Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	**Propose for Uplink Pilot Design in IEEE 802.16m**
Date Submitted	**2008-05-05**
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Re:	IEEE 802.16m-08/016r1: Call for Contributions on Project 802.16m System Description Document (SDD). Target topic: “Uplink Pilot Structures”.
Abstract	This contribution discusses some design considerations of pilot structures in the uplik and provides some pilot structure examples for exposition.
Purpose	For discussion and approval by TGm
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Propose for Uplink Pilot Design in IEEE 802.16m

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1. Introduction

In this contribution we consider and discuss several UL pilot structures for 1-antenna and 2-antenna 802.16m system. Two-dimensional sampling theory will be introduced first we then apply this theory into the design of UL pilots. UL pilot structures are proposed by taking the requirements of utilizing 1-antenna and 2-antenna into 802.16m system and also the necessity of supporting 802.16e system into consideration. Based on the designed basic UL pilot structure we propose the zone concept to develop two kinds of zones, namely, the SP-Zone (Space-Zone) and MB-(Mobility Zone). From these two zones we then define and develop various pilot structures for indoor and outdoor radio environments and also for stationary, mobility and high mobility situations.

2. Design Considerations of Uplink Pilot Structure

2.1 Two-Dimensional Sampling Theorem

The design of pilot structure is based on 2-D sampling theory. Define D_f and D_t are the pilot spacing in the time and frequency domain respectively with their definitions as [1]:

$$D_f \le \frac{1}{2T_m} \tag{1}$$

and

$$D_t \le \frac{1}{2f_d} \tag{2}$$

where T_m is Maximum Delay Spread, f_d is Maximum Doppler Frequency.

Based on the system parameters values as defined in Table 6 of the Drafted 802.16m Evaluation Methodology Document [2] we will calculate and find the possible ranges of symbols and sub-carriers for the pilots to be used for 802.16m. The number of sub-carriers, $N_{subcarrier}$, for a pilot structure can be calculated as:

For D_f:

A duration T_s for an OFDMA symbol is 102.86μs, with 1/8 cyclic prefix (T_{cp}) proposed, it has T_{cp} = 11.43μs, therefore the maximum delay will be bounded by 11.43μs, therefore we have $D_f \leqq$ 43.85KHz. With sub-carrier spacing set at $\triangle f$ = 10.94 *k*Hz, the number of sub-carriers can be calculated is $N_{subcarrier} = D_f / \triangle f = 4$.

For D_t:

The maximal velocity for an MS is 350 *km*/*hr* with carrier frequency at 2.5 *GHz*, its corresponding wavelength is $\lambda = c/f_c = 3x10^8/2.5x10^9 = 0.12$ *m*, then with the MS velocity set at 350 *km/hr*, its corresponding Doppler frequency is $f_d = \upsilon/\lambda$=810 and therefore the value of D_f is limited by 617.2μs. With symbol duration of $T_s = 102.82$ μs we have $N_{symbol} = D_t/T_s = 6$.

From these calculations we have the basic pilot patterns as depicted in the following:

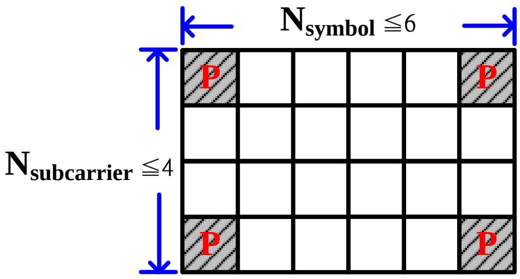

Fig. 1 The allocation of pilots

2.2 Channel Estimation Methods

To obtain the channel characteristics on the location of each data tone, the channel information generated and estimated from some pilot tones that are located at the priori selected positions. The selection of the weighting coefficients depends on the channel variation model used to characterize the channel environment and the estimation error criterion utilized. For numerical analysis, the use of extrapolation is in general considerably more hazardous than the interpolation under the same channel variation model [3]. As a result, the desired pilot arrangement is to have most of the data tones be in between the pilots so as to avoid channel extrapolations as much as possible.

