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Title	**Propose for Uplink Pilot Design in IEEE 802.16m**
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Source(s)	Yih-Guang Jan, Yang-Han Lee, Ming-Hsueh Chuang, Hsien-Wei Tseng, Jheng-Yao Lin, Hsi-Chun Tseng, Po-Jung Lin, Ting-Chien Wang — yihjan@ee.tku.edu.tw Tamkang University (TKU) Shiann-Tsong Sheu — stsheu@ce.ncu.edu.tw National Central University (NCU)
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 uplink and provides some pilot structure examples for exposition.
Purpose	For discussion and approval by TGm
Notice	
Release	
Patent Policy	

Propose for Uplink Pilot Design in IEEE 802.16m

Yih-Guang Jan, Yang-Han Lee, Ming-Hsueh Chuang, Hsien-Wei Tseng, Jheng-Yao Lin,
Hsi-Chun Tseng, Po-Jung Lin, and Ting-Chien Wang
TKU
Shiann-Tsong Sheu
NCU

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. The design of UL pilot structure is based on the considerations of meeting the requirements of utilizing 1-antenna and 2-antenna into 802.16m and also to support the 802.16e. Based on the UL pilot structure designed 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 an MS in 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 the Maximum Delay Spread, f_d is the 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, $N_{subcarrier}$, and the number of symbols, N_{symbol}, for a pilot structure can be calculated as follows:

For D_f:

A time duration T_s for an OFDMA symbol is 91.43μs with 1/8 cyclic prefix (T_{cp}) as proposed, it has T_{cp} = 11.43μs, therefore the maximum delay will be bounded by 11.43μs, it corresponds to $D_f \leqq$ 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 $\lambda = c/f_c = 3\text{x}10^8/2.5\text{x}10^9 = 0.12$ *m*, then with the MS velocity set at 350 *km/hr*, its corresponding Doppler frequency is $f_d = \upsilon/\lambda$=810 *Hz*,and therefore the value of D_t 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:

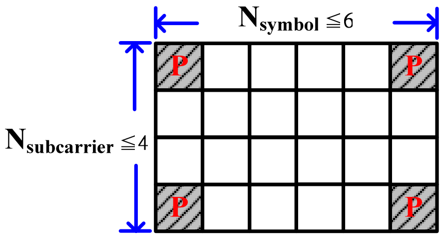


Fig. 1 The allocation of pilots

2.2 Channel Estimation Methods

The channel information generated from pilot tones that are located at the priori selected positions are used to generate the channel characteristic on the location of each data tone. The selection of the weighting coefficient for each pilot channel response in the estimation of channel characteristic for each data tone depends on the channel model used to characterize the channel environment and also 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 in our pilot structure design is to have most of the data tones be located in between the pilots so as to avoid channel extrapolations as much as possible.

2.3 Pilot Structure Examples

From 2-D sampling theory as described in section 2.1 we can evaluate 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 pilot patterns for various tiles and slots considered and recommended for 802.16e are depicted in Fig. 2–Fig. 7 [4]

