Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>	
Title	**Resource Tile Size in IEEE 802.16m Medium Access Control Frame Structure**	
Date Submitted	**2008-03-10**	
Source(s)	Anup Talukdar, Mark Cudak Motorola	Voice: E-mail: Anup.Talukdar@motorola.com *<http://standards.ieee.org/faqs/affiliationFAQ.html>
Re:	Call for contributions IEEE 802.16m-08/005 on the topic of “Downlink Physical Resource Allocation Unit”	
Abstract	This contribution examines the various downlink physical resource allocation unit sizes (i.e. resource tiles) comparing resource allocation tiles spanning 18, 12 and 9 subcarriers.	
Purpose	Discussion and approval	
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Resource Tile Size in IEEE 802.16m Medium Access Control Frame Structure

Anup Talukdar, Mark Cudak
Motorola

Overview

In the IEEE 802.16m Frame structure proposal [1][2], a 20-msec super-frame is divided into four equally sized 5-msec radio frames. Each 5-msec radio frame, in turn, is divided into eight sub-frames. Each sub-frame can be allocated for either downlink or uplink transmission. In the regular sub-frame structure, each sub-frame consists of 6 OFDM symbols. In the frequency dimension, a sub-frame is divided into Resource Tiles (RT) consisting of a number of adjacent sub-carriers. For all practical purposes, the time-frequency resource allocation granularity is 6xN symbols, where N is the size of the RT in number of sub-carriers.

The Resource Tile (RT) size of the 802.16m Medium Access Control Frame (also referred to as Resource Block) has significant impact on the downlink control overhead, channel estimation performance and packing efficiency. In the frequency selective allocation scheme, system throughput depends on the RT size and it also determines the uplink feedback overhead. It is also desirable to adopt an RT structure that can easily co-exist with legacy system's resource allocation scheme. In the following each of the issues is examined and a suitable RT sizes for 16m frame is recommended.

Control overhead

16m like 16e systems will need to assign the resources to users using a resource allocation map like the downlink or uplink map. This resource allocation map will contain assignment messages which describe the time-frequency resources allocated to a user in the downlink or uplink. The assignment messages must use a robust encoding and be transmitted without HARQ support. The size of the resource allocation map depends on the carrier bandwidth, resource allocation granularity and the resource allocation scheme, i.e. whether frequency selective or frequency diversity allocation. For frequency selective allocation scheme, the allocation map size is at least proportional to the number of RTs in the frame. In a pure frequency diversity allocation scheme, the allocation map size is at least proportional to the logarithm of the number of RTs in the frame. Thus RT sizes should be as large as possible, subject to other constraints, in order to reduce the downlink control overhead in the system. The numbers of RTs for the different RT sizes are shown in Table 1:

Table 1 Number of RTs for different RT sizes and carrier bandwidth

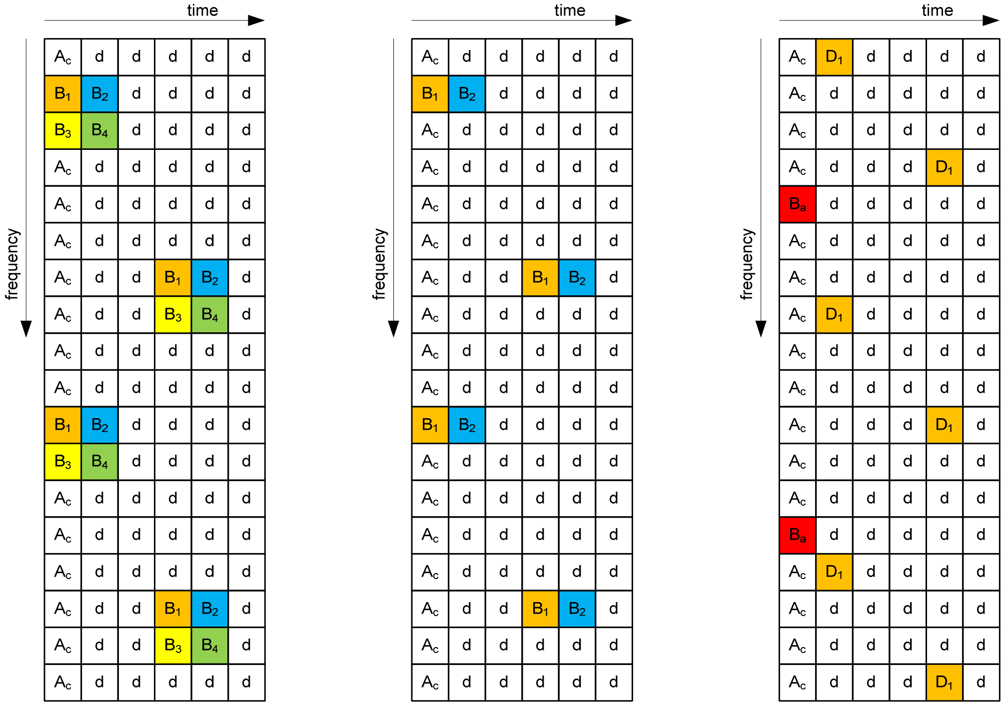
RT size (# sub-carriers)	Number of RTs per sub-frame		
	Bw=5 MHz	Bw=10 MHz	Bw=20 MHz
9	48	96	192
12	36	72	144
18	24	48	96

