Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**OFDMA advantages for the 802.16b**
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Re:	TG4 process of defining the PHY layer.
Abstract	This document contains a summary of the advantages OFDMA modulation has for the 802.16b system performance.
Purpose	This proposal should be used for the PHY specification of the 802.16b
Notice	
Release	
Patent Policy and Procedures	

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OFDMA Advantages for 802.16b system

1 Introduction

The 802.16b is designed to work in the unlicensed frequency bands of 5-6 GHz (but will be applicable to license exempt 2-11GHz where possible), using channel bandwidths of 10, 20MHz (while 5MHZ is optional).

In the past the 802.16b PHY study group has voted for several FFT sizes for the system using different access methods (OFDM/OFDMA), there si currently a consensus that these selection could be improved. The PHY is based on OFDM (Orthogonal Frequency Division Multiplex) modulation, supporting both TDMA and optionally OFDMA Orthogonal Frequency Division Multiple Access. In OFDM the information is imposed onto the medium by modulating multiple carriers transmitted in parallel. In TDMA, all carriers of an OFDM symbol are assigned to one transmitter. In OFDMA the carriers are divided into Sub-Channels. When the OFDMA concept is applied to the uplink, it allows users to operate with smaller power amplifiers, at expense of instantaneous data rate. On the other hand it allows allocating dynamically larger amounts of bandwidth to users capable of utilizing it in terms of their link budget. When applied to the downlink, OFDMA allows transmitting to multiple users in parallel with designated data streams, and allows improving the link budget of disadvantaged users by allocating to their Sub-Channels a larger fraction of their downlink transmit power.

The carrier spacing in frequency is dictated by the multipath characteristics of the channels in which the FWA system is designated to operate. As the channel propagation characteristics depend on the topography of the area and on the cell radius, the amount of carriers and the size of the FFT should be increased, or the bandwidth should be decreased. As the modulation is implemented using the FFT algorithm, the modes are designated by the FFT sizes 64, 256 (low sizes) or 2048 (hi size). Another parameter controlling the multipath mitigation capability, at expense of overhead, is the time-domain guard interval . The size of the guard interval is programmable in the diapason of 1/32 up to 1/4 of the FFT interval duration.

In this document arguments for the advantage of the 2048 FFT, OFDMA mode are given, and benefits for the 802.16b system is given.

2 Supported FFT and Guard Interval (GI) lengths

Both down stream and up stream are defined to accommodate several FFT lengths. Using several FFT sizes is an essential tool to trade off multipath mitigation and channel signal variation rate. Large FFT sizes are used to combat channels that suffer long multipath delays; short FFT's could be used for short-range systems, which suffer fewer multipaths. The Guard Interval (GI) size (in percentage) is responsible to this channel multipath handling on the expense of throughput reduction. The next table summarizes, for several channel bandwidths, the GI duration for different FFT sizes (which determines the excess delay spread handled, the delay spread is about 1/4 of the excess delay spread, this parameter could reach few usec – we will take into consideration only 2.5usec):

GI \ FFT size	64		256		2048	
	10 MHz	20 MHz	10 MHz	20 MHz	10 MHz	20 MHz
1/32	N.A.	N.A.	*0.8usec	*0.4usec	*5.6usec	2.8usec
1/16	N.A.	N.A.	*1.6usec	*0.8usec	11.2usec	*5.6usec
1/8	*0.8usec	*0.4usec	*3.2usec	*1.6usec	22.4usec	11.2usec
1/4	*1.6usec	*0.8usec	*6.4usec	*3.2usec	44.8usec	22.4usec

* Not recommended for these multipath channels

Another advantage of larger FFT size is the better spectral shape of the emitted signal. When using the 2k mode the spectral mask is lowered about 15dB then that of the 64 mode. This will allow better coexistence between systems and cleaner spectrum. An example of the shaping is taken from [1] and presented hereafter:

