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| Release |  |
| Patent Policy |  |

# Propose for Pilot Design in IEEE 802.16m

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## *1. Introduction*

From the contributions in the reference, several pilot patterns were proposed for DL transmission. The uplink pilot pattern could be derived from those downlink pilot patterns. In this contribution we simulate the system performance with different pilot patterns proposed for 802.16m to provide a reference for how to assign pilot patterns for the downlink and uplink for various resource blocks. We also introduce the concept of pilot interference weight (denoted as pilot correlation coefficient) so that various pilot patterns and their combinations can be arranged and designed when a particular interference weight is considered. This combination of pilot patterns can also be used for the identification of users.

## *2. Simulation environment*

In Table 1 we list the overall system parameters used in the simulation and consider three types of resource blocks (RB), namely 6 symbols * 18 subcarriers, 18 * 6, 6 symbols * 12 subcarriers, 12 * 6 and 6 symbols * 10 subcarriers, 10 * 6 in the simulation. The detailed 1024 subcarriers allocations for 18*6, 12*6 and 10*6 resource blocks are tabulated in Table 2.

Table 1. Simulation parameters

| Parameter | Baseline |
|---|---|
| Carrier Frequency | 2.5 GHz |
| System BW | 10 MHz |
| Channel Model | Veh A. with 3km/hr, 60km/hr and 120km/hr |
| Channel Coding | Convolutional Code |
| Antenna Configuration | 2x2 MIMO |
| Modulation and Coding | QPSK |
| Resource Allocation | 1. 6 symbols * 18 subcarriers<br>2. 6 symbols * 12 subcarriers<br>3. 6 symbols * 10 subcarriers |
| Coding Rate | 0.5 |
| Pilot Tone Boost | 2.5dB over data tone |
| Channel Estimation | LS |

Table 2. 1024 FFT OFMDA Subcarrier Allocation

| Type | Parameters | Value |
| --- | --- | --- |
| Type A (18x6) | Number of DC Subcarriers | 1 |
| | Number of Guard Subcarriers: left, right | 80, 79 |
| | Number of Used Subcarriers ($N_{used}$) (including all possible allocated pilots 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 |
| Type B (18x6) | Number of DC Subcarriers | 1 |
| | Number of Guard Subcarriers: left, right | 80, 79 |
| | Number of Used Subcarriers ($N_{used}$) (including all possible allocated pilots 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 |
| Type C (12x6) | Number of DC Subcarriers | 1 |
| | Number of Guard Subcarriers: left, right | 80, 79 |
| | Number of Used Subcarriers ($N_{used}$) (including all possible allocated pilots and the DC subcarrier) | 865 |
| | Number of Subchannels ($N_{Subchannels}$) | 72 |
| | Number of Tiles ($N_{tiles}$) | 432 |
| | Number of Subcarriers per Tile | 12 |
| | Tile per Subchannel | 6 |
| Type D (10x6) | Number of DC Subcarriers | 1 |
| | Number of Guard Subcarriers: left, right | 92, 91 |
| | Number of Used Subcarriers ($N_{used}$) (including all possible allocated pilots and the DC subcarrier) | 841 |
| | Number of Subchannels ($N_{Subchannels}$) | 84 |
| | Number of Tiles ($N_{tiles}$) | 504 |
| | Number of Subcarriers per Tile | 10 |
| | Tile per Subchannel | 6 |
| Type E (12x6) | Number of DC Subcarriers | 1 |
| | Number of Guard Subcarriers: left, right | 80, 79 |
| | Number of Used Subcarriers ($N_{used}$) (including all possible allocated pilots and the DC subcarrier) | 865 |
| | Number of Subchannels ($N_{Subchannels}$) | 72 |
| | Number of Tiles ($N_{tiles}$) | 432 |
| | Number of Subcarriers per Tile | 12 |
| | Tile per Subchannel | 6 |

## *3. Simulation of using various types of resource block*

### *1) Type A RB*

As shown in Fig. 1 it is a 18* 6 resource block with 18 subcarriers and 6 symbols in a resource block with pilot patterns as depicted in the gray square block. From these pilot patterns we select and consider only seven possible types of pilot pattern, types A1 ~ A7. The system performance, expressed by BER vs. QPSK signal to noise ratio, has the results as shown in Fig. 2(a), Fig. 2(b) and Fig. 2(c) for the mobile speed at 3 km,/hr, 60 km/hr and 120 km/hr respectively. For a fixed BER it lists in Table 3, from the results of Fig. 2, the required signal vs. noise ratio to meet the required BER for pilot types A1 ~ A7. By observing this table it finds that with the same pilot pattern density various types of pilot pattern have very close results. Specifically we can use the orthogonal characteristic of Type A3 and Type A4 pilot patterns and select them in the BS communication links so as to reduce the interference influence.

