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Overview of Scattered Pilot and TDM Pilot Aspects for E-UTRA Downlink

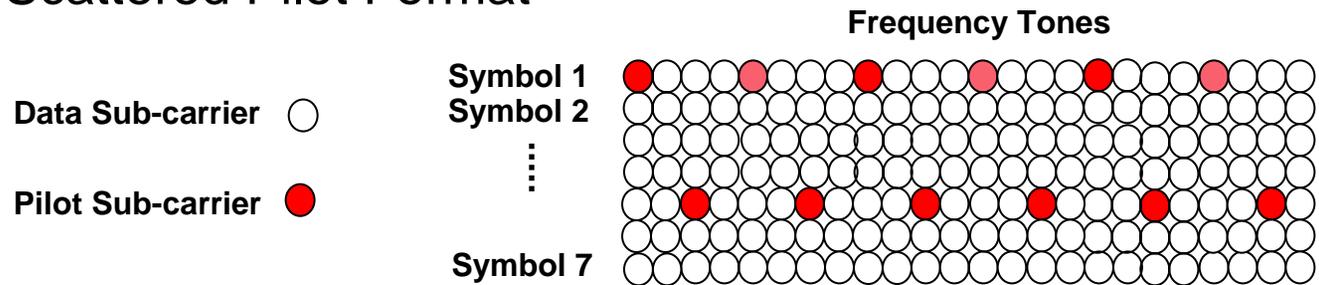
Texas Instruments

Scattered Pilots vs TDM Pilots: Attribute Assessment

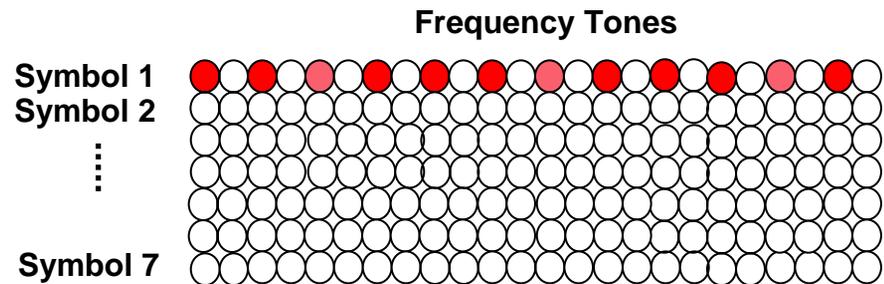
- Shared Data Channel Throughput Aspects
- Shared Control Channel Performance Aspects
- UE Power Savings Capability
- Impact on System, Node B, and UE Complexity

Basic Structures of Suggested Pilot Formats – 1 Tx Antenna

- Scattered Pilot Format



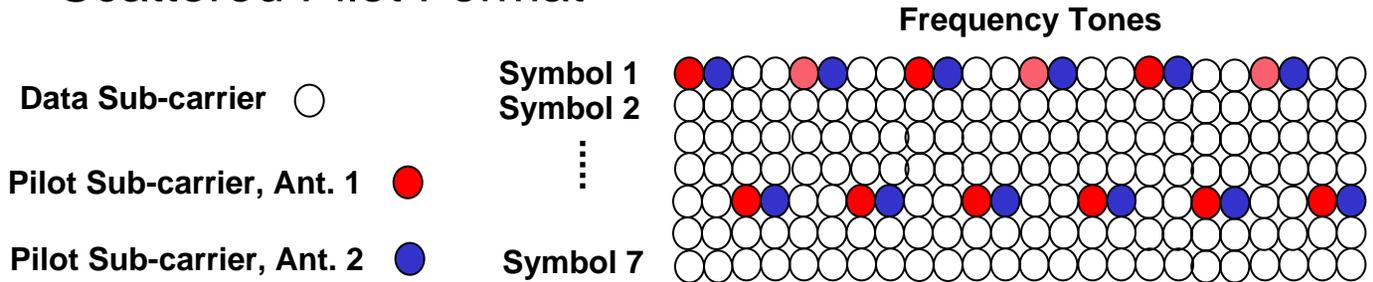
- TDM Pilot Format



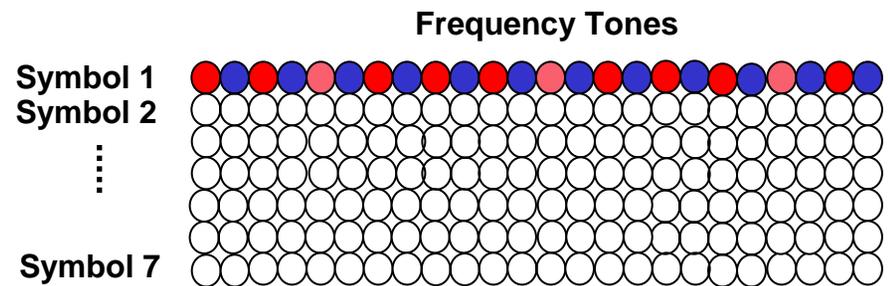
- Performing time interpolation first results to the same frequency density of pilot sub-carriers for the two pilot formats