Frequency Selective Allocation Performance

To achieve high system and user throughput performance using frequency-selective multi-user scheduling, the RT sizes should ideally be as small as possible. However, channel quality feedback requirements and the control overhead for assignment messages also increases with smaller RT sizes. Thus, in practice, there is an RT size that maximizes the system throughput balancing the frequency-selective multi-user scheduling gain and control overheads for both uplink and downlink. There in not much benefit of RT sizes smaller than the granularity of CQI feedback. Contribution IEEE C802.16m-08/090r2 has shown, in the framework of the 802.16m Frame structure, the RT size of 18 sub-carriers provides nearly all of the frequency selective scheduling gain achievable [3]. A smaller RT size of 12 sub-carriers increases the performance by less that 0.1%. On the other hand, a RT size of 12 sub-carriers would increase the channel quality feedback overhead by over 50%. The negilible improvement in system throughput does not justify the large increase in feedback overhead.

Channel estimation performance

For various closed-loop adaptive antenna techniques, use of dedicated pilots can reduce pilot overhead significantly. When dedicated pilots are used, users assigned to sub-frames can use the pilots only in their allocated RTs. In such case, for a given fractional pilot overhead, channel estimation performs better when RT sizes are bigger Thus closed-loop MIMO techniques warrant for larger RT sizes.



A_c	d	d	d	d	d
B_1	B_2	d	d	d	d
B_3	B_4	d	d	d	d
A_c	d	d	d	d	d
A_c	d	d	d	d	d
A_c	d	d	d	d	d
A_c	d	d	B_1	B_2	d
A_c	d	d	B_3	B_4	d
A_c	d	d	d	d	d
A_c	d	d	d	d	d
B_1	B_2	d	d	d	d
B_3	B_4	d	d	d	d
A_c	d	d	d	d	d
A_c	d	d	d	d	d
A_c	d	d	d	d	d
A_c	d	d	B_1	B_2	d
A_c	d	d	B_3	B_4	d
A_c	d	d	d	d	d

4 Tx antenna,
Broadcast pilot

A_c	d	d	d	d	d
B_1	B_2	d	d	d	d
A_c	d	d	d	d	d
A_c	d	d	d	d	d
A_c	d	d	d	d	d
A_c	d	d	d	d	d
A_c	d	d	B_1	B_2	d
A_c	d	d	d	d	d
A_c	d	d	d	d	d
A_c	d	d	d	d	d
B_1	B_2	d	d	d	d
A_c	d	d	d	d	d
A_c	d	d	d	d	d
A_c	d	d	d	d	d
A_c	d	d	d	d	d
A_c	d	d	B_1	B_2	d
A_c	d	d	d	d	d
A_c	d	d	d	d	d

2 Tx antenna,
Broadcast pilot

A_c	D_1	d	d	d	d
A_c	d	d	d	d	d
A_c	d	d	d	d	d
A_c	d	d	d	D_1	d
B_a	d	d	d	d	d
A_c	d	d	d	d	d
A_c	d	d	d	d	d
A_c	D_1	d	d	d	d
A_c	d	d	d	d	d
A_c	d	d	d	d	d
A_c	d	d	d	D_1	d
A_c	d	d	d	d	d
A_c	d	d	d	d	d
B_a	d	d	d	d	d
A_c	D_1	d	d	d	d
A_c	d	d	d	d	d
A_c	d	d	d	d	d
A_c	d	d	d	D_1	d