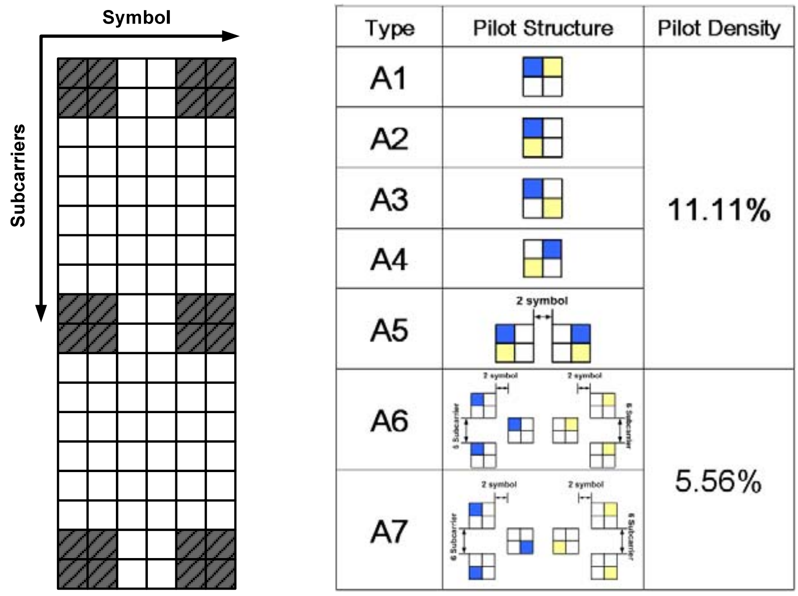
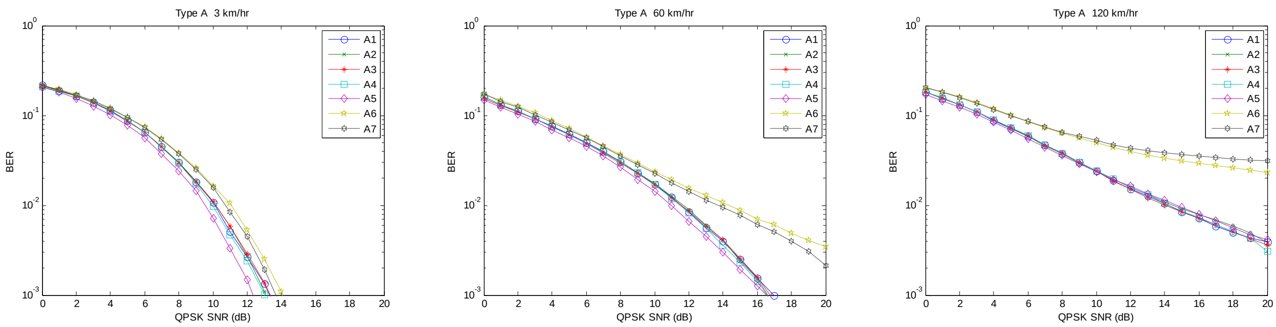



Fig 2. Different pilot pattern for Type A RB




*(a)* *(b)* *(c)*

Fig 2. Simulation Result for Type A RB at (a) 3 km/hr (b) 60 km/hr (c) 120 km/hr

Table 3 Summary of system performance for Type A1~ A7 pilot patterns for Type A resource block

| Speed / Type | 3 km/hr (Low Mobility) | 60 km/hr | 120 km/hr (High Mobility) |
|---|---|---|---|
| A1 @BER=$10^{-2}$ Pilot Density=11.11% | BER= 10 dB | BER= 11 dB | BER= 14 dB |
| A2 @BER=$10^{-2}$ Pilot Density=11.11% | BER= 10 dB | BER= 11 dB | BER= 14 dB |
| A3 @BER=$10^{-2}$ Pilot Density=11.11% | BER= 10 dB | BER= 11 dB | BER= 14 dB |
| A4 @BER=$10^{-2}$ Pilot Density=11.11% | BER= 10 dB | BER= 11 dB | BER= 14 dB |
| A5 @BER=$10^{-2}$ Pilot Density=11.11% | BER= 10 dB | BER= 11 dB | BER= 14 dB |
| A6 @BER=$10^{-2}$ Pilot Density=5.56% | BER= 11 dB | BER= 14 dB | |
| A7 @BER=$10^{-2}$ Pilot Density=5.56% | BER= 11 dB | BER= 14 dB | |

