

Project	<b>IEEE 802.16 Broadband Wireless Access Working Group</b> < <a href="http://ieee802.org/16">http://ieee802.org/16</a> >		
Title	<b>A Mixed OFDM Downlink and Single Carrier Uplink for the 2-11 GHz Licensed Bands</b>		
Date Submitted	<b>2002-08-30</b>		
Source(s)	Moshe Ran, MostlyTek Ltd	Voice: +972-8-9263369 Fax: +972-8-9265129 <a href="mailto:ranmoshe@bezeqint.net">ranmoshe@bezeqint.net</a>	
	David Falconer, Carleton University	Voice: +1 613 520-5722 Fax: +1 613 520-5727 <a href="mailto:ddf@sce.carleton.ca">ddf@sce.carleton.ca</a>	
	Anader Benjamin-Seeyar, AdvantechAMT Inc.	Voice: +(514) 420-0045 (ext.207) <a href="mailto:Anader.Benyamin@AdvantechAMT.com">Anader.Benyamin@AdvantechAMT.com</a>	
Re:	This is a remark for IEEE LMSC Sponsor Ballot of P802.16a/D5 6 August - 4 September 2002		
Abstract	This contribution proposes that the draft standard allow simultaneous use of <i>both</i> the existing OFDM and single carrier modes; i.e. OFDM in the downlink, and single carrier in the uplink. It briefly discusses the advantages and the implications of this arrangement.		
Purpose	Amendment of the current draft to allow a mixed OFDM and SCa compliance of a system with IEEE802.16a for 2-11 GHz licensed bands.		
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# A Mixed OFDM Downlink and Single Carrier Uplink for the 2-11 GHz Licensed Bands

*Moshe Ran*

*MostlyTek Ltd, RE'UT, Israel*

Email: [ranmoshe@bezeqint.net](mailto:ranmoshe@bezeqint.net)

*David Falconer,*

Broadband Communications and Wireless Systems Centre

Dept. of Systems and computer Engineering

Carleton University, Ottawa, Ontario, Canada K1S 5B6

Email: [ddf@sce.carleton.ca](mailto:ddf@sce.carleton.ca)

*Anader Benjamin Seeyar*

AdvantechAMT Inc

Email: [Anader.Benyamin@AdvantechAMT.com](mailto:Anader.Benyamin@AdvantechAMT.com)

## Introduction

The current draft P802.16a/D5 underlies the existence of OFDM and Single Carrier physical layers as two separate and standalone compliant modes for the licensed bands between 2 to 11 GHz. The purpose of this note is to introduce the benefits and the implications of having a mixed mode of OFDM Downlink and Single Carrier with Frequency Domain Equalization (SC-FDE) Uplink; each of them is strictly compatible with the current available OFDM and SC-FDE modes. We are not proposing a new mode, but rather an integration of the existing OFDM and the single carrier modes.

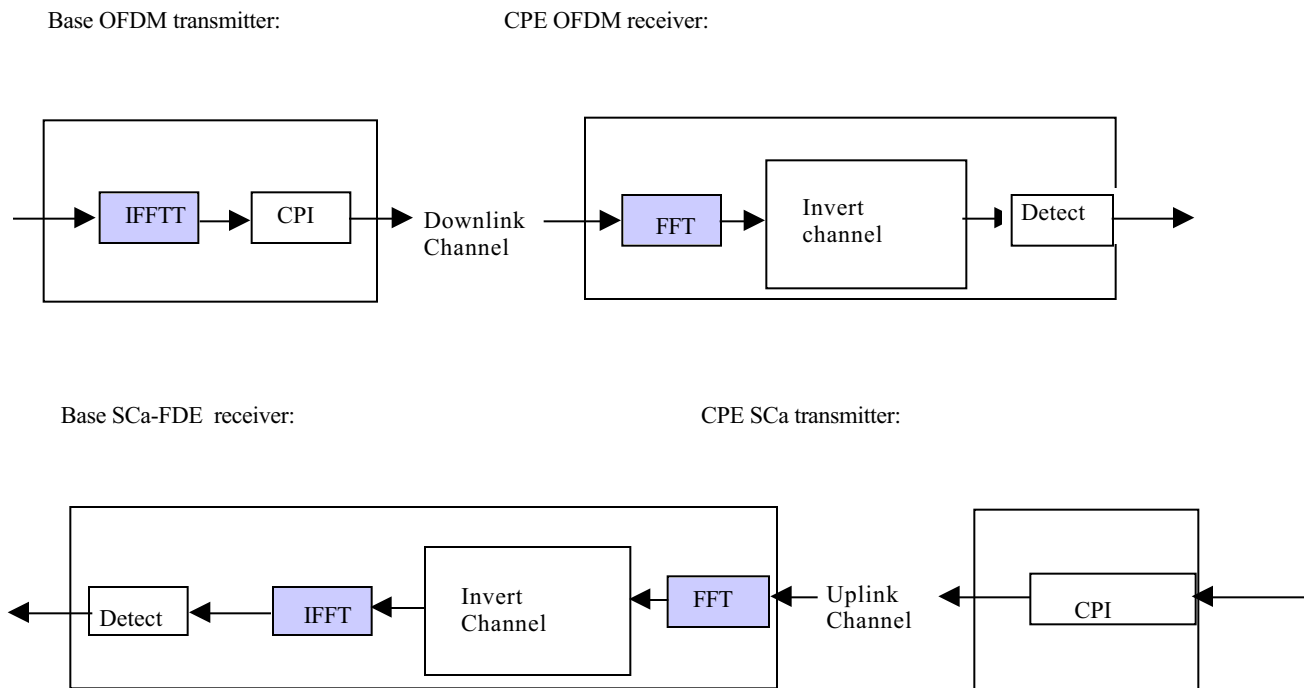
We anticipate that the changes needed in the current draft are minor and can be tackled within the time line of the next meeting.

