Proposal for IEEE 802.16m Downlink Pilot Structure for MIMO

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Re: IEEE 802.16m-08/005 – Call for Contributions on Project 802.16m System Description Document (SDD), on the topic of "Pilot structures as relevant to downlink MIMO" and "Downlink Physical Resource Allocation Unit (Resource blocks and Symbol Structures) "

Purpose: Adopt the proposal into the IEEE 802.16m System Description Document

Scope

- This contribution presents the IEEE 802.16m downlink MIMO pilot design
  - DL MIMO common pilot design
  - DL MIMO dedicated pilot design

IEEE 802.16m System Requirements

- The TGm SRD (IEEE 802.16m-07/002r4) specifies the following requirements:
  - Section 5.7 Support of advanced antenna techniques:
    - “IEEE 802.16m shall support MIMO, beamforming operation or other advanced antenna techniques. IEEE 802.16m shall further support single-user and multi-user MIMO techniques.”
  - Section 6.10 System overhead:
    - “Overhead, including overhead for control signaling as well as overhead related to bearer data transfer, for all applications shall be reduced as far as feasible without compromising overall performance and ensuring proper support of systems features.”
  - Section 7.11 Relative Performance and Section 7.2.1 Relative sector thorugput and VoIP capacity:
    - 2x performance gain over the legacy system is required
- The proposed pilot structure targets the above requirements by optimizing the pilot overhead for multi-antenna support

Background

- In the legacy 16e system, DL MIMO pilots are allocated in every OFDM symbol which require large overhead (10-20% for FUSC, 14-28% for PUSC, 11-22% for AMC).
- Other systems, such as LTE and UMB, have adopted more efficient scattered pilot design, which reduces pilot overhead while having the same or better performance.
  – Common pilot overhead: LTE: 4.8% for 1 Tx, 14.4% for 4 Tx, UMB: 3.1% for 1 Tx, 12.5% for 4 Tx
  – In both system, pilot overhead can be further decreased and still meet the requirement target
- As we consider a new frame structure for 802.16m, we should include a more optimum pilot design.
- With an optimal pilot design, reliable channel estimation should be achieved by using the minimum pilot overhead, under various channel conditions and mobility as required by 16m SRD and EVM:
  - Mobility: optimum performance for: 0-10 km/h; graceful degradation for: 10-120 km/h; connection maintained: 350 km/h
  - Baseline Channel models: ITU Pedestrian B, Vehicular A

Pilot Design Considerations

- Pilot overhead
  - Target of basic common pilot design: <4% for 1 Tx and < 13% for 4 Tx
- Channel estimation quality
- Support of various channel conditions
- CQI and MIMO channel measurement