***2) Type B RB***

As shown in Fig.3, it is a 18* 6 resource block Type B with 18 subcarriers and 6 symbols in a resource block with pilot patterns as depicted in the gray square block. From these pilot patterns we select and consider only five possible types of pilot pattern, types B1 ~ B5. The system performance, expressed by BER vs. QPSK signal to noise ratio, has the results as shown in Fig. 4(a), Fig. 4(b) and Fig. 4(c) for the mobile speed at 3 km,/hr, 60 km/hr and 120 km/hr respectively. For a fixed BER it lists in Table 4, from the results of Fig. 4, the required signal vs. noise ratio to meet the required BER for pilot types B1 ~ B5. By observing this table it finds that with the same pilot pattern density various types of pilot patterns have very close results.

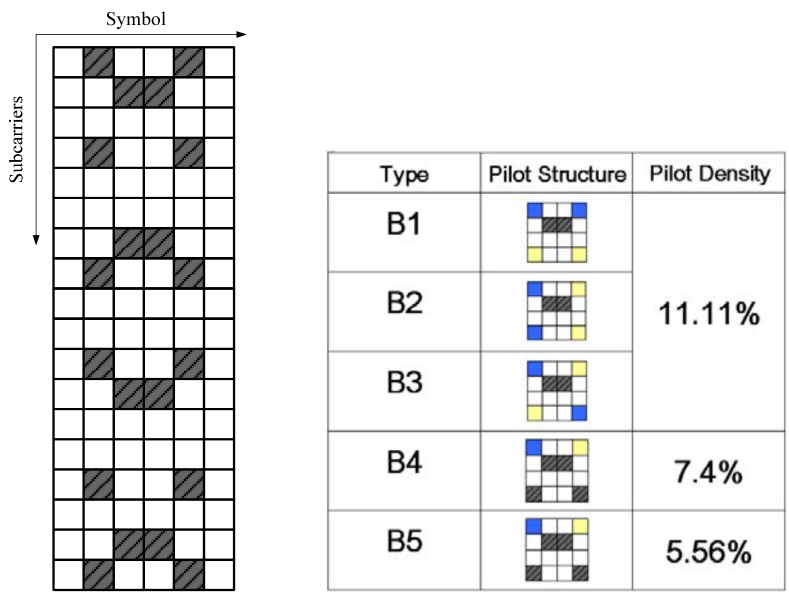
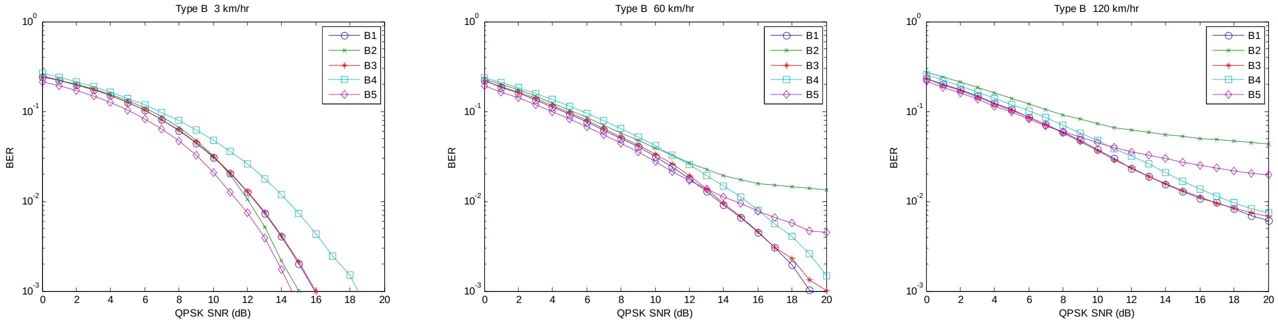