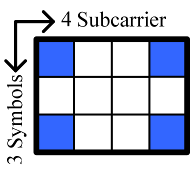


Fig. 2 1-antenna 4x3 tile for 802.16e

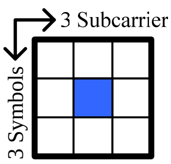


Fig. 3 1-antenna 3x3 tile for 802.16e

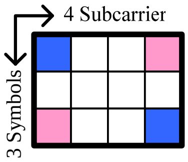


Fig. 4 2-antenna 4x3 tile for 802.16e

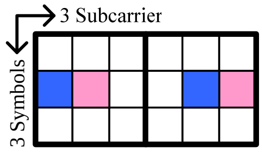


Fig. 5 2-antenna 3x3 tile for 802.16e

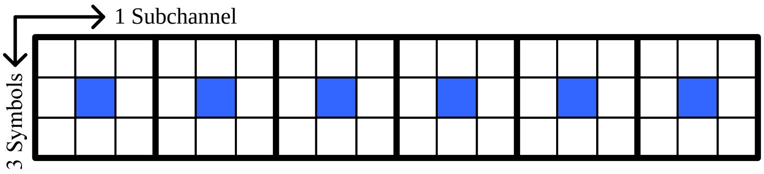


Fig. 6 Slot for 1-antenna 3x3 tile for 802.16e

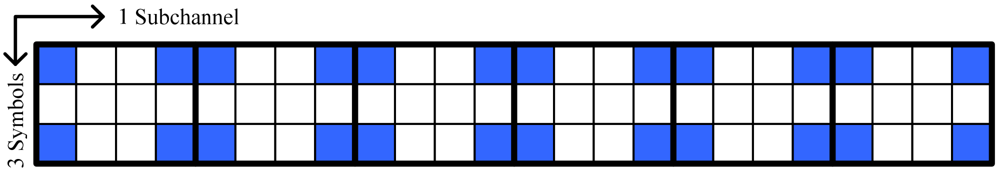


Fig. 7 Slot for 1-antenna 4x3 tile for 802.16e

2.3.2 Uplink Tile and Pilots Type for 802.16m

Based on the uplink pilot patterns for the 802.16e as described in the previous sub-section, we propose the following pilot structures for the uplink tiles and slots for 802.16m.

As described in Section 2.1 of our analysis, the number of symbols for a tile should be less than 6 while the number of subcarriers should be less than 4. As shown in Fig. 14 – Fig.16 when we decrease the symbols consequently from 6 to 3 the tile with size of 3x3 or 4x3 will generate the best performance at different mobile speeds therefore we select the tile with size 3x3 as our pilot structure.

We then define the size of a slot, the minimum size of a transmission unit. A slot is composed of 6 tiles therefore we have a slot of size 18x6 for a tile of size 3x3. In Fig. 11 it shows the pilot pattern for a slot of size 18x3 for 1-antenna system while it shows in Fug. 12 is the pilot pattern for a slot of size 18x3 for 2- antenna system. For a tile of size 4x3, it has a slot of size 24x3 for 2-antenna system as shown in Fig. 13.