2.3 Pilot Structure Examples

From the equations as 2-D sampling theory as described in section 2.1 we can calculate the pilot spacing we will calculate and find the possible ranges of symbols and sub-carriers for the pilots to be used for 802.16m

2.3.1 Uplink Tile and Pilots Type for 802.16e

Some uplink tile and pilots types considered and recommended for 802.16e are depicted in Fig. 2–Fig. 7 [4]

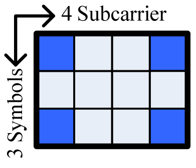

Fig. 2 1-antenna 4x3 Tile for 802.16e

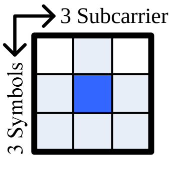

Fig. 3 1-antenna 3x3 Tile for 802.16e

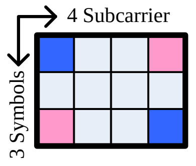

Fig. 4 2-antenna 4x3 Tile for 802.16e

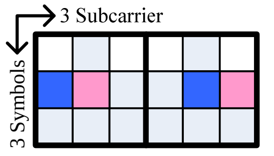

Fig. 5 2-antenna 3x3 Tile for 802.16e

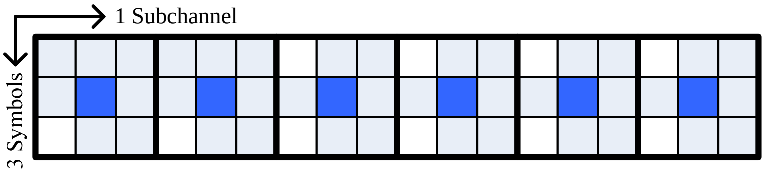

Fig. 6 Slot for 1-antenna 3x3 tile for 802.16e

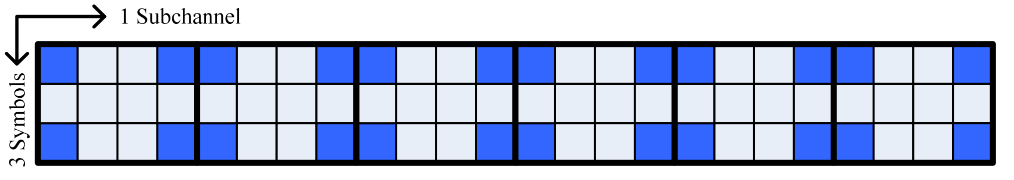

Fig. 7 Slot for 1-antenna 4x3 tile for 802.16e

2.3.2 Uplink Tile and Pilots Type for 802.16m

Based on uplink tile and pilots type for 802.16e as described in the previous sub-section, we propose the following structures for the uplink tile and pilots type for 802.16m

