Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	**Symbol duration Extended Interleaved FDMA as Uplink Multiple Access Technique for 802.16m**
Date Submitted	2008-01-16
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Re:	IEEE C802.16m-07/047 - Call for Contributions on Project 802.16m System Description Document (SDD)
Abstract	Proposed Symbol duration Extended I-FDMA for uplink gives unity PAPR and better link level coded BER performance than DFT-spread OFDMA and OFDMA
Purpose	To be discussed by TGm for incorporating the proposal into IEEE 802.16m standard
Notice	
Release	
Patent Policy	

Symbol duration Extended Interleaved FDMA as Uplink Multiple Access Technique for 802.16m

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Motivation

OFDMA with tile based resource allocation is used in the uplink of IEEE 802.16e [1]. DFT-spread OFDMA (D-OFDMA) has CM and PAPR less than OFDMA [2]. Interleaved FDMA (I-FDMA) can be viewed as a special case of D-OFDMA, where it is possible to achieve a PAPR of unity for QPSK. However, unlike OFDMA or D-OFDMA where pilot sub-carriers can be embedded along with the data sub-carriers, I-FDMA typically requires time-multiplexed pilots in order to track fast fading channels. The other seeming limitation is that since (symbol) sequence repetition is used to create the equi-spaced sub-carriers in the frequency domain (which we will refer hereafter as a frequency "comb"), the sub-carriers extend up to the edges of the frequency band, making it difficult to provide for guard-bands. Also, such comb-like structure could potentially reduce the flexibility of bit-rate allocation and interference averaging. The above considerations have perhaps prevented emerging access standards such as the LTE to consider I-FDMA for the uplink.

Yet, in many countries with large open and rural areas where macro-cells (~25km radius) are required, the unity PAPR of I-FDMA can significantly help in providing higher uplink margins, especially for fixed and pedestrian users.

Proposed Technique

We propose a Symbol duration Extended Interleaved FDMA (SE-IFDMA) as the uplink multiple access technique where:

(1) Unity PAPR is retained (for M-ary PSK)
(2) The symbol duration is extended in order to ensure that the *used band-width* on the UL is exactly equal to that on the OFDMA downlink (or D-OFDMA UL)
(3) By using high-quality decision-directed channel tracking (DDCT), the need for temporally multiplexing pilot combs is avoided
(4) The techniques in (2) and (3) ensure that the spectral efficiency of the SE-IFDMA scheme is equal to (or more than) that of OFDMA or D-OFDMA schemes
(5) Flexible allocation of combs to various users is possible
(6) Interference averaging is possible by hopping the comb allocations over time
(7) As in diversity spaced OFDMA allocations and in the equi-spaced D-OFMDA scheme, this SE-IFDMA can also accrue the full frequency diversity by using the outer FEC code
(8) If all the users on the uplink are power-controlled, then the impact of inter-carrier interference will be no worse than the localized D-OFDMA scheme in LTE

We also propose an uplink frame structure for SE-IFDMA whereby (assuming 1024-pt FFT):

(1) The first three symbols (slot #0 in Fig. 5) in the UL frame will carry long pilot combs in a reuse-1/3 manner to enable high quality channel estimation
(2) UL ranging code will also be assigned combs from slot #0, and the ranging code will be 2 symbols long
(3) Long pilot combs will have 256 sub-carriers; short pilot combs are also defined with either 32 or 64 sub-carriers
(4) Every active user in the sector is assigned either a long pilot comb or a short pilot comb, followed by multiple data combs over the UL frame

Flexible resource allocation on the uplink is enabled. A comb-tree (similar to OVSF code-tree used in W-CDMA) is used to provide user combs, and the assigned comb can be signaled on the downlink MAP with very low overhead. Since interference free, high-quality channel estimation is possible, coded BER performance is not only better than that of the localized D-OFDMA, but is also better than the equi-spaced D-OFDMA or diversity mapped OFDMA techniques.