## The mixed mode Downlink OFDM, Uplink SC-FDE

The proposed mixed mode PHY standard shall allow implementation of WirelessMAN system based on P802.16a Single Carrier PHY (as defined in section 8.3) and OFDM PHY (as defined in 8.4) approach for WirelessMAN systems for licensed frequencies between 2 to 11 GHz. This approach will ensure to fully benefit from the features of each technology to make cost effective CPE with NLOS operation capability.

The proposed PHY system adopts TDM/ TDMA bandwidth sharing scheme. The Downlink (DL) signal is transmitted from the Base Station to all assigned Subscriber Stations using a carrier frequency in broadcast Time Division Multiplex (TDM) with the OFDM method. The Uplink (UL) signal is burst from the Subscriber Station sharing the same RF carrier with other assigned Subscriber Stations to the Base Station in Time Division Multiple Access (TDMA) mode. This access scheme can be either FDD or TDD, strictly compliant with Section 8.3.1.4 of P802.16a/D5 Both duplexing schemes have intrinsic advantages and disadvantages, so for a given application the optimum duplexing scheme to be applied depends on deployment-specific characteristics, i.e., bandwidth availability, Tx-to-Rx spacing, traffic models, and cost objectives.

Figure 2.1 illustrates a top-level implementation of a mixed mode Single carrier and OFDM system.



**Figure 2.1: A Simple Mixed mode SC and OFDM system**

CPI=cyclic prefix insertion; FFT=Fast Fourier transform; IFFT=inverse FFT

## The benefits of Downlink OFDM, Uplink SC-FDE

This arrangement – OFDM in the downlink and single carrier in the uplink has the following potential advantages:

- Concentrating most of the signal processing complexity at the base station. The hub has two inverse FFT operations and one FFT, while the subscriber has just one FFT for receiving the downlink OFDM signal.
- The subscriber transmitter is single carrier, and thus is simple and inherently more efficient than an OFDM system transmitter in terms of power consumption, due to the reduced power back-off requirements of the single carrier mode. This will minimize the cost of a subscriber's power amplifier. On the other hand, the use of OFDM in the downlink, as well as minimizing the FFT processing in the subscriber unit, will bring the benefits of OFDM powerful coding and multiplexing flexibilities.
- The uplink TDMA single carrier mode is simple and efficient; short MAC messages can be transmitted in very short-duration bursts, whereas OFDM burst lengths must be multiples of the FFT block length.
- The mixed mode is a step towards interoperable Wireless-SCa and WirelessMAN-OFDM systems.
- Mixed modes with DL OFDM and UL SC-FDE are also investigated for air interface of 4G mobile systems [Fal02b].

## Required changes in P802.16a/D5 draft:

- For the mixed mode, for the uplink will use exactly all the system profiles and the TLVs defined in Sub-clauses 8.3,11 and 12.
- For downlink OFDM standard will use exactly all the system profiles and TLVs used in Sub-clauses 8.4, 11 and 12.
- P.2 line 64: add sentence to the paragraph –  
**Additionally, a system shall comply to the standard if its downstream complies with the OFDM PHY as described in 8.4 and its upstream with the SCa PHY as described in 8.3.**

## Summary

The proposed mode of OFDM in the downlink and single carrier in the uplink, with frequency domain equalization (SC-FDE), provides a beneficial for WirelessMAN terminal cost/performance tradeoff, compared to pure OFDM or pure SC-FDE in both directions. The OFDM and SC-FDE technologies are well understood (see references below), as are their reduced signal processing complexities for channels with large delay spread, relative to classical time-domain equalization methods. These advantages hold as well for future mobile terminal as considered by IEEE 802.16 Mobile Wireless MAN Study Group.

## References

[Fal01] D. Falconer, S.L. Ariyavisitakul, A. Benyamin-Seeyar and B. Eidson, "White Paper: Frequency Domain Equalization for Single-Carrier Broadband Wireless Systems", [www.sce.carleton.ca/bbw/papers/Ariyavisitakul.pdf](http://www.sce.carleton.ca/bbw/papers/Ariyavisitakul.pdf).

[Fal02a] D. Falconer, S.L. Ariyavisitakul, A. Benyamin-Seeyar and B. Eidson, "Frequency Domain Equalization for Single-Carrier Broadband Wireless Systems", *IEEE Communications Magazine*, Vol. 40, No. 4, April 2002, pp. 58-66.

[Fal02b] D. Falconer, "A Mixed OFDM Plus Single-Carrier Mode Air Interface", *contribution to WG4 in 6<sup>th</sup> WWRF Meeting*, London, June 25-26, 2002. [<http://www.wireless-world-research.org> (see WWRF6, working group 4 contributed document)]

[Spr02] A. Springer, A. Koppler, H. Witschnig and R. Weigel, "Robust and Efficient W-LAN Systems for Very High Data Rates Employing Single Carrier Transmission with Frequency Domain Equalization", *contribution to WG4 in 6<sup>th</sup> WWRF Meeting*, London, June 25-26, 2002. [<http://www.wireless-world-research.org> (see WWRF6, working group 4 contributed document)]