Fig 3. Different pilot pattern for Type B RB




*(a)* *(b)* *(c)*

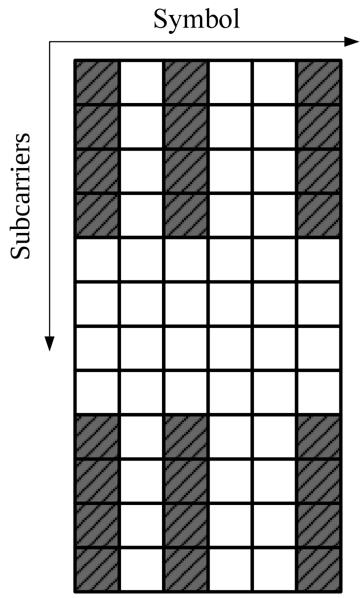
Fig 4. Simulation Result for Type B RB at (a) 3 km/hr (b) 60 km/hr (c) 120 km/hr

Table 4 Summary of system performance for Type B1~ B5 pilot patterns for Type B resource block

| Speed / Type | 3 km/hr (Low Mobility) | 60 km/hr | 120 km/hr (High Mobility) |
|---|---|---|---|
| B1 @BER=$10^{-2}$ Pilot Density=11.11% | BER= 12 dB | BER= 14 dB | BER= 16 dB |
| B2 @BER=$10^{-2}$ Pilot Density=11.11% | BER= 12 dB | | |
| B3 @BER=$10^{-2}$ Pilot Density=11.11% | BER= 12 dB | BER= 14 dB | BER= 16 dB |
| B4 @BER=$10^{-2}$ Pilot Density=7.4% | BER= 14 dB | BER= 15 dB | BER= 18 dB |
| B5 @BER=$10^{-2}$ Pilot Density=5.56% | BER= 11 dB | BER= 15 dB | |

***3) Type C RB***

As shown in Fig.5, it is a 12* 6 resource block Type C with 12 subcarriers and 6 symbols in a resource block with pilot patterns as depicted in the gray line block. From these pilot patterns we select and consider only six possible types of pilot pattern, types C1 ~ C6. The system performance, expressed by BER vs. QPSK signal to noise ratio, has the results as shown in Fig. 6(a), Fig. 6(b) and Fig. 6(c) for the mobile speed at 3 km,/hr, 60 km/hr and 120 km/hr respectively. For a fixed BER it lists in Table 5, from the results of Fig. 6, the required signal vs. noise ratio to meet the required BER for pilot types C1 ~ C6. By observing this table it finds that with the same pilot pattern density various types of pilot patterns have very close results.



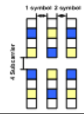
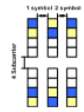
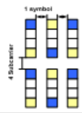
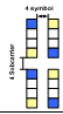
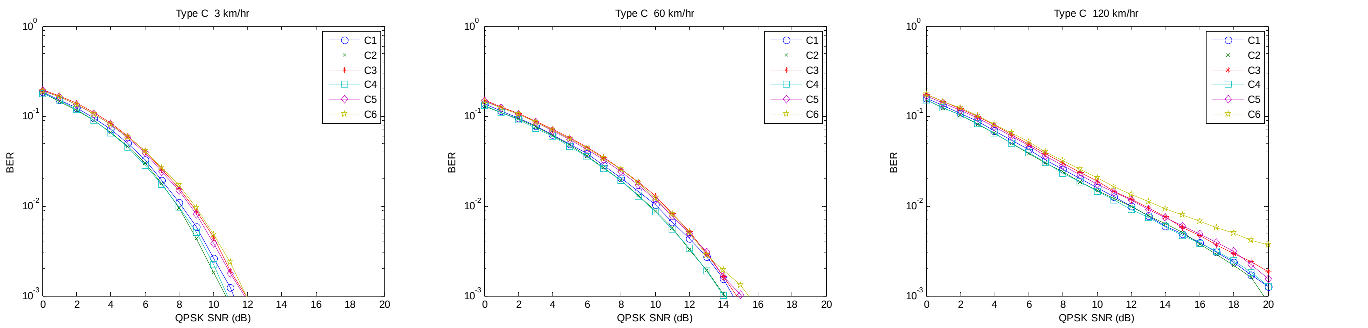

| Type | Pilot Structure | Pilot Density |
|---|---|---|
| C1 |  | 16.67% |
| C2 |  | |
| C3 |  | |
| C4 |  | |
| C5 |  | |
| C6 |  | 11.11% |