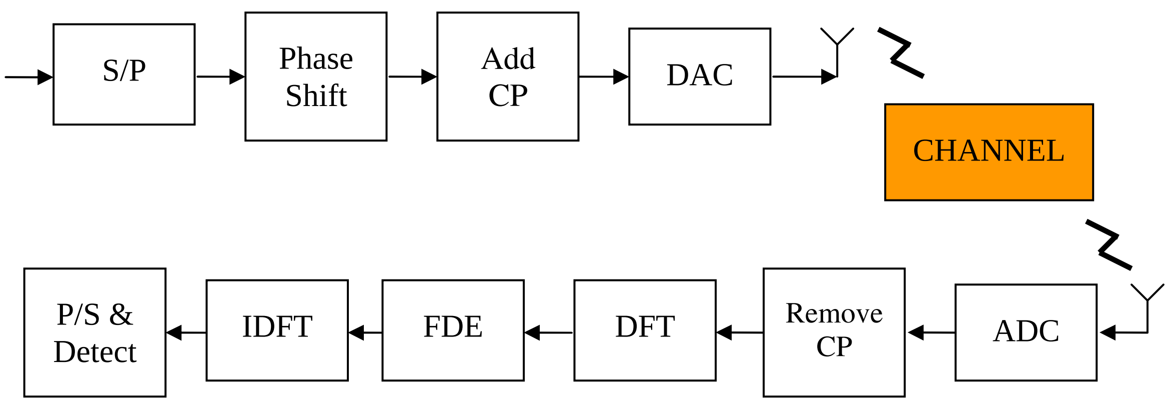
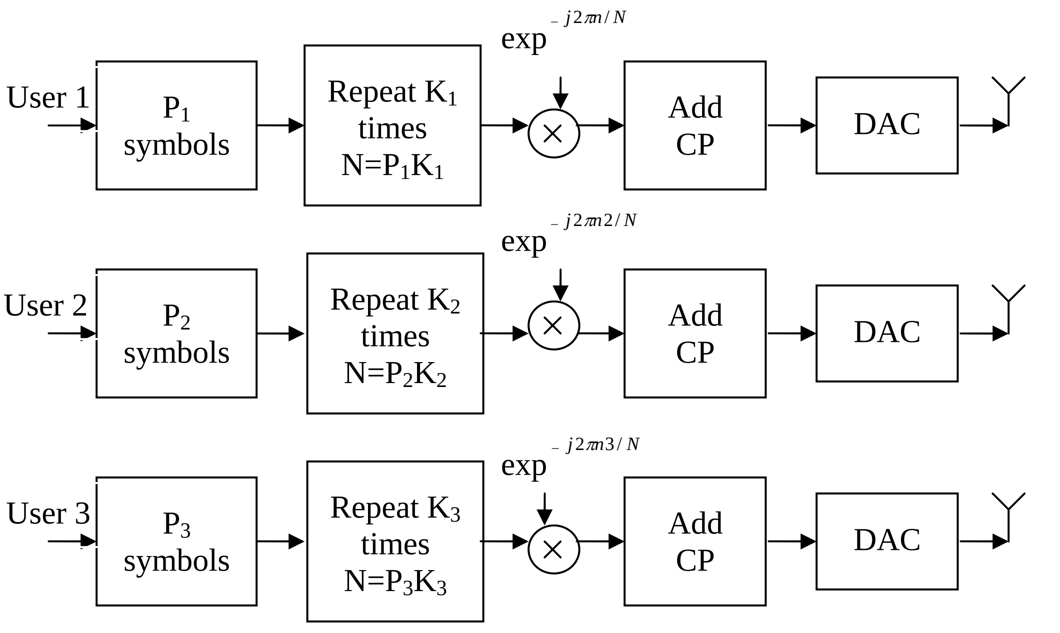


Fig. 1: Block Diagram of Symbol duration Extended I-FDMA

***Example*:** FFT size N=1024, P_1=256, K_1=4, P_2=128, K_2=8, P_3=128, K_3=8



n = [0 1 2 3 ….(N-1)]

Fig. 2 Transmission from multiple users in Uplink

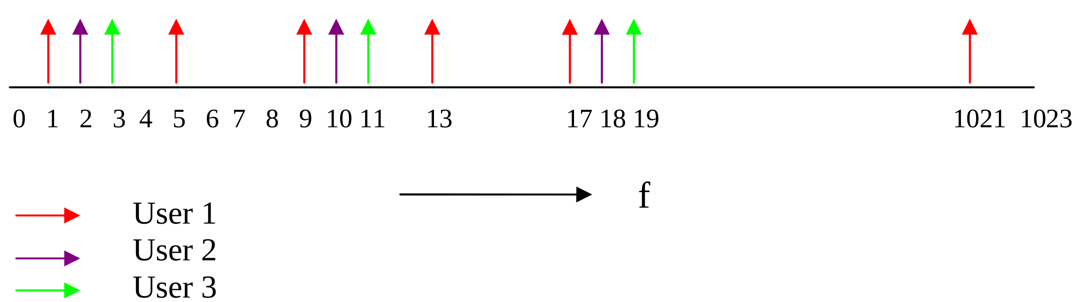


Fig. 3 Multiplexing multiple users in Uplink

- Every user occupies a comb (red/magenta/green) in frequency domain
- Phase shift applied to a user's data determines the comb occupied by the user's data in frequency domain