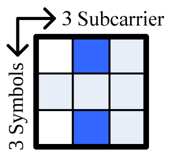

Fig. 8 1- antenna 3x3 Tile for 802.16m

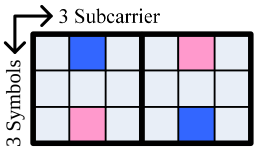

Fig. 9 2-antenna 3x3 Tile for 802.16m

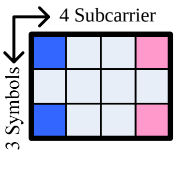

Fig. 10 2-antenna 4x3 Tile for 802.16m

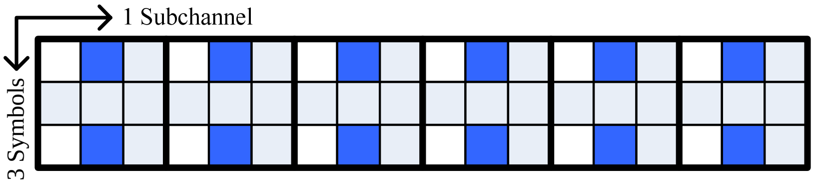

Fig. 11 Slot for 1-antenna 3x3 tile for 802.16m

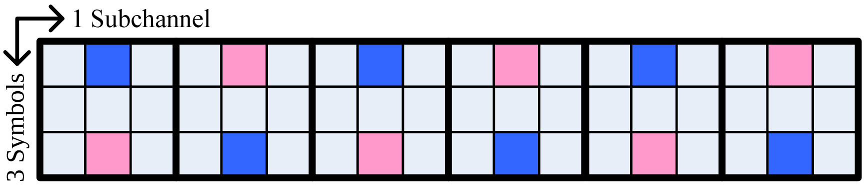

Fig. 12 Slot for 2-antenna 3x3 tile for 802.16m

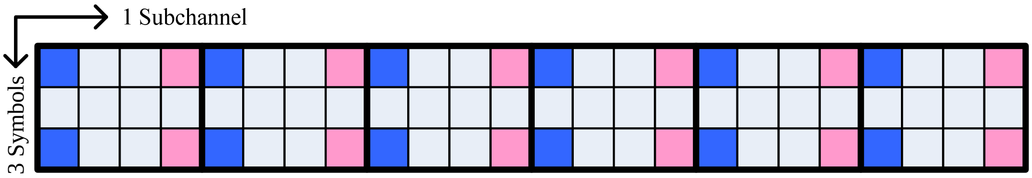

Fig. 13 Slot for 2-antenna 4x3 tile for 802.16m

3. *Simulation Results*

In this section we provide several simulation results to illustrate the effectiveness and performance of the pilot structures as we proposed. We consider a 2-antenna spatial multiplexing MIMO-OFDM system with FFT size 1024. The source symbols are generated from the QPSK constellation. The maximum Doppler shift is set to be 810 *Hz*, which corresponds to a *350 km/hr* vehicle speed with 2.5 *GHz* carrier frequency. The ITU vehicular A channel model is adopted in the simulation, in this model the power delay profile, with 3.7 μs maximum delay spread, and the channel time variation characteristics follow the well-known Jakes' model. In the following simulations two 1-D linear interpolations, time and frequency domain interpolations, are implemented consecutively to estimate the channel responses for data tones that are located between pilots, while for other data tones two –dimensional linear interpolation technique is applied. The relevant simulation parameters are listed in the following table.

Table 1. Simulation Parameters

Parameter	***Baseline***
Carrier Frequency	2.5 GHz
System BW	10 MHz
Channel Model	Veh A. with 3 *km/hr*, 120 *km/hr*,250 *km/hr* and 350 *km/hr*
Channel Coding	Convolutional Code

Antenna Configuration	2-antenna
Modulation and Coding	QPSK
Resource Allocation	1. 3 symbols * 18 subcarriers 2. 3 symbols * 24 subcarriers
Coding Rate	0.5
Pilot Tone Boost	2.5dB over data tone
Channel Estimation	LS

3.1. Comparison to PUSC Difference RB Size Pilot Pattern at Different Speed

We first simulate and compare the BER performance of our proposed pilot structures with those pilot patterns considered in STC PUSU model. It is further assumed that it has totally 24 OFDM symbols generated in the UL transmission. For a MS at speed of 3 *km/hr*, 120 *km/hr*, 250 *km/hr* and 350 *km/hr* the simulated BER performance has the result as shown in Figures 14- 17 respectively. Although it has relative low pilot density in our proposed pilot structure, it has performance slightly better than the conventional STC PUSC to indicate the effectiveness of our proposed pilot pattern.