Fig 5. Different pilot pattern for Type C RB




*(a)* *(b)* *(c)*

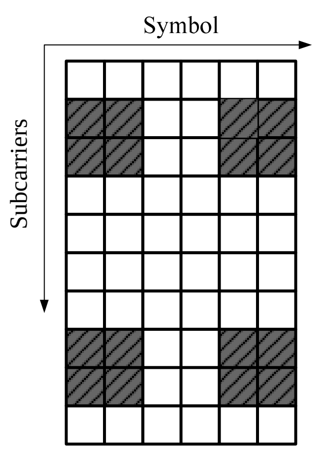
Fig 6. Simulation Result for Type C RB at (a) 3 km/hr (b) 60 km/hr (c) 120 km/hr

Table 5 Summary of system performance for Type C1~ C6 pilot patterns for Type C resource block

| Speed / Type | 3 km/hr (Low Mobility) | 60 km/hr | 120 km/hr (High Mobility) |
|---|---|---|---|
| C1 @BER=$10^{-2}$ Pilot Density=16.67% | BER= 8 dB | BER= 11 dB | BER= 12 dB |
| C2 @BER=$10^{-2}$ Pilot Density=16.67% | BER= 8 dB | BER= 11 dB | BER= 12 dB |
| C3 @BER=$10^{-2}$ Pilot Density=16.67% | BER= 9 dB | BER= 11 dB | BER= 13 dB |
| C4 @BER=$10^{-2}$ Pilot Density=16.67% | BER= 8 dB | BER= 11 dB | BER= 12 dB |
| C5 @BER=$10^{-2}$ Pilot Density=16.67% | BER= 9 dB | BER= 11 dB | BER= 13 dB |
| C6 @BER=$10^{-2}$ Pilot Density=11.11% | BER= 9 dB | BER= 14 dB | BER= 14 dB |

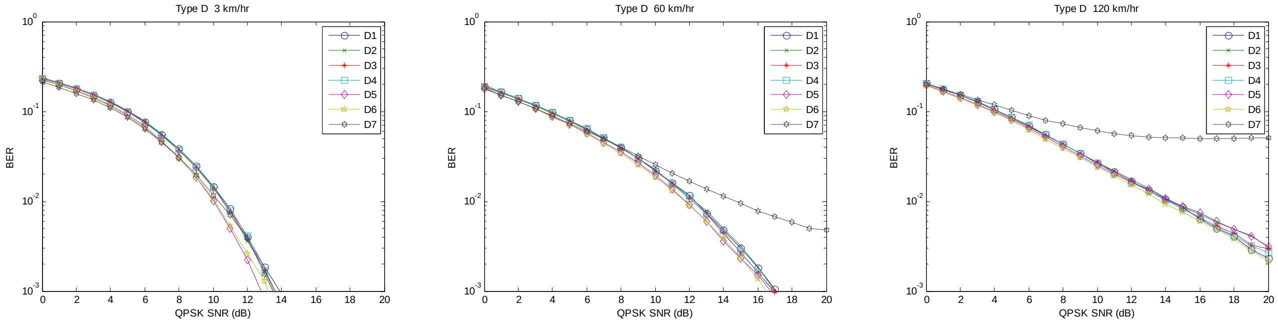
***4) Type D RB***

As shown in Fig.7, it is a 10* 6 resource block Type D with 10 subcarriers and 6 symbols in a resource block with pilot patterns as depicted in the gray square block. From these pilot patterns we select and consider only six possible types of pilot pattern, types D1 ~ D7. The system performance, expressed by BER vs. QPSK signal to noise ratio, has the results as shown in Fig. 8(a), Fig. 8(b) and Fig.8(c) for the mobile speed at 3 km,/hr, 60 km/hr and 120 km/hr respectively. For a fixed BER it lists in Table 6, from the results of Fig. 6, the required signal vs. noise ratio to meet the required BER for pilot types D1 ~D7. By observing this table it finds that with the same pilot pattern density various types of pilot patterns have very close results. Specifically we can use the orthogonal characteristic of Type D3 and Type D4 pilot patterns and select them in the BS communication links so as to reduce the interference influence.




| Type | Pilot Structure | Pilot Density |
|---|---|---|
| D1 | | 13.33% |
| D2 | | |
| D3 | | |
| D4 | | |
| D5 | 2 symbol | |
| D6 | 4 Subcarrier | |
| D7 | 2 symbol, 4 Subcarrier | 6.66% |