Ex: N = 1024

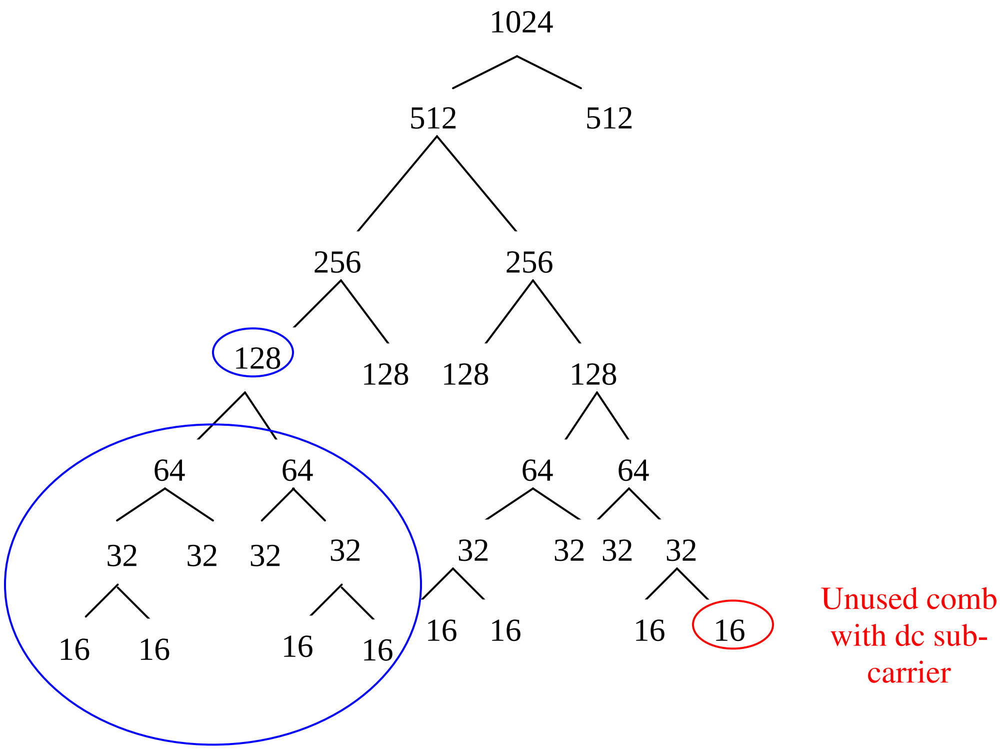


Fig. 4 Subcarrier assignment to users in uplink

- A user can occupy only one node
- A node corresponds to a particular comb/subcarrier allocation in frequency domain
- Number associated with a node indicates number of subcarriers per symbol allocated to the user occupying the node
- When a node is occupied by a user, none of the children of that node can be occupied by a different user
- A user has a fixed number of comb/subcarrier allocation choices for a given number of subcarriers per symbol and FFT size