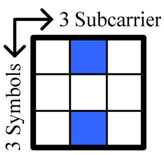


Fig. 8 1- antenna 3x3 tile for 802.16m

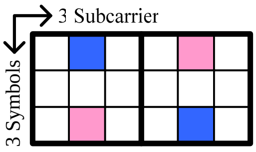


Fig. 9 2-antenna 3x3 tile for 802.16m

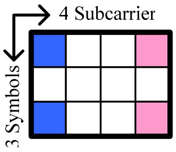


Fig. 10 2-antenna 4x3 tile for 802.16m

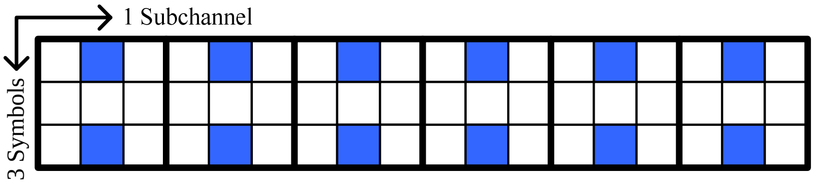


Fig. 11 Slot for 1-antenna 3x3 tile for 802.16m

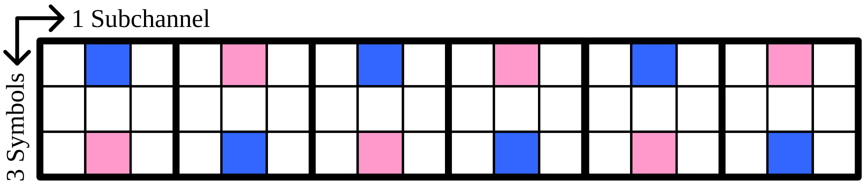


Fig. 12 Slot for 2-antenna 3x3 tile for 802.16m

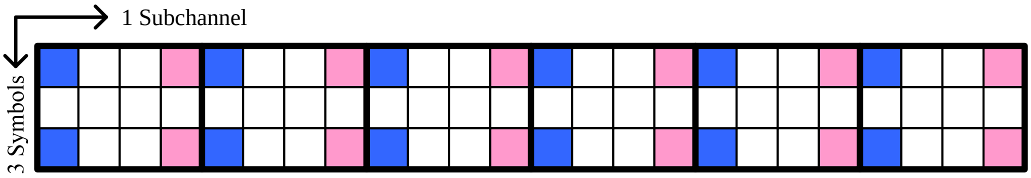


Fig. 13 Slot for 2-antenna 4x3 tile for 802.16m

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 locations of 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. Performance Comparison with Pilot Structures for Tiles Considered in the STC PUSC Model

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

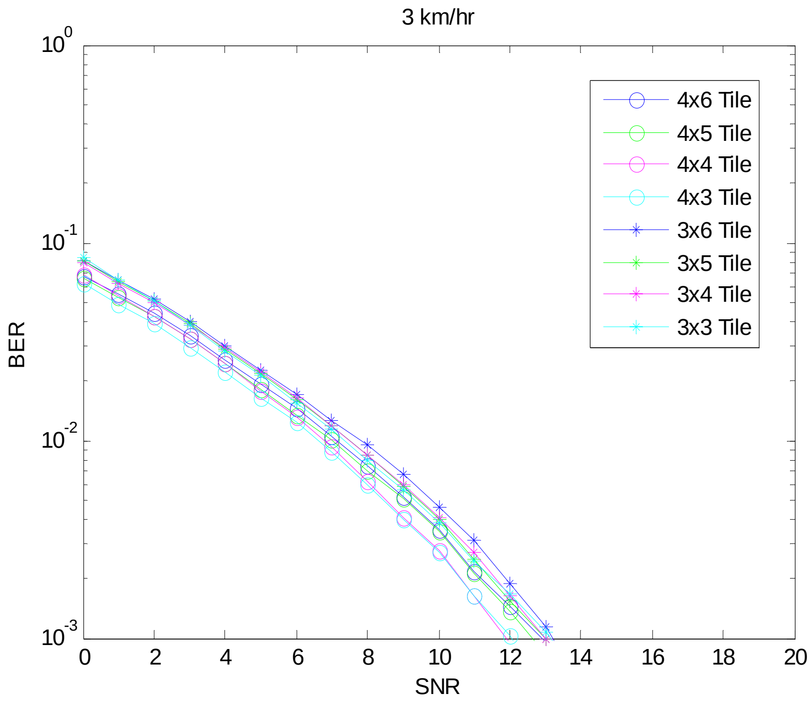


Fig. 14. BER vs. SNR with various tile size when the MS is moving at velocity 3 *km/hr*