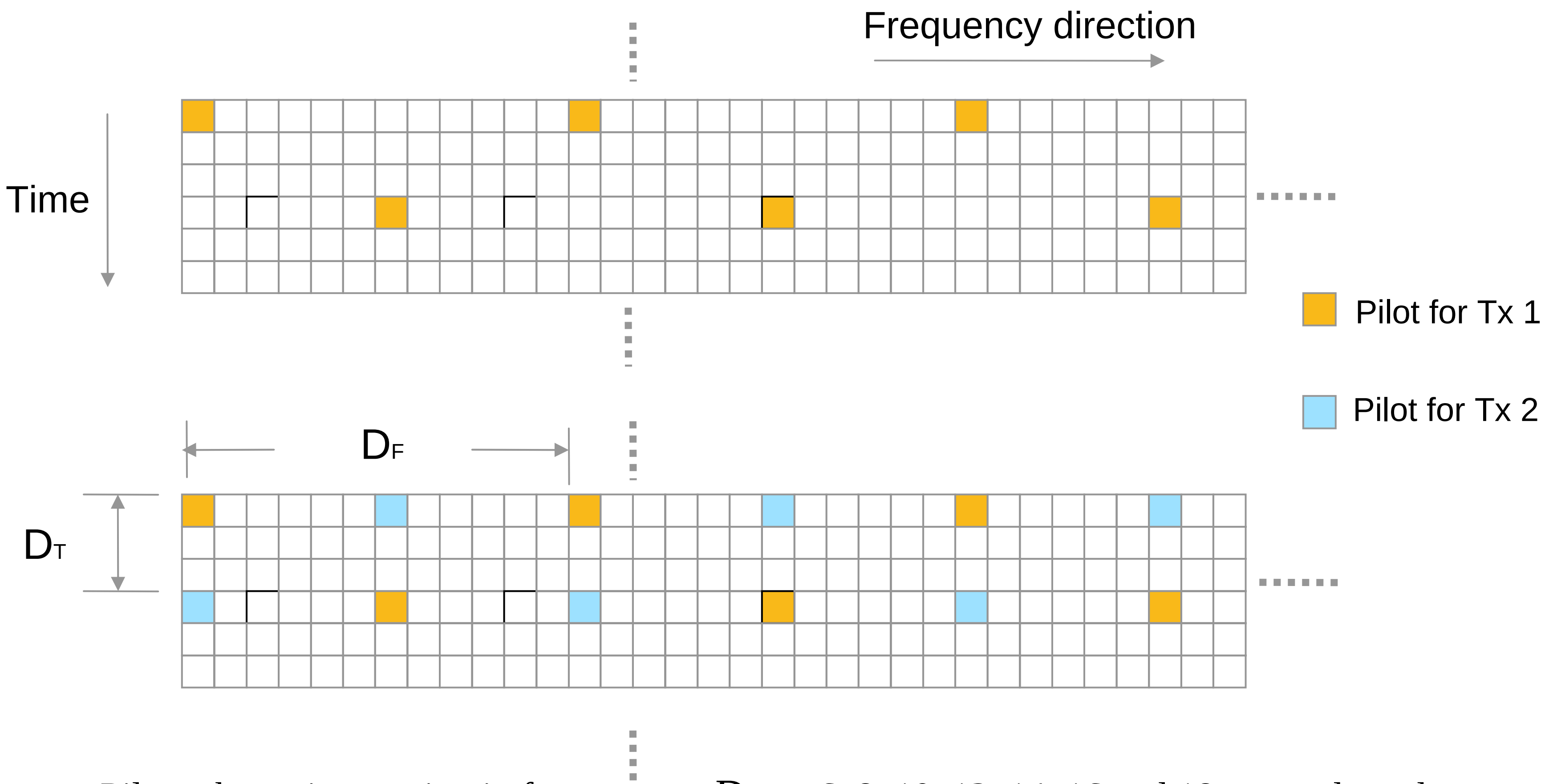
Overview of Downlink Pilot Design (1/2)

- Both common pilot and dedicated pilot are proposed for IEEE 802.16m
- Roles of DL common pilot
  - Common pilots are pilots that are not precoded or beamformed.
  - It is used for 1) control channel demodulation, 2) non-precoded data demodulation, 3) DL precoded data demodulation with explicit precoder information included in control signaling, 4) CQI and MIMO channel measurement
  - Channel estimation using common pilots does not need to be confined within a resource block. Therefore, the channel estimation performance can be improved with lower pilot density compared to dedicated pilot.
  - We target to the common pilot design to support up to 4 MIMO streams
- Roles of DL dedicated pilot
  - Dedicated pilots are pilots that are precoded or beamformed with the data
  - It is used for precoded data demodulation when explicit precoder information is not included in control signaling
  - Dedicated pilots typically require higher pilot density within a resource block as channel estimation is confined within one or more RBs assigned to a MS.
  - The advantage of dedicated pilot is that it can support high number of physical transmit antennas
  - We target the dedicated pilot design to support up to 4 MIMO streams

Overview of Downlink Pilot Design (2/2)