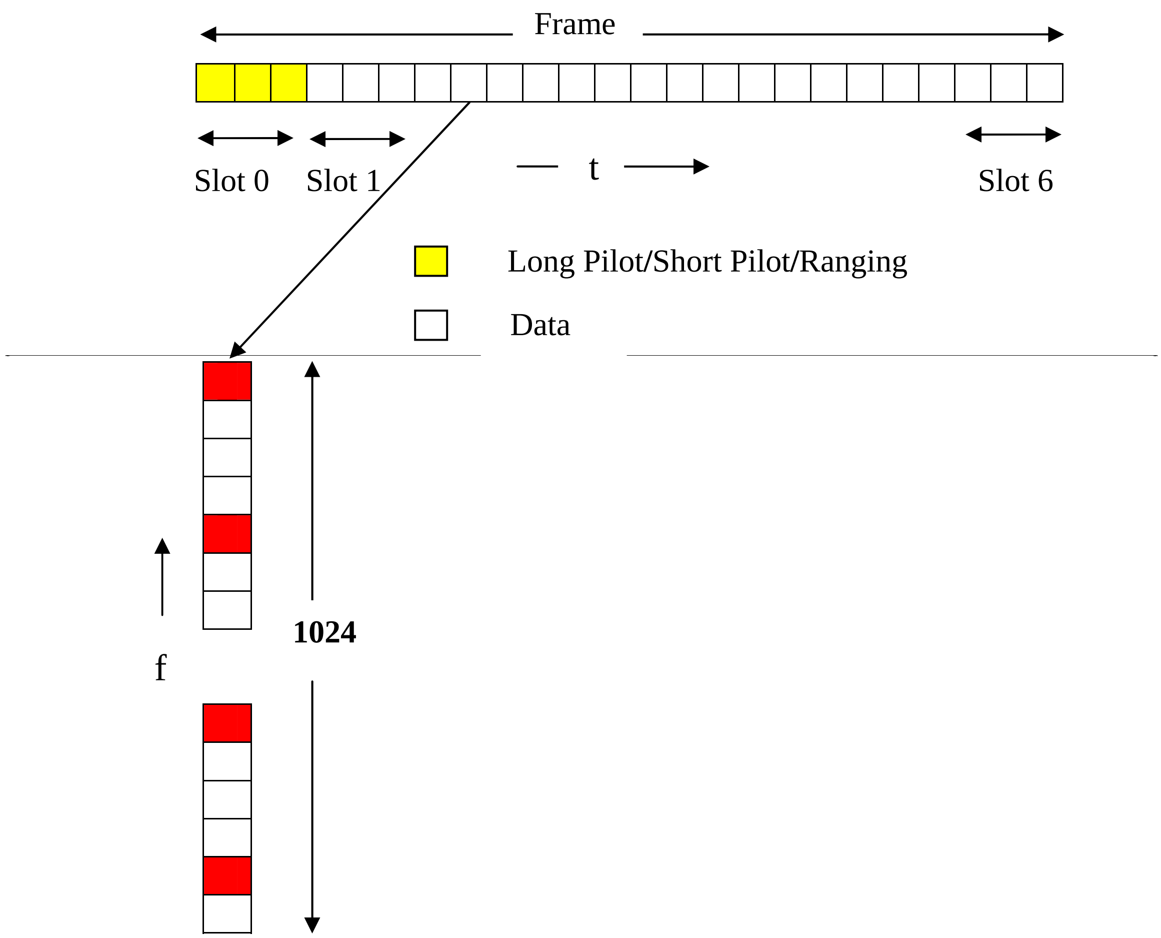


Fig. 5 UL Frame Structure of Symbol duration Extended I-FDMA

- 1 Frame = 7 Slots
- Size of resource block : 16X3 (16 subcarriers and 3 symbols)
- A user must be allocated at least one resource block per slot
- A user can be allocated multiple resource blocks per slot
- A user can be allocated minimum 16 to maximum 512 subcarriers in a symbol
- Slot 0 is for Long Pilot, Short Pilot and Ranging; Slot 1- Slot 6 is for data
- Allocated subcarriers must be equally spaced and spread over the entire frequency band
- Physical location of subcarriers assigned to a user remains fixed for a frame

Comparison with DFT-spread OFDMA

We know that DFT-spread OFDMA and OFDMA perform very similar in terms of block error rate with gaps less than 0.5 dB [2]. Again Cubic Metric and PAPR of DFT-spread OFDMA is less than OFDMA [2]. We therefore compare our proposed uplink MA technique with DFT-spread OFDMA with localized subcarrier allocation and DFT-spread OFDMA with equally spaced subcarrier allocation.