Single Stream,
Dedicated pilot
(for data region)

Bn: broadcast pilot, Ba: Broadcast pilot, Dn: dedicated pilot
Ac: control channel, d: data

Figure 1 Pilot pattern for the 18 sub-carrier Resource Tiles

Figure 1 shows a typical resource tile for a 4 Tx Antenna Base Station, 2 Tx Antenna Base Station and a single stream transmission with dedicated in pilots. In all cases, the first symbol in time contains symbols for a resource allocation channel labled, A_c. Broadcast pilots are also contained in all cases labeled with a capital "B" and subscript "n". The subscript "n" identifies whether the pilots are assigned to a particular antenna or the allocation channel. A capital "D" identifies all dedicated pilots in the single stream case. Finally, all the remaining symbols are labeled with a lowercase "d" to represent data symbols. Similar formats scaled for 9 subcarrier and 12 subcarrier RTs are used to examine packing efficiency in the next sections. For more information on link performance see contributions IEEE C802.16m-08/122 and IEEE C802.16m-08/123.

Packing efficiency

In general, for most internet traffic--such as web browsing, streaming video or email traffic—the RT size is not an issue as the payload is much smaller than IP Maximum Transmission Unit (MTU) and any padding represents a small fraction of the assigned RTs. However, for applications with small packet sizes, such as VoIP, the frame packing efficiency is sensitive to the RT size. In general, smaller RT sizes are useful to achieve better frame packing efficiency. However, due to availability of discrete sets of MCS levels, certain anomalies occur. In Figure 2-7, frame packing efficiencies for 3 different RT sizes are shown when different pilot configurations are used. In these figures, the efficiency is measured in terms of fractional unused resources due to allocation of an integer number of RTs for a VoIP packet. The packing efficiencies of active mode VoIP packets, which are 44 bytes for 12.2 kbps AMR codec with header compression, are shown in Figures 2-4. In these results, the pilot and control overheads have been accounted for as described in the previous section and shown in Figure 1. For the RT sizes of 12 and 9 sub-carriers, the pilot overheads have been prorated down to an integer number of pilot symbols. The corresponding pilot overheads are described in Table 2.

Table 2 Pilot overheads used for results shown in Figure 2-4

RT size (# sub-carriers)	4 Tx antenna, broadcast pilot	2 Tx antenna, broadcast pilot	Single stream, dedicated pilot
9	14.8%	7.4%	5.6%
12	15.3%	8.3%	7.4%
18	14.8%	7.4%	5.6%

IFrom these results it can be observed that, all RT sizes have similar packing efficiences especially at low SINR values. At the high SINR values, RT size of 9 sub-carriers has the best packing efficiency. However, with a RT size of 9 sub-carriers, the downlink control overhead associated with resource allocation will be higher. Therefore, any advantage in packing efficiency must be considered with respect the overall performance. Morever, other techniques may be used to reduced the packing inefficiency.