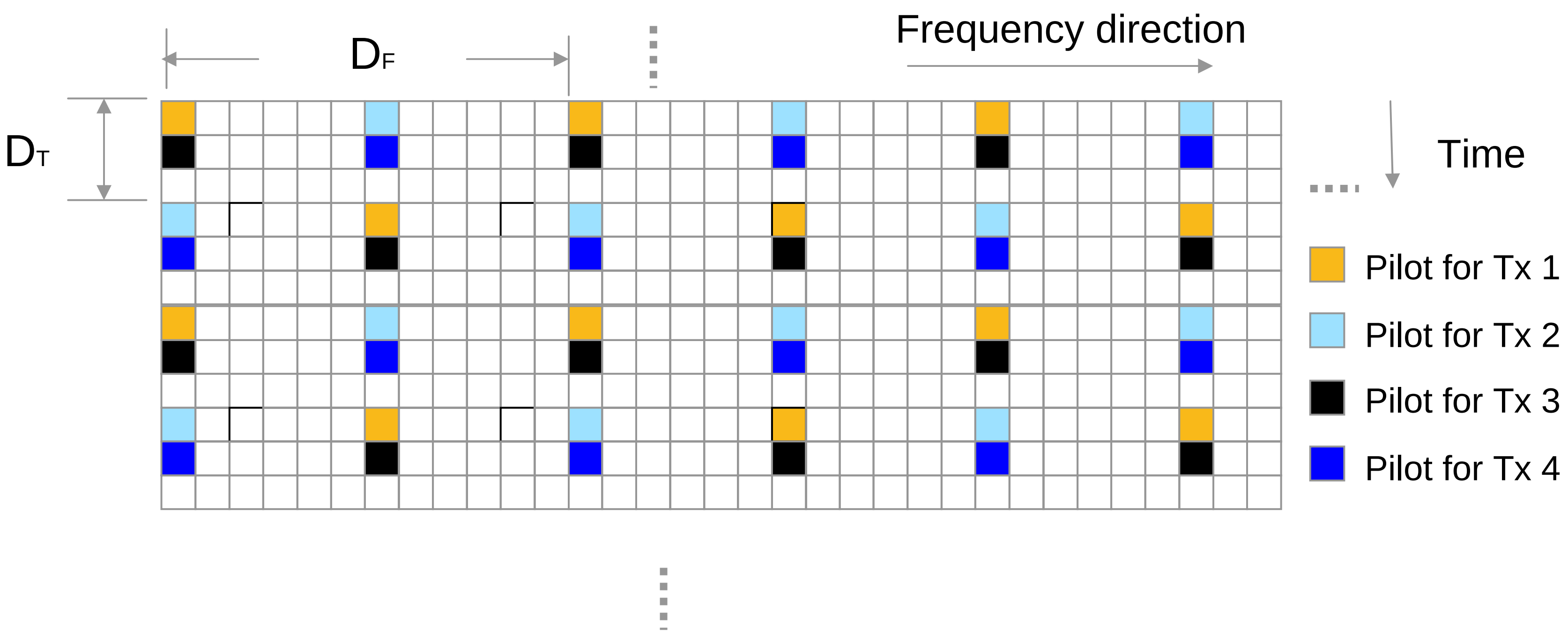
- Scattered pilot design, as adopted in LTE and UMB, is proved to be a good design for optimal trade-off between channel estimation performance and overhead
  - Allows 2-dimensional channel interpolation.
  - Support a wide range of mobility scenarios: low or high mobile speed; and small or large channel delay spread.
  - Same pilot pattern can be used for single antenna port or multiple antenna ports.
  - Same pilot design can be used for TDD and FDD, single carrier operation and multi-carrier operation.
  - MS design can be simplified with the above advantages
  - Allows orthogonal pilot planning among sectors
  - Other design approach, such as TDM, FDM or CDM, has its own advantages at certain conditions but can't meet overall design requirements

Common Pilot Design for 1 and 2 Tx Ports



- Pilot sub-carrier spacing in frequency D_F = 6, 8, 10, 12, 14, 16 and 18 are evaluated
- Pilot symbol spacing in time D_T = 3 is designed for supporting mobile speed up to 350km/h
- Pilot overhead for (D_F, D_F) = (12, 3) is 2.78% for 1 Tx, 5.56% for 2 Tx