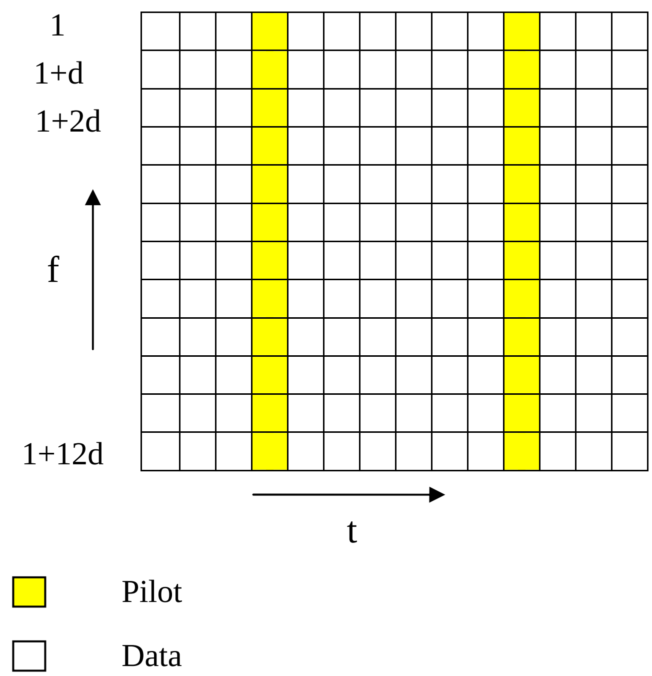
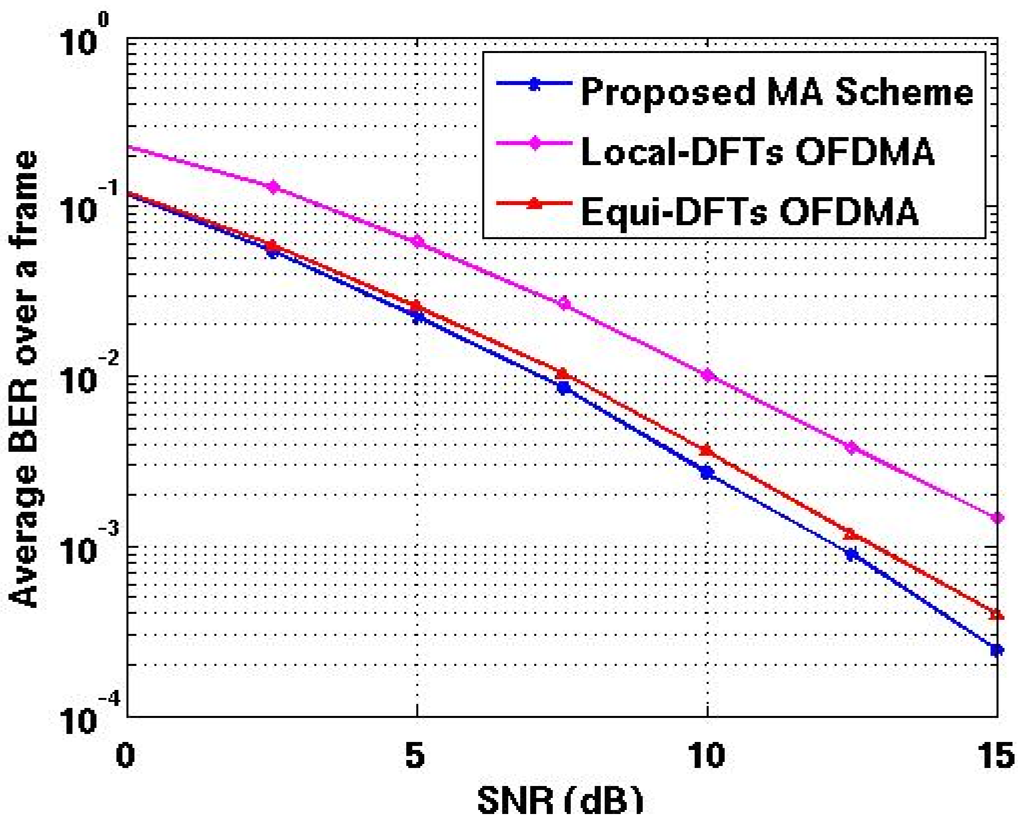