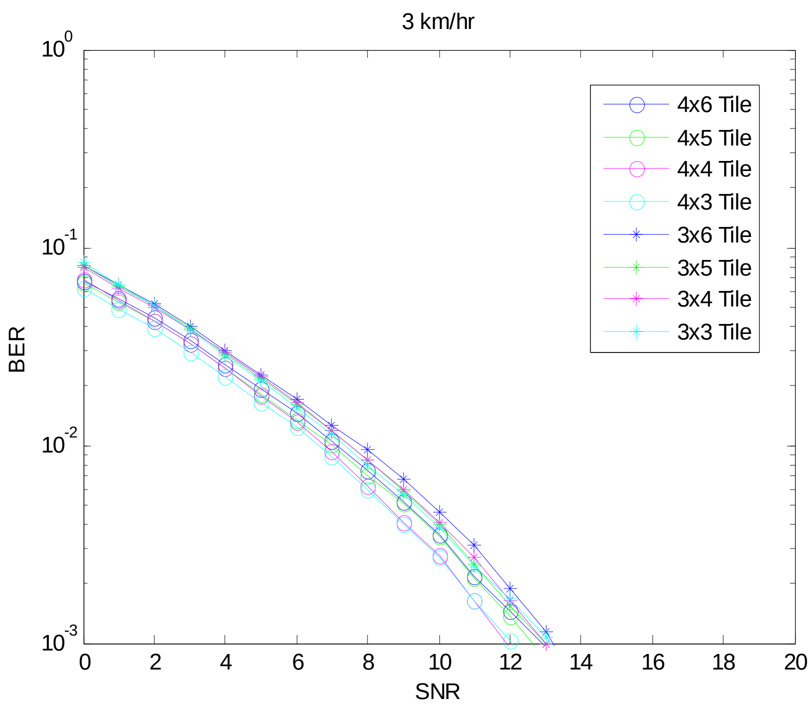

Fig. 14. BER vs. SNR with various tile size when the MS is moving at velocity 3 *km/hr*

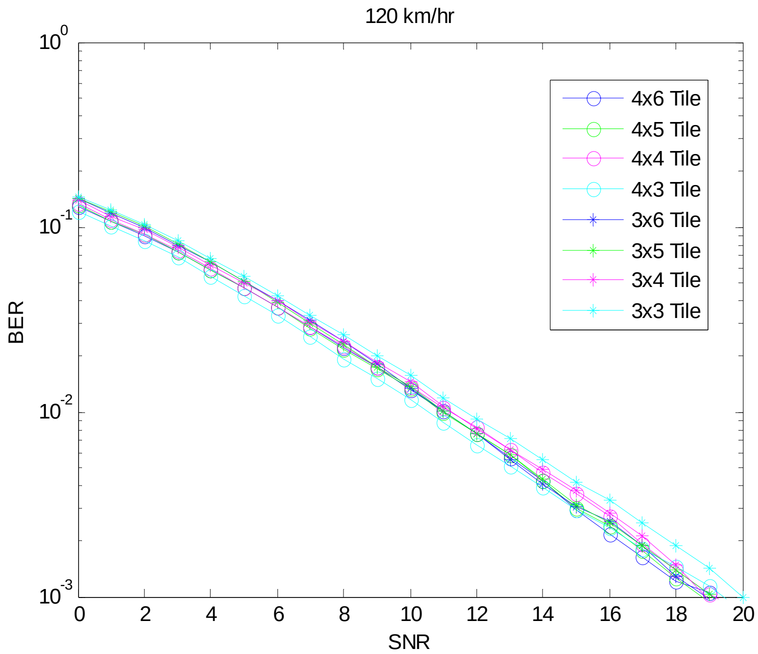

Fig. 15. BER vs. SNR with various tile size when the MS is moving at velocity 120 *km/hr*