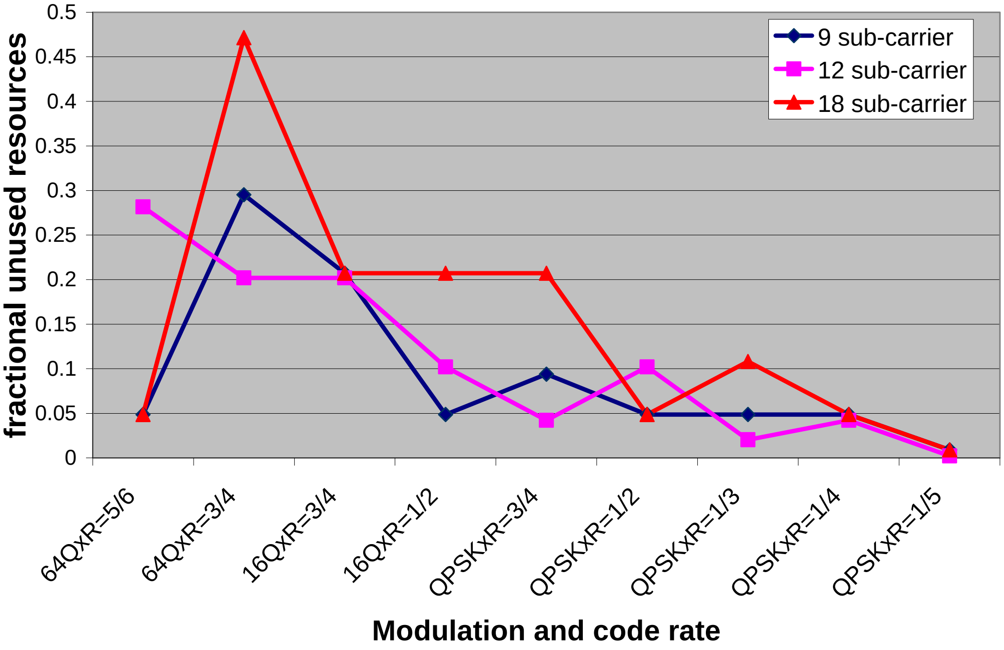


Figure 2 Packing efficiency of active mode VoIP packet (packet size=44bytes); transmission scheme is 4 transmit antenna with broadcast pilots

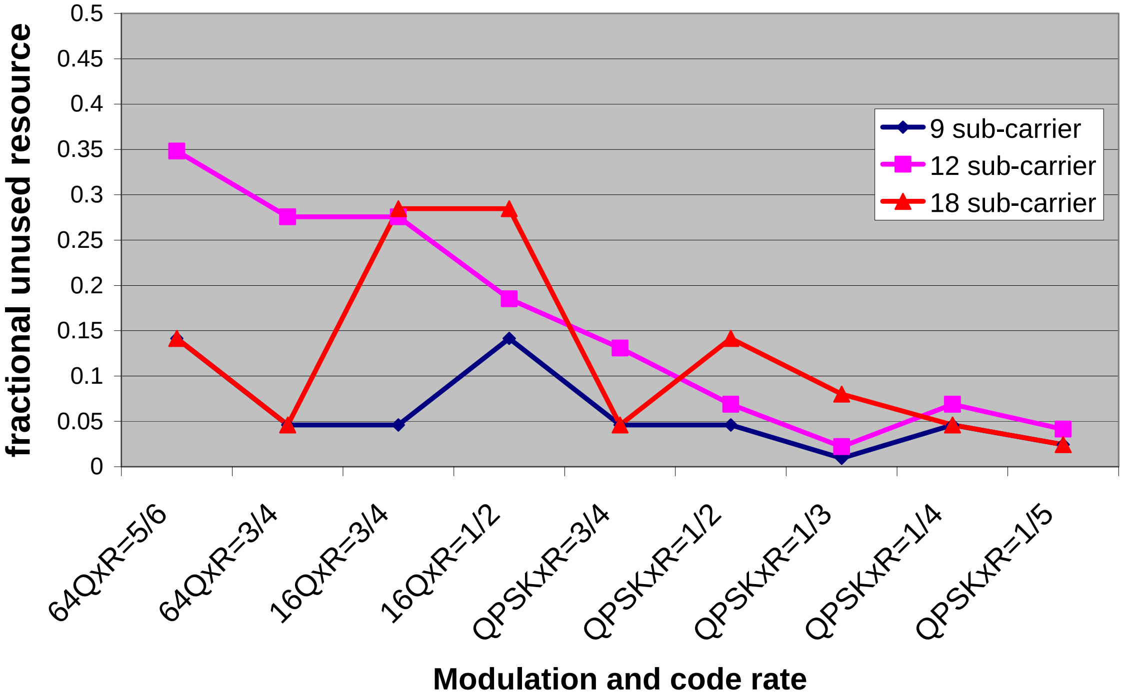


Figure 3 Packing efficiency of active mode VoIP packet (packet size=44bytes); transmission scheme is 2 transmit antenna with broadcast pilots