Common Pilot for 4 Tx ports

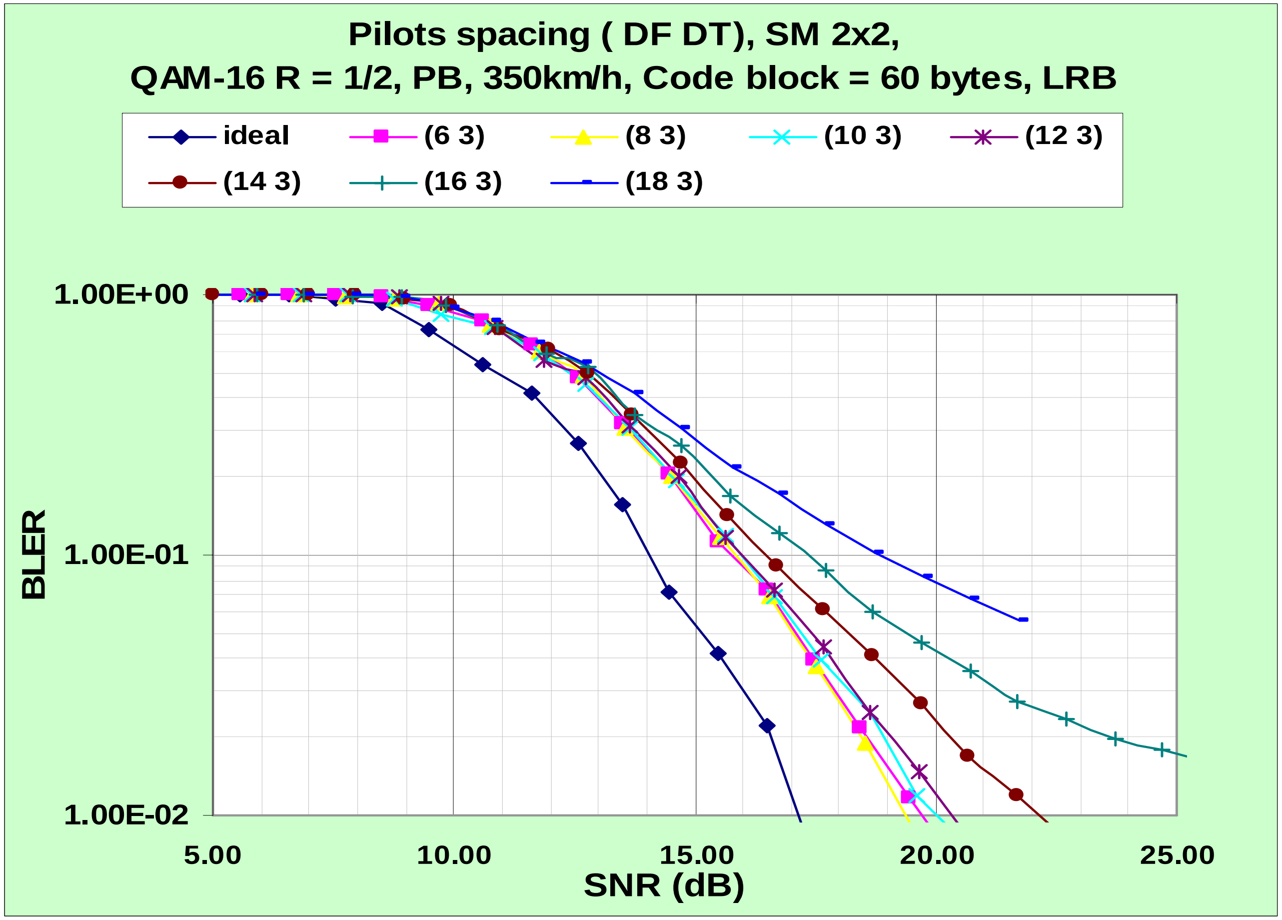


- Pilot overhead for $(D_F^{(1,2)}, D_T^{(1,2)}, D_F^{(3,4)}, D_T^{(3,4)})$ = (12, 3, 12, 3) is 11.1%
- All 4 Tx ports have the same pattern
- Support mobile speed up to 350km/h for 4 Tx ports