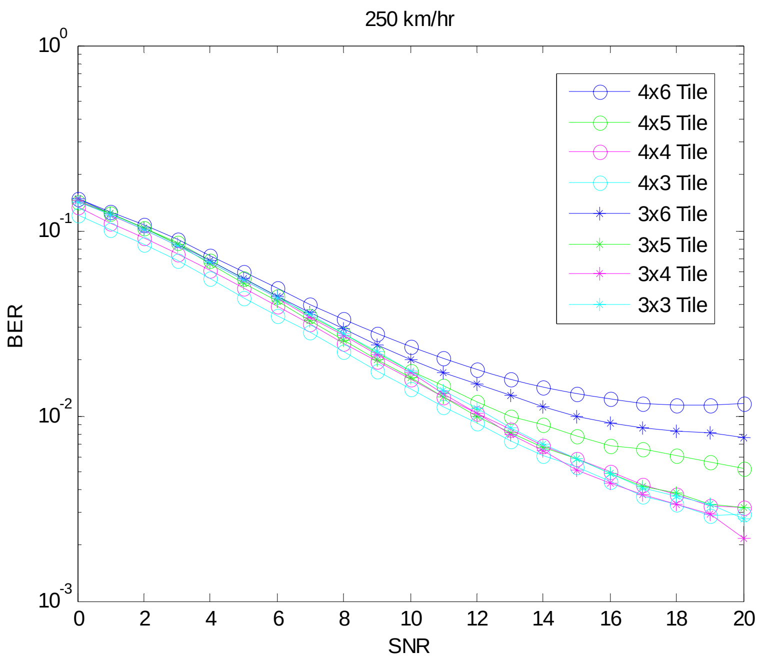

Fig. 16. BER vs. SNR with various tile size when the MS is moving at velocity 250 *km/hr*

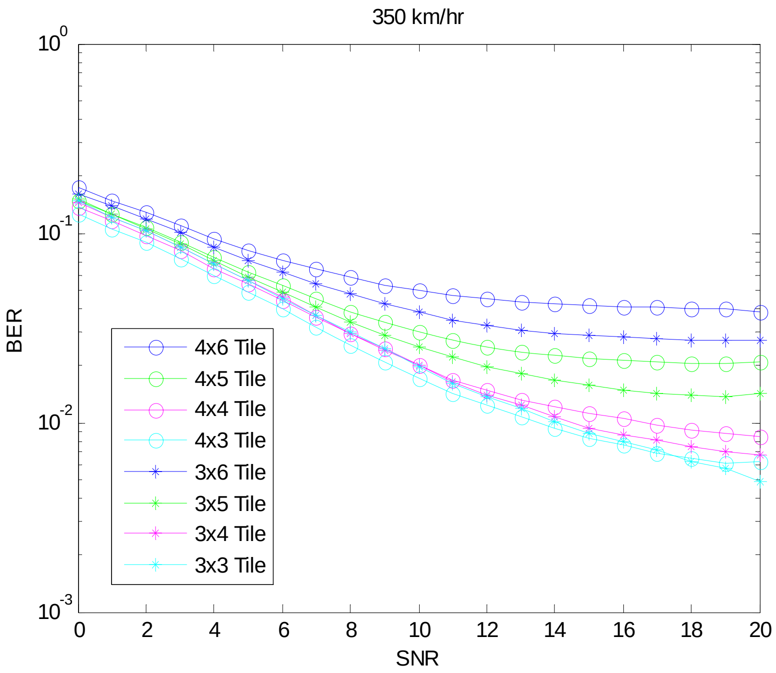

Fig. 17. BER vs. SNR with various tile size when the MS is moving at velocity 350 *km/hr*

B. Comparison to 18x3 and 24x3 slot for PUSC Pilot Pattern

In this example, the BER performances from two patterns of 18x3 and 24x3 slot as illustrated in Figure 12 and Figure 13 and tabulated in the following table are simulated and compared. In pattern 1, each slot in the four UL subframes enables to utilize the pilots on the adjacent slot so as to enhance the channel estimation for data tones located at the tiles edge; however, in pattern 2, each slot can use its own pilots to perform channel estimation. It has the simulation result as shown in Figure 17. From the figure it shows that the performance of pattern 2 is only slightly worse than the result obtained from pattern 1.