Fig 7. Different pilot pattern for Type D RB




*(a)* *(b)* *(c)*

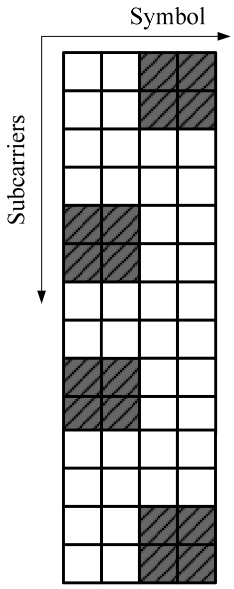
Fig 8. Simulation Result for Type D RB at (a) 3 km/hr (b) 60 km/hr (c) 120 km/hr

Table 6 Summary of system performance for Type D1~ D7 pilot patterns for Type D resource block

| Speed / Type | 3 km/hr (Low Mobility) | 60 km/hr | 120 km/hr (High Mobility) |
|---|---|---|---|
| D1 @BER=$10^{-2}$ Pilot Density=13.33% | BER= 11 dB | BER= 12 dB | BER= 14 dB |
| D2 @BER=$10^{-2}$ Pilot Density=13.33% | BER= 11 dB | BER= 12 dB | BER= 14 dB |
| D3 @BER=$10^{-2}$ Pilot Density=13.33% | BER= 11 dB | BER= 12 dB | BER= 14 dB |
| D4 @BER=$10^{-2}$ Pilot Density=13.33% | BER= 11 dB | BER= 12 dB | BER= 14 dB |
| D5 @BER=$10^{-2}$ Pilot Density=13.33% | BER= 10 dB | BER= 12 dB | BER= 14 dB |
| D6 @BER=$10^{-2}$ Pilot Density=13.33% | BER= 10 dB | BER= 12 dB | BER= 14 dB |
| D7 @BER=$10^{-2}$ Pilot Density=6.66% | BER= 10 dB | BER= 15 dB | |

***5) Type E RB***

As shown in Fig.9, it is a 14* 2 resource block Type E with 14 subcarriers and 2 symbols in a resource block with pilot patterns as depicted in the gray square block. From these pilot patterns we select and consider only six possible types of pilot pattern, types E1 ~ E7. The system performance, expressed by BER vs. QPSK signal to noise ratio, has the results as shown in Fig. 10(a), Fig. 10(b) and Fig.10(c) for the mobile speed at 3 km,/hr, 60 km/hr and 120 km/hr respectively. For a fixed BER it lists in Table 7, from the results of Fig. 10, the required signal vs. noise ratio to meet the required BER for pilot types E1 ~ E7. By observing this table it finds that with the same pilot pattern density various types of pilot patterns have very close results. Specifically we can use the orthogonal characteristic of Type E3 and Type E4 pilot patterns and select them in the BS communication links so as to reduce the interference influence.



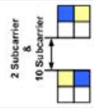
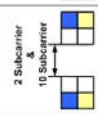
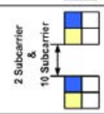
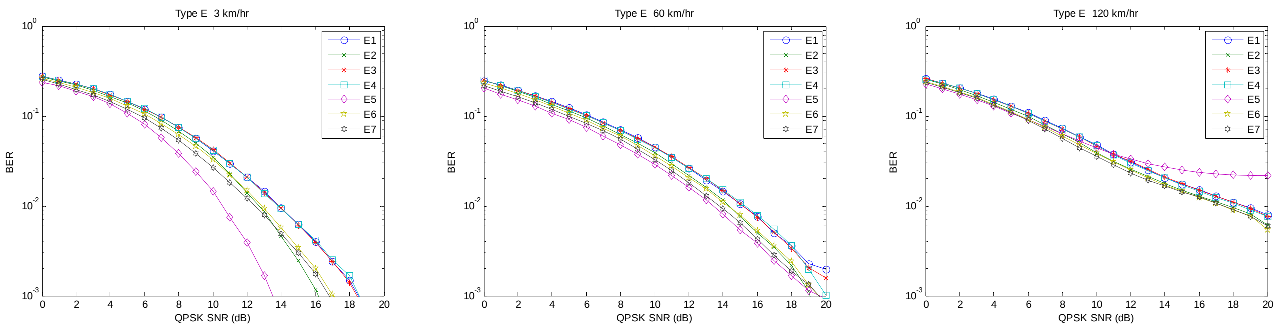

| Type | Pilot Structure | Pilot Density |
|---|---|---|
| E1 |  | 14.28% |
| E2 |  | |
| E3 |  | |
| E4 |  | |
| E5 |   | |
| E6 |   | |
| E7 |   | |