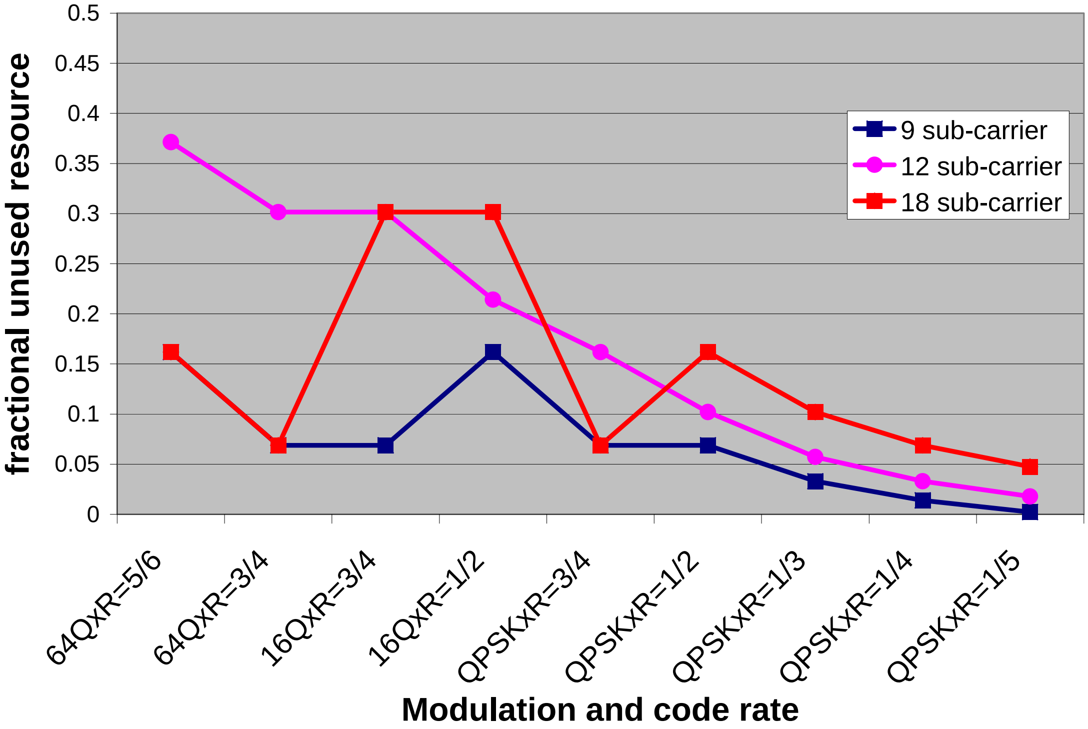


Figure 4 Packing efficiency of active mode VoIP packet (packet size=44bytes); transmission scheme is single stream with dedicated pilots

Rate Matching

An alternative method to using smaller RT sizes is to use rate matching schemes which utilizes the entire resources of the RTs to improve performance, instead of leaving a fraction of the payload unused. In this case, the channel coding can be rate adapted to send redundancy bits instead of null padding bits improving the overall Eb/No performance of the physical layer transmission. IEEE C802.16m-07/010 discusses the application rate matching for turbo codes in IEEE 802.16m [4].

Figure 5 shows the effective coding rate with rate matching for the various configuration of 18 subcarrier RTs. In all case, it shows that an effective coding rate near the reference can be achieved with no packing inefficiency. The additional redundancy improves the link margin allowing the scheduler to backoff on the power allocation to the particular user. Rate matching is superior to null padding and allows the optimum utilization of 18 subcarrier RT tiles.