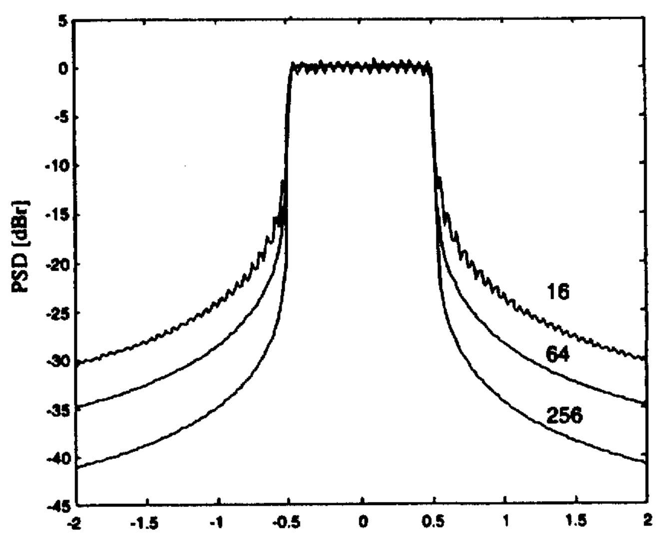


Figure 1: spectrum of OFDM symbol with using different FFT sizes

Figure 1 illustrates the decay of the OFDM symbol when using different sizes of FFT.

3 Power Concentration and Adaptive Power Control

The OFDMA access in the downlink and uplink has many advantages. The biggest advantage beside the long symbol duration is the power concentration it enables. The power concentration is achieved due to power emission only on the Sub-Channels allocated. Therefore the energy of the user is transmitted only on selected carriers and not on all-useable carries. By this technique users and Base Station can manipulate the amount of energy putted on different Sub-Channels. This power concentration can add up to **15dBb** per carrier when transmitting from the user, Comparing the power that could be emitted on all the bandwidth, for one Sub-Channel using 53 carriers, combined with a Backward APC (Automatic Power control) will give the optimum performance.

The Base Station can also regulate the amount of power on the different Sub-Channels and reach as much as 6dB concentrations gain. This technique is referred to as Forward APC (Automatic Power control), and is used in order to regulate the power to the users on the down stream.

This power concentration leads to several advantages:

- Better coverage
- Enable a larger APC range which is vital for larger cells
- Excellent Reuse factor
- Better channel availability
- Can use simpler and cheaper PA
- Can have better SNR for a transmitted signal
- Reach the distances specified for the system (better distances with the same EIRP).

Anti jamming advantages

As for example if we shall compute the radius of the system cell using the following parameters:

- 20MHZ channel Bandwidth
- 16QAM modulation
- One Sub-Channel transmission
- Receiver NF=4dB
- Assuming power emission of 30dBm
- Using a 30° antenna at the SS and 60° at the BS
- Simple propagation model for LOS and NLOS

Using the Channel model [8] for Sub-Urban model, we get the following results (for Urban areas the results are much worse, and the validation of the standard is in question):

64 OFDM: ~2.5Km for LOS, ~300m for NLOS

2k OFDMA: 14.5Km for LOS, ~715m for NLOS

As we can see the advantages of the OFDMA system are tremendous.

4 Co-Existence

For Co-Existence issues, only issues where OFDMA gives more advantages then the regular techniques that can be used are given. Techniques as DFS and frequency management are not elaborated because they are common to all FFT sizes.

4.1 Operation in presence of interference

The interference in the MAN environment can be categorized into:

- Narrow band jamming

- Partial band jamming
- Pulse jamming
- Other operating system jamming and coexistence with IEEE802.11a, HiperLAN2.

4.1.1 Narrow band jamming

Narrow band jamming can be treated by:

- Using time shaping on the symbol and then equalization (the more FFT points used the better the shape is)
- Using jamming detection and then a smart ECC, which can erase bad symbols.

In any case when using large FFT sizes (especially in OFDMA), jammers at the base station are more effectively suppressed (due to the FFT filtering) and destroys less carriers (in percentage sense) then for small FFT size.

4.1.2 Partial band jamming

Detecting bad symbol can treat partial band jamming, which allow the usage of smart ECC, which can erase bad symbols. The OFDMA (2k mode) has a 15dB “processing gain” against wide band jammers or other 802.11a, HiperLAN2 interferers.