Performance Evaluation of Common Pilots

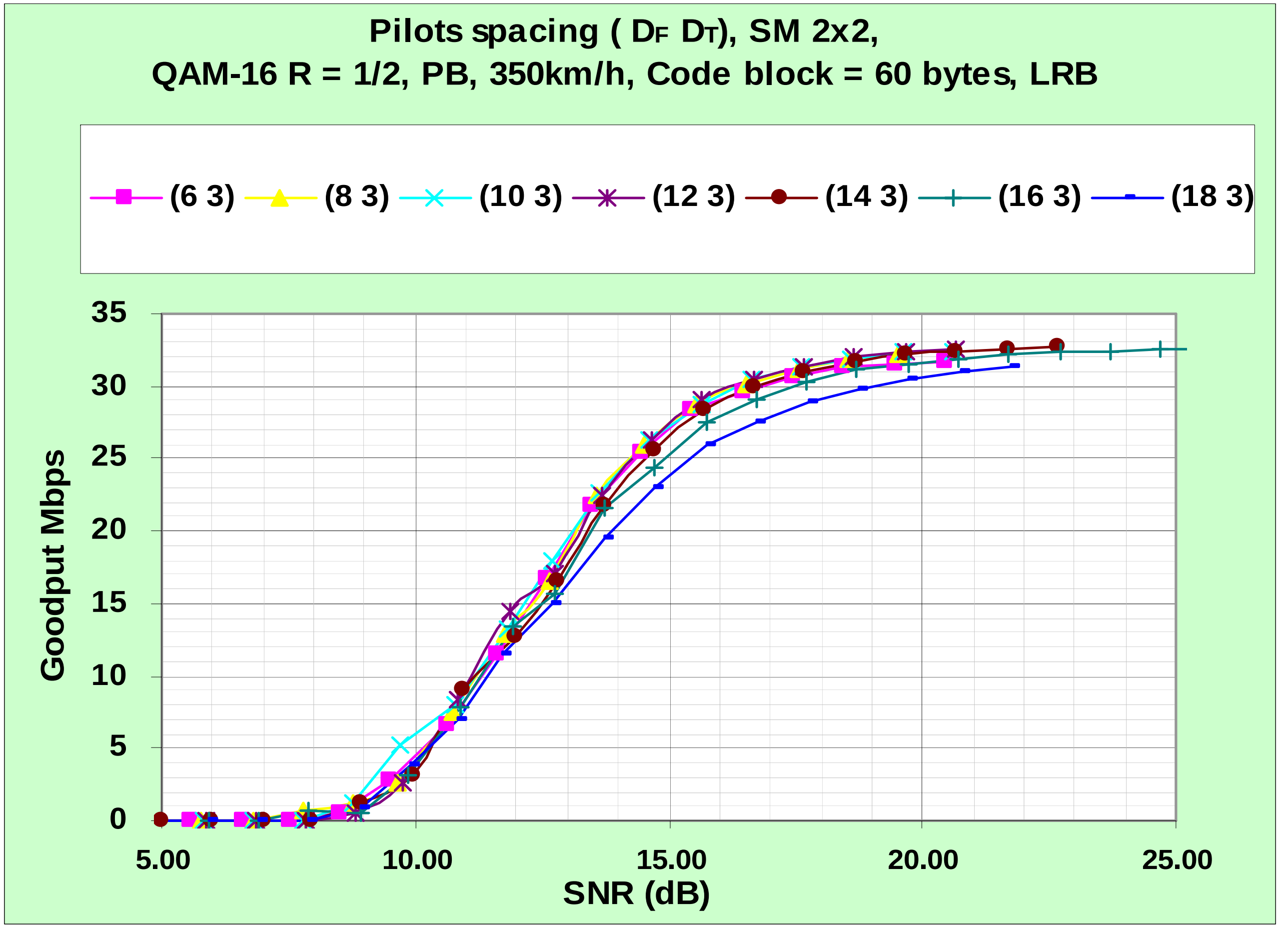
- Purpose of evaluation
  - Determine pilot spacing for common pilots
    - The selection criterion is to meet performance target at various scenarios with the lowest overhead
- Simulation conditions
  - Carrier frequency = 2.5GHz, 10MHz bandwidth
  - 1024 FFT size
  - 865 useful subcarriers (including DC tone)
  - Pilot power boost level: 3dB above data tone (such that total pilot symbol power is kept the same as non-pilot symbol.
  - Channel models: PB and VA, up to 350km/h
  - Channel coding: convolutional turbo code
  - MIMO configurations: SM 2x2, Double STTD 4x2
  - Receiver type: MMSE
  - MCS: QAM-16 R=1/2, block size = 60 bytes

Evaluation results for pilot spacing (1/4)