Table 2

Type	Parameters	Value
18x3	Number of DC Subcarriers	1
	Number of Guard Subcarriers: left, right	80, 79
	Number of Used Subcarriers (N_{used}) (including all possible pilot and the DC subcarrier)	865
	Number of Subchannels ($N_{Subchannels}$)	48
	Number of Tiles (N_{tiles})	288
	Number of Subcarriers per Tile	18
	Tile per Subchannel	6
24x3	Number of DC Subcarriers	1
	Number of Guard Subcarriers: left, right	92, 91
	Number of Used Subcarriers (N_{used}) (including all possible pilot and the DC subcarrier)	841
	Number of Subchannels ($N_{Subchannels}$)	35
	Number of Tiles (N_{tiles})	210
	Number of Subcarriers per Tile	24
	Tile per Subchannel	6

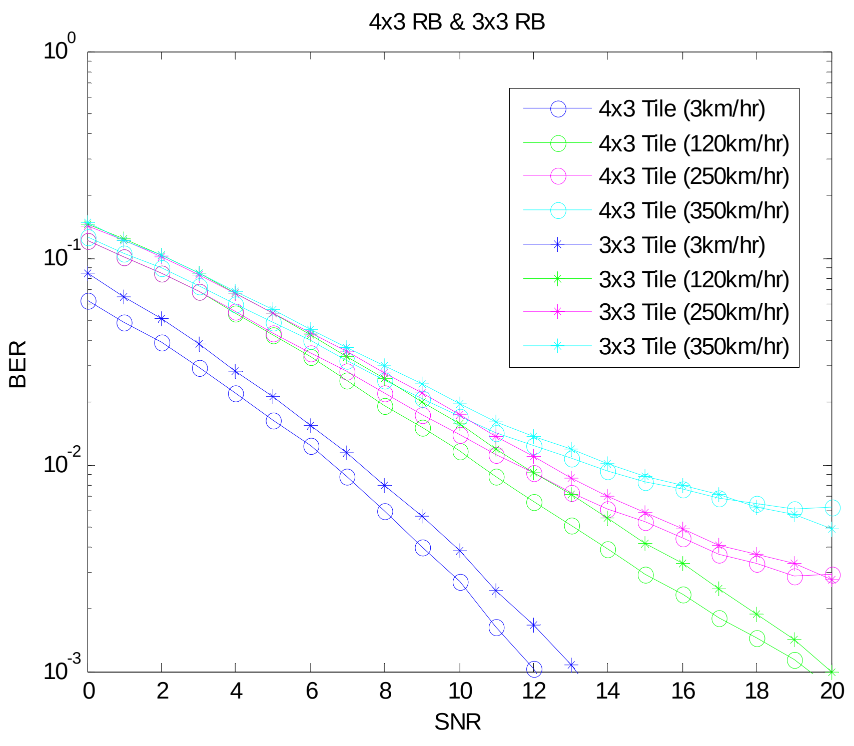

Fig. 18. BER vs. SNR with various slot size when the MS is moving at velocity 3 *km/hr*, 120 *km/hr*, 250 *km/hr* and 350 *km/hr*

4. *SP-Zone (Space-Zone) and MB-Zone (Mobility-Zone) for UL Pilot Design*

From the basic tile structure as defined in the previous section, the consideration of the radio environment such as it is indoor or outdoor transmission and the mobile moving status such as it is in stationary, mobility or in high mobility, we have SP-Zone (Space –Zone) and MB-Zone (Mobility Zone) as shown in Fig. 19. In the SP-Zone it determines the number of sub-carriers in the pilot spacing when it is in the indoor or outdoor environment. In the indoor transmission it needs to use a smaller number of sub-carriers in the pilot spacing to form a tile of the resource block than the number of sub-carriers required in the outdoor transmission since it has more serious multipath effect in the indoor than that in the outdoor environment. It is exemplified in Fig. 19. In the MB-Zone we determine the number of symbols in the pilot spacing when the mobile speed is in the status of stationary, mobility or high mobility situation and this determination of symbols required is based on its Doppler effect. When the mobile is moving in a higher speed it needs to use a larger number of symbols in the tile of a resource block than the mobile is moving in a lower speed since the higher speed mobile will have higher Doppler effect than that of a lower speed mobile. It is exemplified in Fig.19. It consequently considers the number of symbols required in determining the pilot spacing to form the tile of a resource block.