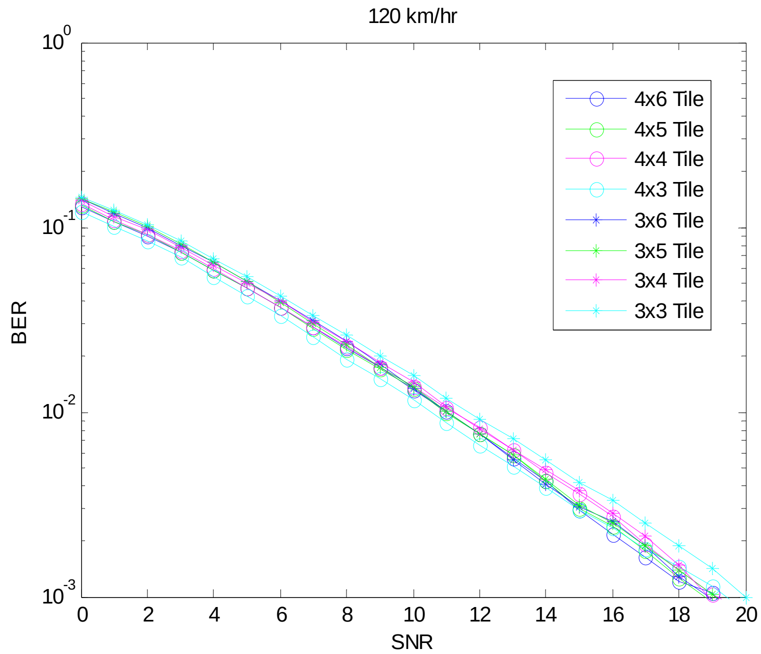


Fig. 15. BER vs. SNR with various tile size when the MS is moving at velocity 120 *km/hr*

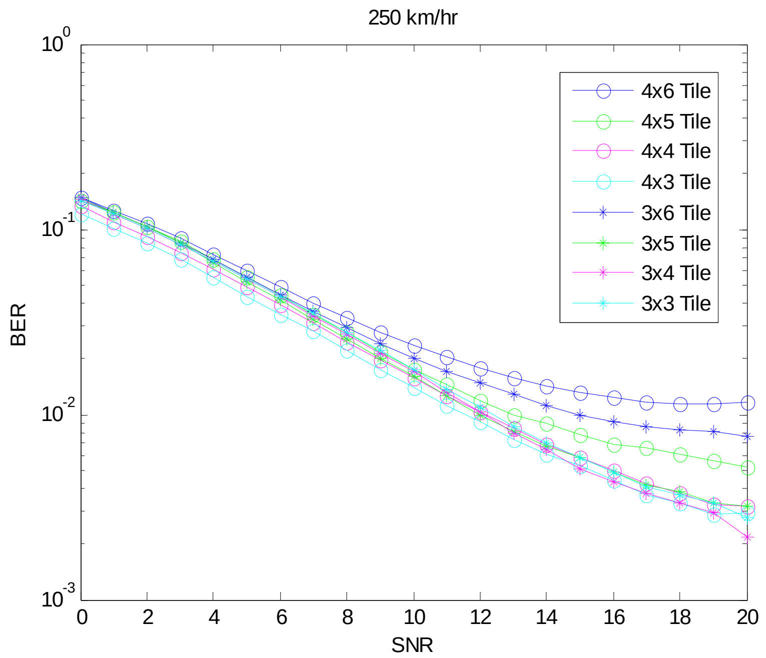


Fig. 16. BER vs. SNR with various tile size when the MS is moving at velocity 250 *km/hr*

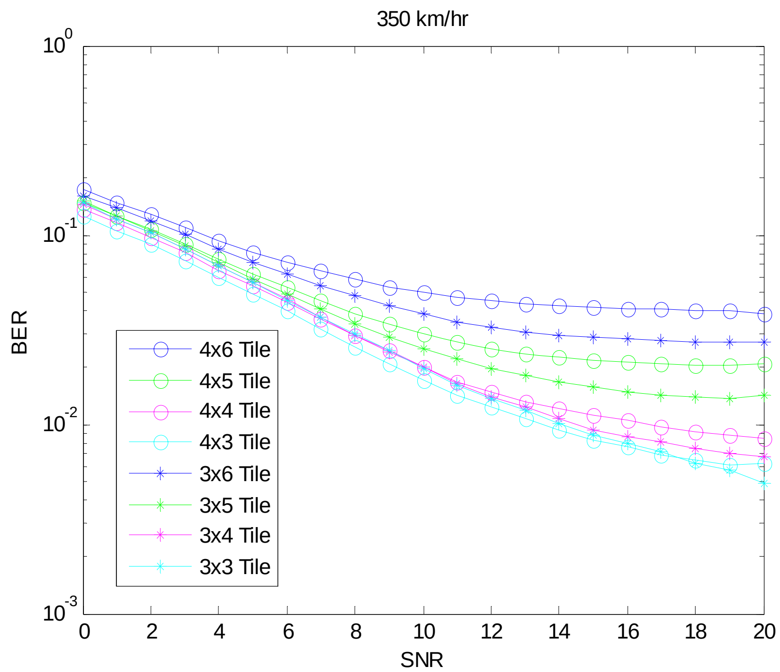


Fig. 17. BER vs. SNR with various tile size when the MS is moving at velocity 350 *km/hr*