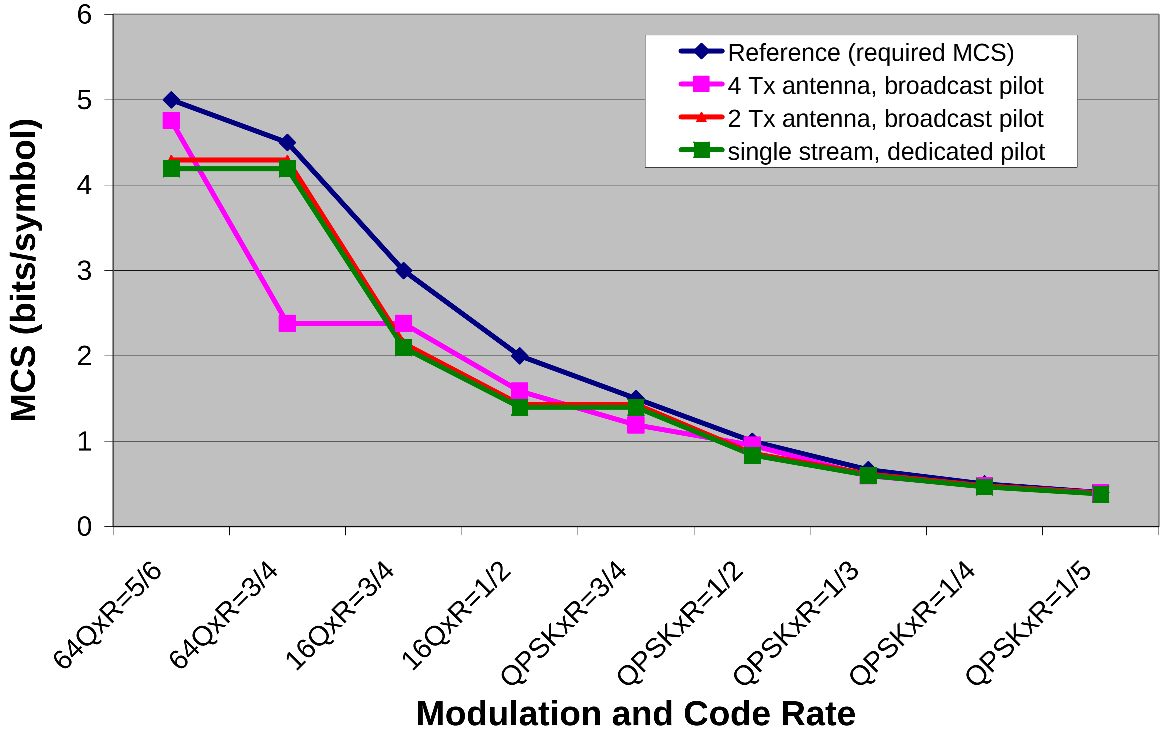


Figure 5 Rate matched MCS of a VoIP packet for various transmission schemes using 18 sub-carrier RT

Legacy compatibility

IEEE 802.16e supports frequency selective scheduling in the form of BAND AMC permutation. As is well known, the Band AMC permutation is based on a 1x9 tile format grouping the tiles in a 2x3 format to provide Band AMC subchannels which are exactly 18 subcarriers wide. An 18 subcarrier RT will fit exactly two Band AMC subchannels in time and spans the same bandwidth. An 18 subcarrier RT would allow for frequency multiplexing 16m and 16e if the task group were inclined to enable that mode of operation.

Summary

The size of the Resource Tile (RT) in the 802.16m frame structure has significant impact on the overall system performance. The following observations have been made:

- RT tiles smaller than 18 subcarriers provide less than 0.1% sector throughput improvement for frequency selective scheduling while increasing the CQI feedback overhead by 50%.
- Packing efficiencies are comparable for both 18 and 12 subcarrier RTs. Although certain applications with very small payloads may benefit from improved packing efficiency, the overall benefit will be small.
- Rate matching schemes may be employed to eliminate all packing inefficiency even for small for applications with small payloads.
- Allocation control overhead will increase with smaller RT size as the number of bits necessary to communicate an allocation is required to describe the greater number of allocable RTs.

---------------------------------- PROPOSED TEXT FOR SDD SECTION --

A sub-frame will be subdivided in to Resource Tiles (RTs) of 6 by 18 subcarriers forming the basis allocable unit. Table XXX belows shows the number of RTs available for various operating bandwidths.

Table XXX Number of RTs for different operating bandwidths

Number of RTs per sub-frame		
Bw=5 MHz	Bw=10 MHz	Bw=20 MHz
24	48	96

References

[1] Sassan Ahmadi, Phil Barber and Lei Wang, "Proposed 802.16m Frame Structure Baseline Content Suitable for Use in the 802.16m SDD," IEEE C802.16m-08/118r1, March 3, 2008

[2] Mark Cudak, Fred Vook, Kevin Baum, Tim Thomas, Anup Talukdar, Marc De Courville, Amitava Ghosh, Fan Wang, Bishwarup Mondal, Chandy Sankaran, Jeff Zhuang, Jeff Bonta and Steve Emeott, “Proposed Frame Structure for IEEE 802.16m,” IEEE C802.16m-08/008, January 16, 2008

[3] JinSoo Choi, JinSam Kwak, Bin-Chul Ihm and SungHo Moon, "Basic Resource Block and Pilot Allocation Design in IEEE 802.16m," IEEE C802.16m-08/090r2, January 16, 2008

[4] Keith Blankenship, Mark Cudak and Fred Vook, “Rate Matching in 802.16m”, IEEE C802.16m-07/010, January 16, 2008.