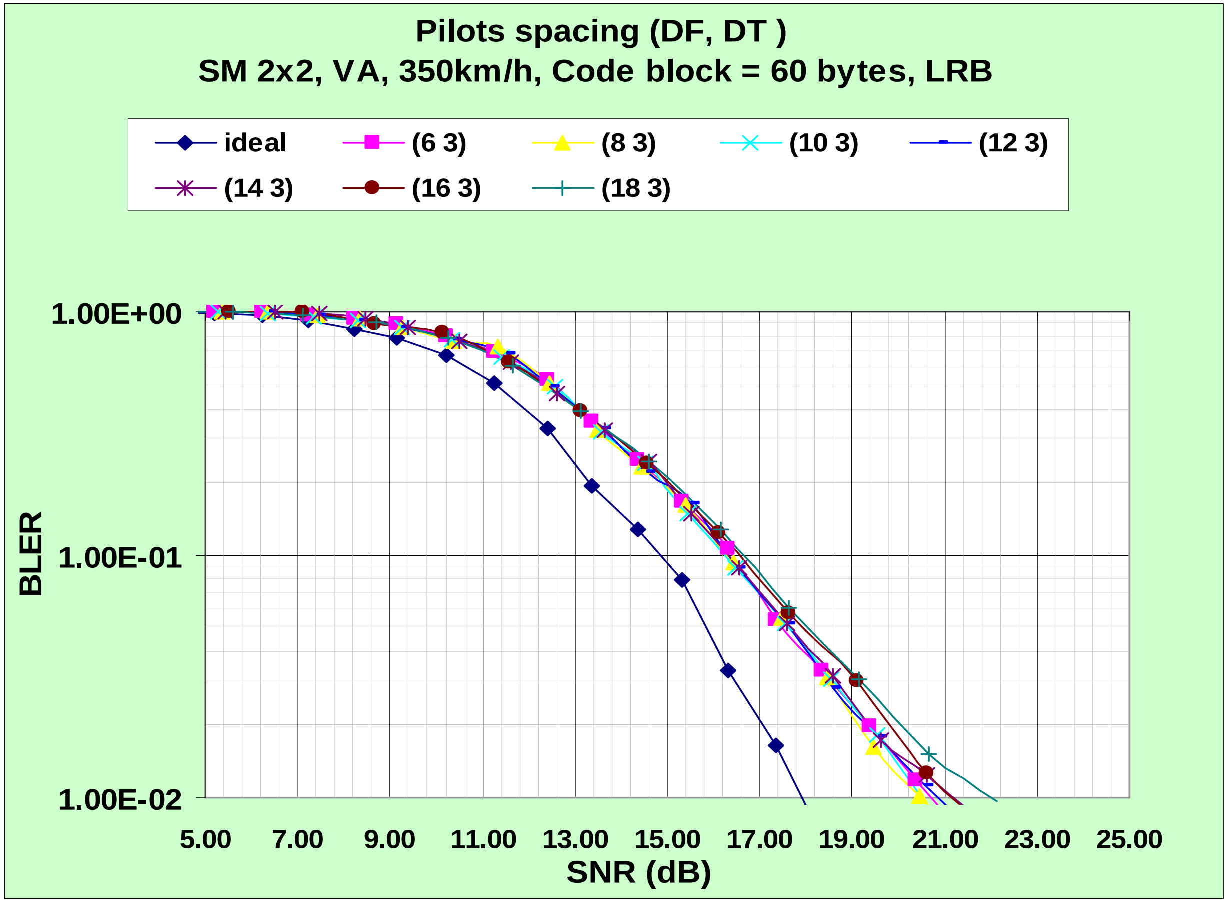
- BLER performances difference for DF= 6 to 12 are within 0.8dB, and becomes >3dB for DF ⩾14
- Overhead is not taken into account in BLER performance

Evaluation results for pilot spacing (2/4)