B. Performance Comparison with Pilot Structures for Slots Considered in the STC PUSC Model

In this example, the BER performances for slots of 18x3 and 24x3 as illustrated in Figs. 12 and 13 and with other parameters as tabulated in Table 2 are simulated and compared. In the 24x3 pattern , each tile in the four UL subframes enables to utilize the pilots on the adjacent tile so as to enhance the channel estimation for data tones located at the tiles edge; however, in the 18x3 pattern, each tile can use its own pilots to perform channel estimation. Its simulation result is shown in Fig. 18.   From the figure it shows that the performance of 18x3 pattern is only slightly worse than the result obtained from 24x3 pattern.

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

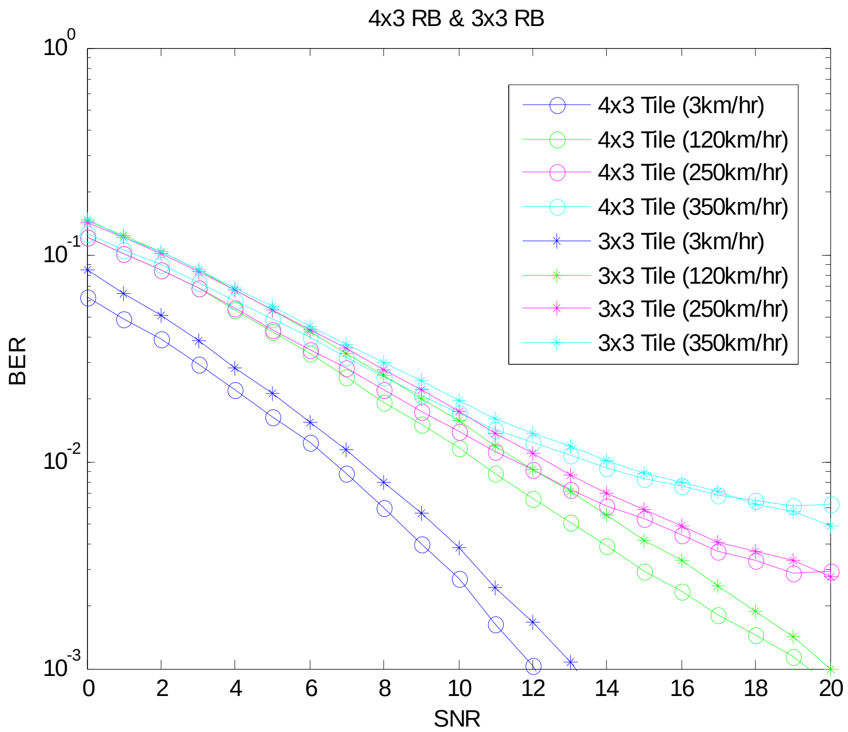


Fig. 18. BER vs. SNR with various slot size when the MS moves at velocity 3 *km/hr*, 120 *km/hr*, 250 *km/hr* and 350 *km/hr*

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 and by considering the radio environment such as the indoor or outdoor transmission and the mobile moves speed such as it is in the status of stationary, mobility or high mobility, we propose to define SP-Zone (Space –Zone) and MB-Zone (Mobility Zone) as shown in Fig. 19. In the SP-Zone it selects the number of sub-carriers between 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 between 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 between pilot spacing when the mobile moves in various speed, and this determination is based on the magnitude of its Doppler effect. When the mobile moves in a higher speed it needs to use more symbols in the tile of a resource block than the mobile moves in a lower speed since the higher speed mobile will have higher Doppler effect than that of a lower speed mobile. It is also exemplified in Fig.19.