Fig. 6 Frame Structure of DFT-spread OFDMA

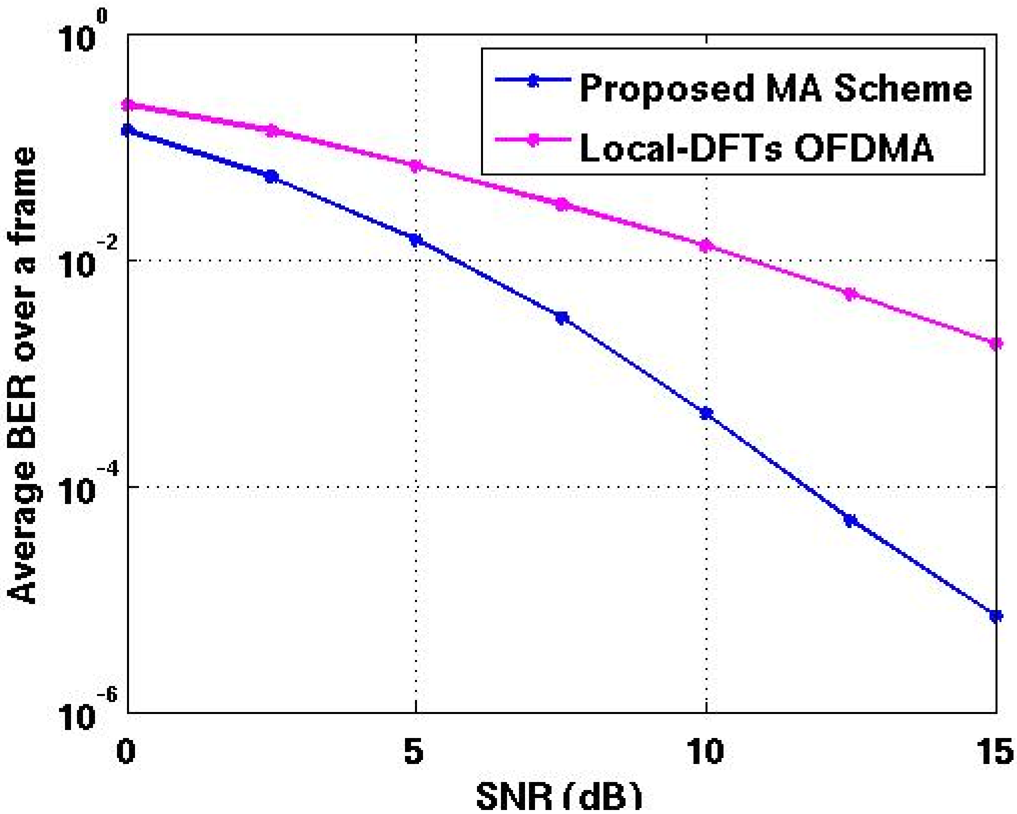
Parameters used in Simulation [3], [4]

Symbol duration Extended I-FDMA	**DFT-spread OFDMA**
Channel Model: WINNER Rural Macro-cell Vehicle speed: 30 km/h Modulation: QPSK Coder: ½ rate Turbo coder MIMO: 1X2 Pilot : Data = 1:7 BW = 10 MHz FFT size = 1024 Resource block: 64X3	Channel Model: WINNER Rural Macro-cell Vehicle speed: 30 km/h Modulation: QPSK Coder: ½ rate Turbo coder MIMO: 1X2 Pilot : Data = 1:7 BW = 10 MHz FFT size = 1024 Resource block: 48X7 (64X3)

Coded BER Plots



Coded BER Plots – Frequency Selective Channel



Comparison between Symbol duration Extended I-FDMA and WiMAX

Symbol duration Extended I-FDMA	**WiMAX**
Pilot : Data = 1:7 BW = 10 MHz FFT size = 1024 Subcarrier spacing = 8.9828 KHz Used subcarriers per symbol = 1008 Used BW = 9.1984 MHz Symbol duration (without CP) = 111.3 microsec Oversampling – NIL Data bits per msec = 7763 (assuming BPSK modulation)	Pilot : Data = 1:3 BW = 10 MHz FFT size = 1024 Subcarrier spacing = 10.9375 KHz Used subcarriers per symbol = 840 Used BW = 9.1984 MHz Symbol duration (without CP) = 91.43 microsec Oversampling factor = 28/25 Data bits per msec = 6860 (assuming BPSK modulation)

Disadvantages

- Inter-carrier Interference increases
- Effective Doppler increases
- Fixed options for comb/subcarrier allocation in uplink

Advantages

- PAPR at MS is unity for constant modulus constellation
- Uplink data bit rate increases by 13%
- Uplink overhead reduces drastically
- Uplink BER performance improves by 2 dB apart from an increase in uplink data transmission rate by 13%
- Turbo coder used for IEEE 802.16e-2005 can be used in MS

References

[1] IEEE 802.16e-2005
[2] IEEE C802.16m-07/239r1, "Proposal for Incorporating Single-carrier FDMA into 802.16m"
[3] IEEE 802.16m-07/002r4, "802.16m System Requirements"
[4] IEEE 802.16m-07/037r2, "Draft 802.16m Evaluation Methodology"

Proposed changes

[Insert in the ToC in the PHY layer in the appropriate sections (like Multiple Access Scheme, PHY Processing,Subcarrier Allocation, etc) provisions for SC-FDMA.]

x.x.x.x Symbol duration Extended I-FDMA