Fig 9. Different pilot pattern for Type E RB




*(a)* *(b)* *(c)*

Fig 10. Simulation Result for Type E RB at (a) 3 km/hr (b) 60 km/hr (c) 120 km/hr

Table 7 Summary of system performance for Type E1~ E7 pilot patterns for Type E resource block

| Speed / Type | 3 km/hr (Low Mobility) | 60 km/hr | 120 km/hr (High Mobility) |
|---|---|---|---|
| E1 @BER=$10^{-2}$ Pilot Density=14.28% | BER= 14 dB | BER= 15 dB | BER= 18 dB |
| E2 @BER=$10^{-2}$ Pilot Density=14.28% | BER= 13 dB | BER= 14 dB | BER= 18 dB |
| E3 @BER=$10^{-2}$ Pilot Density=14.28% | BER= 14 dB | BER= 15 dB | BER= 18 dB |
| E4 @BER=$10^{-2}$ Pilot Density=14.28% | BER= 14 dB | BER= 15 dB | BER= 18 dB |
| E5 @BER=$10^{-2}$ Pilot Density=13.33% | BER= 10 dB | BER= 13 dB | |
| E6 @BER=$10^{-2}$ Pilot Density=14.28% | BER= 13 dB | BER= 14 dB | BER= 18 dB |
| E7 @BER=$10^{-2}$ Pilot Density=14.28% | BER= 13 dB | BER= 14 dB | BER= 18 dB |

## 4. *Pilot Correlation Coefficient*

As shown in Fig. 17 and Fig. 18, we use the Type A and Type C pilot patterns as examples to illustrate the variations of ‘pilot correlation coefficient’. In Fig. 17 we consider six square pilot blocks with each square block consisting of four pilots. The ‘Basic’ pilot structure is defined as that in the six square pilot blocks each block contains the same pilot patterns. If we change a square pilot block to its corresponding orthogonal square block then the resulting overall pilots have only 20 pilots that have the same locations as the basic pilot structure and the pilot correlation coefficient is 20/24, designated as the 20/24 pilot structure in the figure. By continuingly invert the pilot locations in each four pilots block we can get the pilot structures of 16/24 till 0/24, i.e. in the designation of 16/24 it has with 16 pilots having the same pilot locations with the basic pilot structure and no similar pilots with the basic pilot structure in the 0/24 structure. Consequently for a pilot structure denoted as M/24 with 0<=M<=24 it has M pilots in 24 pilots with the same pilot locations with the basic pilot structure. Similarly in line type pilot structure as in Fig. 18 we can also define a pilot structure with certain pilot correlation coefficient comparing with the basic pilot structure.
Consequently if we use the Type A in Fig. 17 as an example it has a total possible pilot permutations of $6^6$(46656) and if we assign each pilot combination as an user ID, i.e. each pilot structure is an user ID then we can not only select certain pilot structures to guarantee low level of interference in the data transmission between MS and BS but also to have a systematic management and distribution of the users.

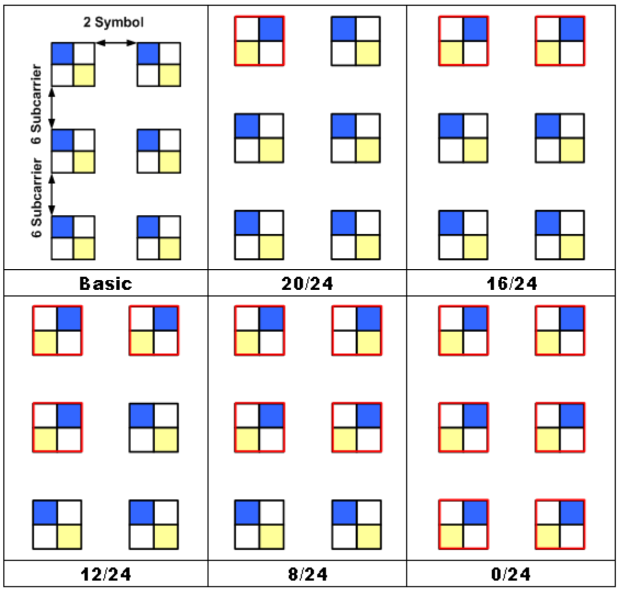



Fig 17. Certain pilot structures with different pilot correlation coefficient for square type pilot