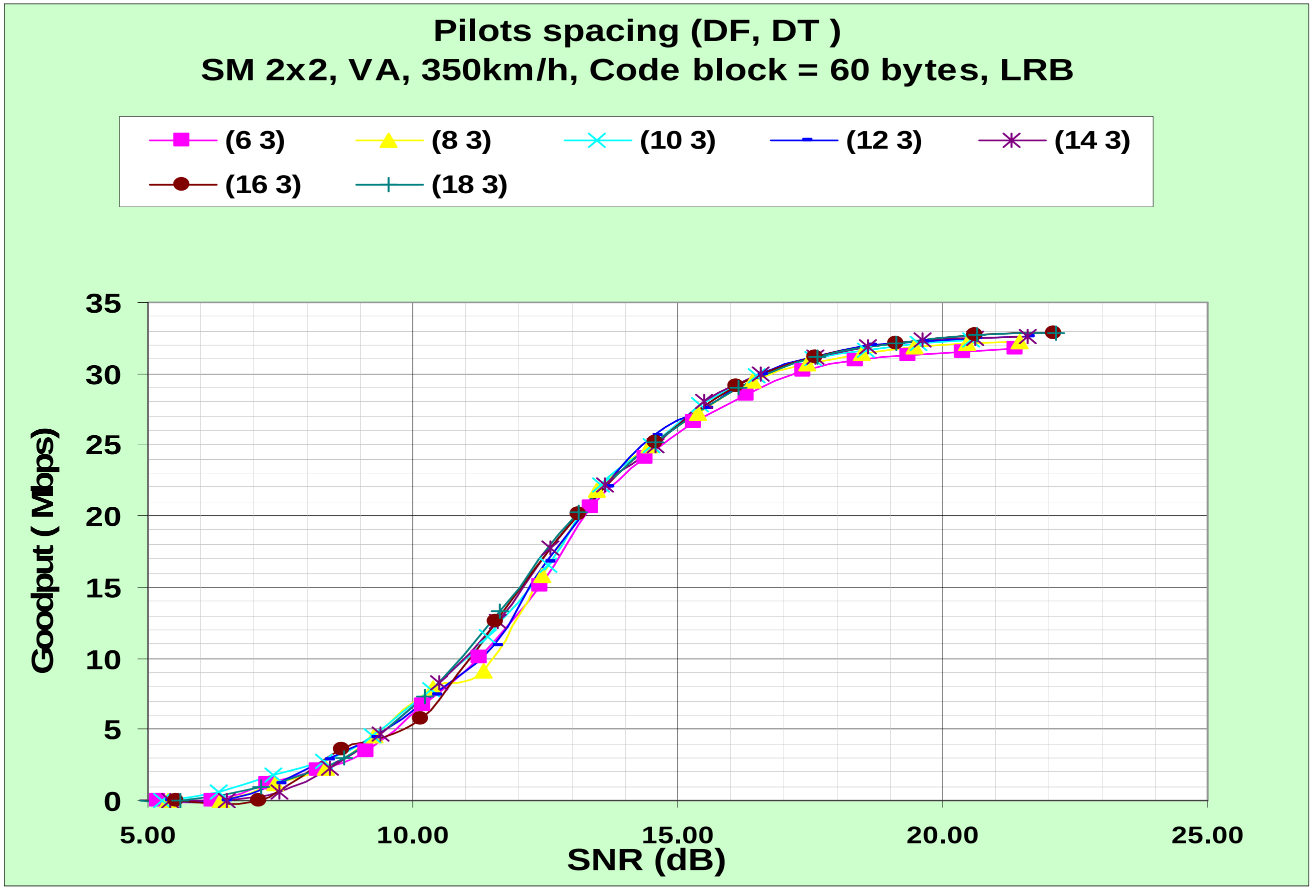
- Goodput = Max Data Rate * (1 – BLER); Max Data Rate = Max # of Info bits in one sub-frame / time duration of a sub-frame.
- Pilot spacing of (D_F D_T) = (12, 3) is the overall best.

Evaluation results for pilot spacing (3/4)



- Since VA channel has smaller delay spread, BLER is not very sensitive to D_F between 6 and 14.
- Degradation becomes observable when $D_F \geqslant 16$.

Evaluation results for pilot spacing (4/4)



- Since VA channel has smaller delay spread, BLER is not very sensitive to D_F between 6 and 14.

DL Resource Block (RB) and Basic Channel Unit (BCU)

- We define two types of resource unit, one is the resource block (RB). The other is the Basic Channel Unit (BCU).
- Resource Block (RB) is the smallest unit that can be assigned to an MS. It is targeted for VoIP or other small-packet application. A BCU consists of multiple RBs. It is targeted for non-VoIP applications where small granularity of resource size is not required. See IEEE C802.16m-08/175 for details.
- Size of RB and BCU are determined by the following factors
  - To support small packet (e.g. VoIP) transmission, an RB size of 12 sub-carriers by 6 symbols, i.e. 72 tones (including pilots) is chosen for its adequate granularity and flexibility (see IEEE C802.16m-08/177 for details).
  - To support non-VoIP transmission and control signalling, BCU size of 3 RBs is selected (see IEEE C802.16m-08/175 for details).
  - The choice of RB size should also alignment with the pilot design
    - Align with the spacing of basic common pilot pattern so as to save signalling overhead and reduce implementation complexity. From our evaluation in this proposal, optimal spacing in frequency for common pilot is 12 subcarriers.
- Overall, we recommend an RB size of 12 sub-carriers x 6 symbols.

Summary

- Scattered pilot design is recommended for common pilots
- Pilot spacing of (12, 3) is recommended for DL common pilot for 1-4 Tx ports
- Details of dedicated pilot design will be provided later