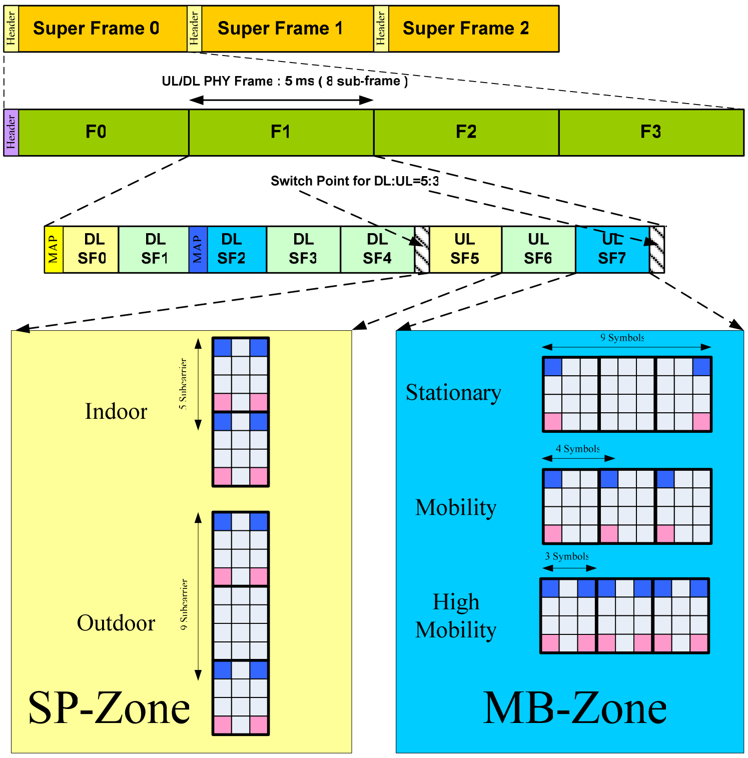


Fig.19 Design example for the UL pilot structure by using SP-Zone and MB-Zone

4.1 Pilot Structure for SP-Zone and MB-Zone

4.1.1 Pilot Structure in a Basic Tile Unit in SP-Zone and MB-Zone

1) Pilot Structure in a Basic Tile Unit

a. 3x3 tile

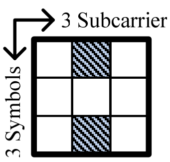


Fig. 20 3x3 tile for 802.16m

b. 4x3 tile

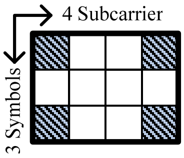
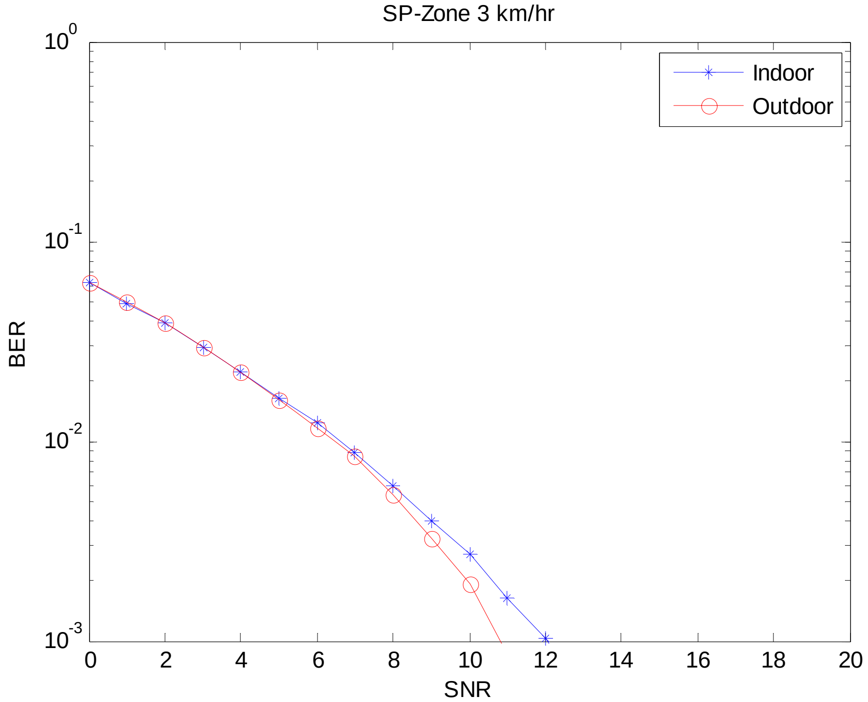
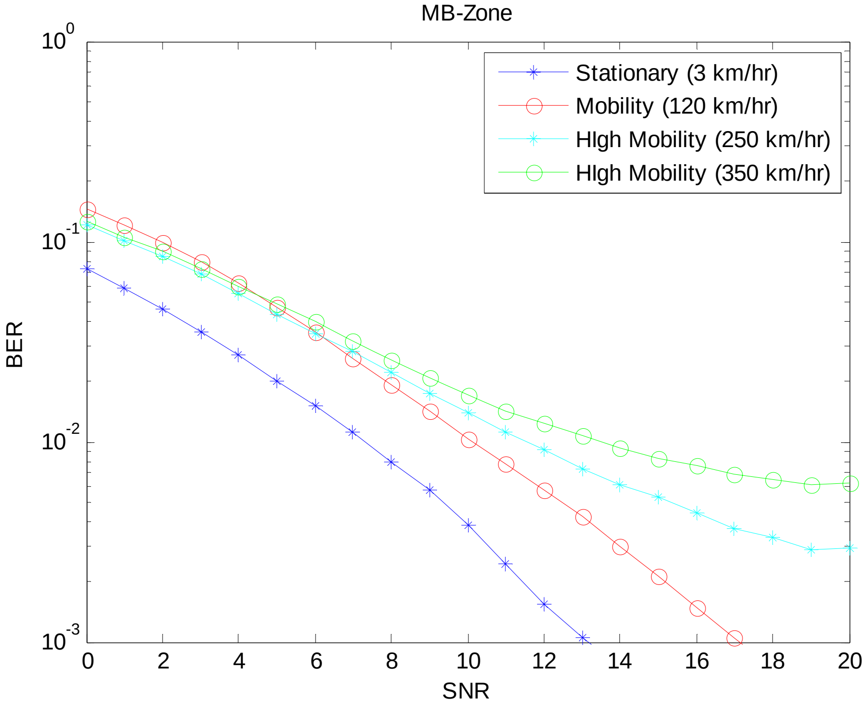


Fig. 22 4x3 tile for 802.16m

2) Ranges of Subcariers and Symbols Between Pilot Spacing in SP-Zone and MB-Zone

Direction / Tile Type	Subcarrier Direction		Symbol Direction	
	Minimum Pilot Spacing	Maximum Pilot Spacing	Minimum Pilot Spacing	Maximum 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 of pilot structure for 1-antenna and 2-antenna 802.16m. The pilots should be maximally spaced so as to improve the system spectral efficiency, meanwhile they should also encompass the remaining data tones in the tile/slot units as much as possible so as to reduce the usage of channel extrapolation. We also propose in this contribution to use SP-Zone and MB-zone concepts to design pilot structure so that to use different numbers of subcarriers and symbols between pilots according to the radio environment and mobile speed so that the MS and BS will always have better system performance than by using the conventional fixed number of subcarriers and symbols between pilots.

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[2] IEEE 802.16m-07/002r4, "IEEE 802.16m system requirements."

[3] W. H. Press, S. A. Teukolsky, W. T. Vetterling, and B. P. Flannery, Numerical recipes in C: the art of scientific computing, Second Edition, Cambridge University Press, 1995.

[4] IEEE Std 802.16e-2005 and IEEE Std 802.16-2004/Cor1-2005 (Amendment and Corrigendum to IEEE Std 802.16-2004), "IEEE Standard for local and metropolitan area networks, Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems, Amendment 2: Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in License Bands," Feb 28, 2006

[5] IEEE C802.16m-08/008, "Proposed frame structure for IEEE 802.16m."

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