4.1.3 Pulse jamming

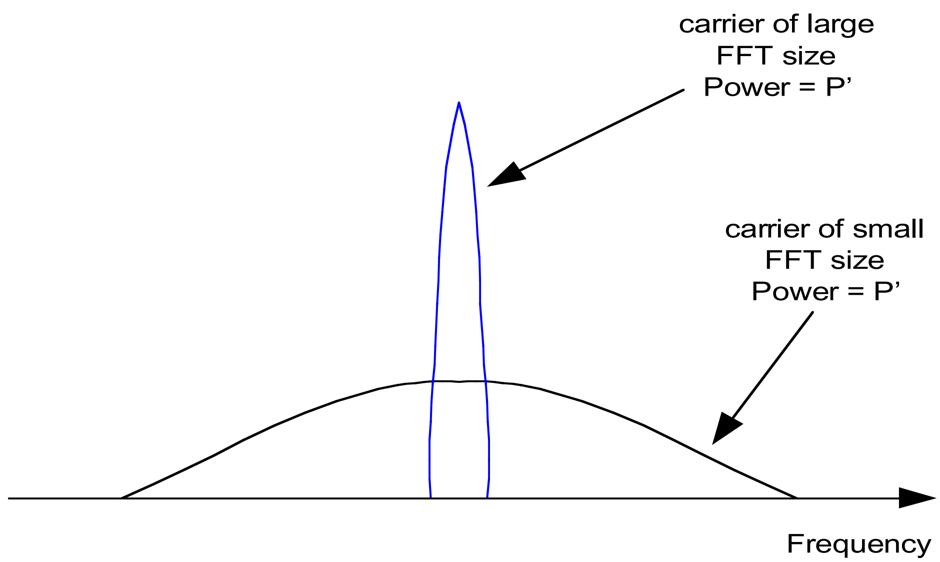
Short time interference can be sold by time interleaving the data. The usage of the Sub-Channel notion enables time interleaving of the Sub-Channel over time, the small packet length enables easy time interleaving and better statistical multiplexing.

4.1.4 Other operating system jamming and coexistence with IEEE802.11a, HiperLAN2

Best coexistence between the 802.16b PHY and the IEEE802.11a, HiperLAN2 will occur when using large FFT sizes for 802.16b. When using large FFT size the carrier bandwidth is about 10KHz (compared to more then 300KHz for 64 FFT size). This bandwidth difference gains us a “processing gain” of 15dB in total.

Furthermore the FFT which is a filter help decreasing the all around interference by at least 13dB, when considering all the above in a scenario where both system are to work with the same power emittion the TG4 has a 28dB advantage in jamming rejection of the IEEE802.1a, HiperLAN2 signal. When using smaller FFT sizes the advantage decrease.

The following figure illustrates this scheme:



The figure illustrates the advantage when performing the large FFT over the small size FFT, where:

- for the large size FFT we get $\frac{S}{N} = {OFDMA}/{802.11a - Jammer} = 15dB$
- for the small size FFT we get $\frac{S}{N} = {802.11a}/{OFDMA - Jammer} = 0dB$

4.1.5 Other jamming rejection or Coexistence tools

There are more ways to have two systems work together without interfering one another:

- The usage of directive antennas
- The usage of adaptive array and null steering

Both are antenna-based techniques, which can remove or help prevent interferences.

5 Conclusions

In the document we gave several explanations on how OFDMA improves the 802.16b system. We believe that the mandatory and optional modes today should be redefined to allow fast time to market (by using existing hardware), ease of implementation and the power of OFDMA.

We would like to make all three FFT modes as mandatory to the 802.16b, while implementing one mode will be standard compliant.

6 References

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[3] Richard V. Nee and Ramjee Prasad, OFDM for wireless multimedia communicatons , Artech House Publishers,2000.

[4] 802163c-00_33 – Initial OFDM/OFDMA PHY proposal for the 802.16.3 BWA

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[7] EN301-958 — DVB-RCT draft standard

[8] 802.16.3c-01/29r1 — Channel model for fixed wireless applications