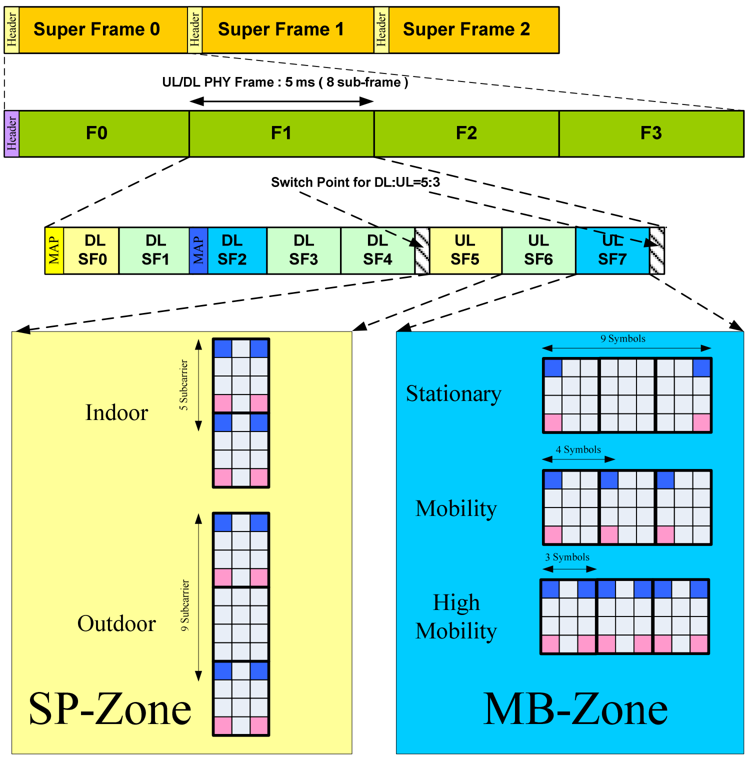

Fig.19 design example for the UL structure by using SP-Zone and MB-Zone

4.1 Design pilot for SP-Zone and MB-Zone

4.1.1 Basic unit for Pilot spacing in SP-Zone and MB-Zone

1) Basic uint for Pilot spacing

a. 3x3 Tile

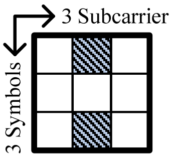

Fig. 20 3x3 Tile for 802.16m

b. 4x3 Tile

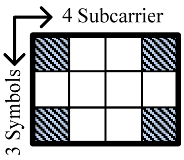

Fig. 22 4x3 Tile for 802.16m

2) Define range for Pilot spacing

Direction / Tile Type	Frequency Direction		Symbol Direction	
	Mini. Pilot Spacing	Max. Pilot Spacing	Mini. Pilot Spacing	Max. Pilot Spacing
3x3 Tile (Fig.8 and Fig.9)	4 Subcarrier	16 Subcarrier	3 Symbol	9 Symbol
4x3 Tile (Fig.10 and Fig.11)	4 Subcarrier	24 Subcarrier	3 Symbol	9 Symbol

5. Conclusion

This contribution provides some design considerations for 1-antenna and 2-antenna pilot structure design, which includes

Pilot spacing constraint: the pilots should be maximally spaced so that to improve the system spectral efficiency. The resulting pilot spacing is derived from the system parameters and requirements and based on the two-dimensional sampling theorem.

a) Pilots should encompass the remaining data tones as much as possible so as to reduce the usage of channel extrapolation.

b) It proposes to use the SP-Zone to determine the number of sub-carriers in the frequency domain and simultaneously to use the MB-Zone to determine the number of symbols in the time domain so that the mobile will have the best performance in its data transmission under various transmission environments.

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[6] IEEE 802.16m-07/037r2, "Draft IEEE 802.16m evaluation methodology."