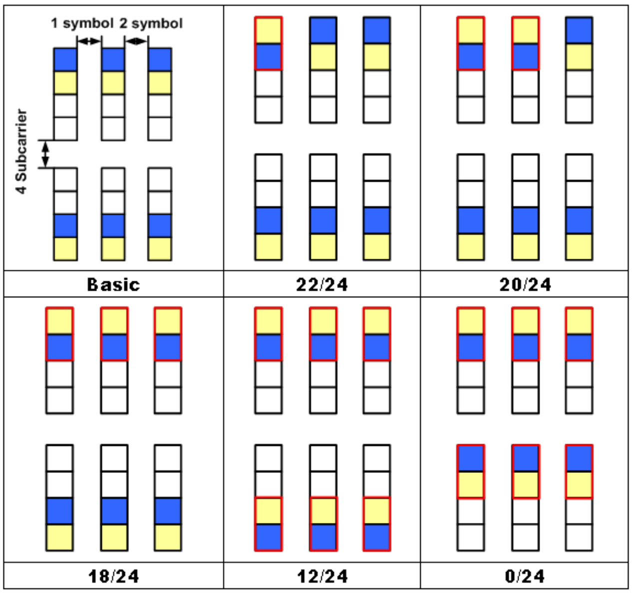



Fig 18. Certain pilot structures with different pilot correlation coefficient for line type pilot

## *5. Conclusion*

In this contribution we simulate the system performance for five types, Type A ~ Type E, pilot structures. It is observed that some the pilot patterns are orthogonal each other, and we can use this orthogonal characteristic to reduce the interference influence in the data transmission between BS and MS. We also propose to consider the characteristic of pilot correlation coefficient so that we can provide proper pilot patterns for various interference criterions. It can further use and assign different pilot patterns as users IDs, i.e. each user is assigned a distinct pilot pattern, therefore we can not only use different pilot patterns to reduce the communication interference between BS and MS but also to manage and distribute the users in a more systematic manner.

***REFERENCES***


[1] *IEEE 802.16m-08/121r1, Yuval Lomnitz, Huaning Niu, Jong-kae Fwu, Sassan Ahmadi, Hujun Yin, "Symbol structure design for 802.16m – resource block and pilots"*

[2] *IEEE 802.16m-08/123, Fred Vook, Tim Thomas, Mark Cudak, Bishwarup Mondal, Fan Wang, Kevin Baum, Jeff Zhuang, Amitava Ghosh, "Recommendations for Downlink Data Subchannel and Pilot Format Design in IEEE 802.16m*

[3] *IEEE 802.16m-08/139r2, Chih-Yuan Lin, Pei-Kai Liao, Ciou-Ping Wu, Paul Cheng, "Design Considerations of Pilot Structures for Downlink MIMO Transmission "*

[4] *IEEE 802.16m-08/153, Bin-Chul Ihm, Jinsoo Choi, Wookbong Lee, "Pilot related to DL MIMO"*

[5] *IEEE 802.16m-08/172r1, Dongsheng Yu, Mo-Han Fong, Jianglei Ma, Hang Zhang, Sophie Vrzic, Robert Novak, Jun Yuan, Anna Tee, Sang-Youb Kim, Kathiravetpillai Sivanesan, "Proposal for IEEE 802.16m Downlink Pilot Structure for MIMO"*

[6] *IEEE 802.16m-08/188r3, Taeyoung Kim, Jeongho Park, Junsung Lim, Jaeweon Cho, David Mazzarese, Hokyu Choi, Jaehee Cho, Heewon Kang, Yungsoo Kim, DS Park, "Design of Resource Allocation Unit Structure for IEEE 802.16m"*

[7] *IEEE 802.16m-08/194, Jihyung Kim, Seung Joon Lee, Young Seok Song, Byung-Jae Kwak, Choong Il Yeh, Wooram Shin, Dong Seung Kwon, "Resource block with pilot structure"*

[8] *IEEE 802.16m-08/004, "Project 802.16m Evaluation Methodology Document (EMD)"*