spectrum for the 2-11 GHz PMP BWAS**
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Re:	In response to the Call For Contributions, by IEEE 802.16.3-00/07r1
Abstract	One of the key characteristics of the 802.16.3.Standard is modulation. This contribution compares the advantages/disadvantages of Single Carrier QPSK/QAM, OFDM, or Spread Spectrum signaling techniques for the 2 to 11 GHz bands PMP Fixed Broadband Wireless Access Systems', and based on this analysis and actual experience with PMP Fixed BWAS bands proposes that QPSK/QAM be used in the proposed 802.16.3 Standard.
Purpose	The Task Group 3 should specify that Single Carrier QPSK/QAM be used for the proposed 802.16.3 Standard as is currently specified for the 802.16.1.and ETSI BRAN Hiperaccess
Notice	
Release	
Patent Policy and Procedures	

Comparison of QPSK/QAM, OFDM, and Spread Spectrum for 5GHz PMP BWAS

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Introduction

One of the key characteristics of the 802.16.3.Standard is modulation. This paper presents a comparison of three modulation choices for broadband wireless access systems: single-carrier QPSK/QAM, OFDM and Spread Spectrum.

Single-carrier QPSK/QAM

Single-carrier QPSK/QAM is proven technology. Time-division systems (as opposed to spread spectrum) can provide fast, dynamic capacity allocation, which is ideal for statistical multiplexing of bursty sources [1]. For many users, web-browsing demands high downstream data rates, and low upstream data rates (asymmetrical capacity). However, small businesses may demand symmetrical capacity in both directions, or perhaps even a higher upstream capacity for web-hosting. This means that dynamic allocation of the downstream and upstream capacity is very important.

One problem with single-carrier systems is that in severe multipath channels, an adaptive equalizer is needed, requiring intensive processing at high data rates [2]. However, for line-of-sight (LOS) BWA systems with directional antennas, only a short equalizer of not more than 8 feedforward taps would be required. This is reasonably easy to achieve with current processors. Another problem with single carrier systems operating is susceptibility to interference. In order to solve this problem, some form of dynamic frequency selection (DFS) will be required.

Single-Carrier QPSK / QAM	
Advantages	Disadvantages
1.High bit rates, proven technology, chosen by 802.16.1 and ETSI BRAN Hiperaccess	1. Susceptible to multipath interference (needs an equalizer)
2. Efficient, dynamic capacity allocation for bursty sources.	2. Susceptible to interference (needs interference avoidance technique)

OFDM

Orthogonal frequency division multiplexing (OFDM) is a type of multicarrier modulation. OFDM uses overlapped orthogonal signals to divide a frequency-selective channel into a number of narrowband flat-fading channels. Instead of transmitting the data symbols sequentially at a high symbol rate on a single carrier, a block of symbols is encoded using the Fast Fourier Transform (FFT), and transmitted in parallel over a number of subchannels. The subchannels are spaced by the inverse of the symbol time, so making them orthogonal. Individual subchannels will have a symbol period longer than the multipath delay spread, and so OFDM is useful for avoiding multipath interference. If a particular subchannel has high noise or interference, then it can be deactivated, so reducing the effects of fading and interference.

OFDM technology is still under development, and there are a number of problems to be solved. Firstly, the guard bands and cyclic prefix reduce data throughput. Frequency offsets between transmitter and receiver must be removed with automatic frequency control (AFC), otherwise the subcarriers will no longer be orthogonal. Synchronization of multicarrier schemes is more difficult than single carrier because there may be hundreds of samples per multicarrier symbol. Finally, because there are a large number of subcarriers, the combined signal has a very large peak-to-average power ratio (PAPR), and to maintain linearity over this range, the power amplifier (PA) requires back-off by as much as 10dB. OFDM is very attractive for mobile radio transmission where multipath interference is severe. It is shown in [3], [4] that the BER performance of an OFDM system is very similar to that of a single-carrier system. OFDM performance can be improved through the use of channel coding and PAPR reduction techniques (although this introduces more complexity).

OFDM	
Advantages	Disadvantages
1. Mitigates multipath	1. High complexity and deployment costs
	2. Guard bands reduce efficiency
	3. Frequency offsets require accurate AFC
	4. Synchronization is difficult
	5. High peak-to-average power ratio requires PA back-off

Spread Spectrum

Spread spectrum is divided into 2 groups: frequency hopping spread spectrum (FHSS), and direct sequence spread spectrum (DSSS) (also known as CDMA). Spread spectrum (both FHSS and DSSS) is proposed in IEEE802.11(b), for bit rates up to 11Mbps. In the USA, radios operating in the 2.45GHz ISM band are required to use spread spectrum if their transmit power exceeds 0dBm.

Spread spectrum systems simplify frequency planning, because additional users can be added in an ad-hoc manner, with only a small degradation in signal quality as the number of users increases. Spread spectrum gives high immunity to interference, and this is particularly important in the unlicensed frequency bands. The major problem with spread spectrum is that data rates higher than about 10Mbps are difficult to achieve due to the large bandwidth and processing needed [1], [2]. It is possible for DSSS systems to co-exist with single-carrier TDMA systems, providing that notch filters are used by both systems to remove interference. DSSS systems may use a RAKE receiver to improve performance in the presence of multipath propagation, although this adds extra complexity.

FHSS	
Advantages	Disadvantages
1. Simple frequency planning	1. Low bit rates
2. Good interference rejection	
3. Low-power, low-cost radios	

DSSS	
Advantages	Disadvantages
1. Simple frequency planning	1. Medium bit rates (up to 11Mbps)
2. Good interference rejection	
3. Very low access delay	

Proposal

Considering the above analysis, a single-carrier QPSK/QAM system is recommended, due to its high efficiency in dynamically allocating capacity. QPSK/QAM systems are simple to implement and have the lowest peak-to-average power ratio, requiring minimal PA back-off. QPSK/QAM use a proven technology and is the technology that has been chosen by both 802.16.1 and ETSI BRAN Hiperaccess. For fixed directional antennas, equalization can be easily performed [1]. Interference avoidance can be achieved with Dynamic Frequency Selection (DFS) techniques.

References

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