Exemplary Structures of Pilot Formats – 2 Tx Antennas

- Scattered Pilot Format



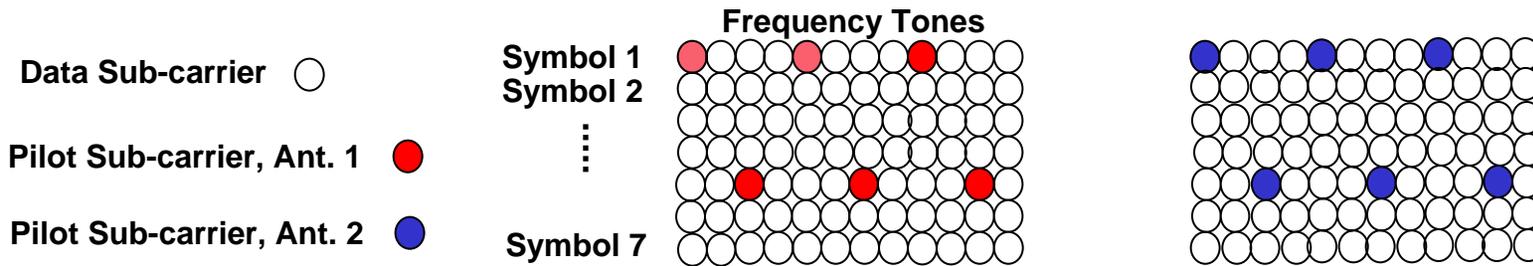
- TDM Pilot Format



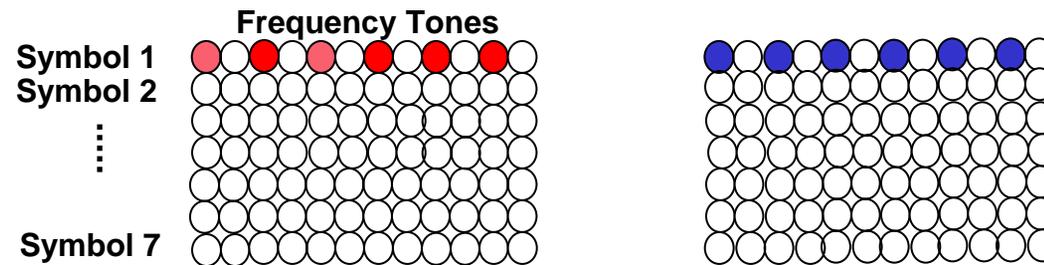
- Several structures have been proposed for 2 Tx and 4 Tx antennas
 - Exemplary ones meet the frequency density need for sub-urban channels
- Performing time interpolation first results to the same frequency density of pilot sub-carriers for the two pilot formats

Exemplary Structures of Pilot Formats – 2 Tx Antennas

- Scattered Pilot Format – Orthogonal Pilots Between 2 Antennas



- TDM Pilot Format – Orthogonal Pilots Between 2 Antennas



- More sensitive to frequency domain variations – no actual gains
- Performing time interpolation first results to the same frequency density of pilot sub-carriers for the two pilot formats

General Pilot Format Properties for 2 or More Tx Antennas

- Numerous Proposed TDM and Scattered Pilot Formats
 - orthogonal or non-orthogonal pilot sub-carriers between 2 antennas
 - orthogonality is limited by the frequency coherent length of the channel
 - transmit pilot sub-carriers from some antennas at a latter OFDM symbol (similar to scattered pilot)
 - transmit pilot sub-carriers from all antennas at the first/second OFDM symbol
- For any TDM Pilot Format, Scattered Pilot Format for each antenna (or antenna pair) can be designed relative to TDM one as for 1 Tx Antenna
 - Similar comparisons and conclusions apply as for 1 Tx antenna

Shared Data Channel Throughput

- Low speeds: Similar BLER Performance for QPSK and 16-QAM, small Scattered Pilot Gains for 64-QAM
- High speeds: TDM pilot fails even with QPSK modulation for UE speeds above 150 Kmph (2.6 GHz) without time interpolation to next TTI
 - e.g. next TTI is multicast, needed for inter-frequency measurements, etc.
 - TDM pilot always suffers substantial losses for higher order modulations
- Suggested solution for TDM pilot shortcoming: UE dedicated pilots
- Some Consequences of UE dedicated pilots
 - High speed UEs use distributed frequency scheduling
 - Dedicated pilots must provide channel estimation for entire frequency band
 - Dedicated pilots will consume additional frequency resources (overhead)
 - If even one high speed UE is scheduled, pilot format is effectively scattered
 - Pilot distribution may differ among cells

Shared Data Channel Throughput

- Throughput Performance Implications of Dedicated Pilots
 - Overhead increase → less achievable throughput than for Scattered pilots
 - Pilot power allocation to first OFDM symbol is sub-optimal and wasteful
 - Additional overhead decreases throughput for all UEs
 - Sector throughput decreases by 7%-10% depending on pilot overhead
 - Additional overhead may complicate allocation of frequency resources

→ Scattered Pilot Offers Better Throughput for All UEs

Shared Control Channel Performance

- UE Uses Less Pilot Power for Channel Estimation with Scattered Pilot
 - To achieve power savings the second part of scattered pilots is not used
 - 25% (50%) less pilot power if UE is (not) scheduled in preceding TTI
 - FER Impact: 0.2-0.8 dB loss with Scattered Pilot (relative to TDM Pilot)
 - Trivial Overall Performance Impact for Scattered Pilot Format
 - Increase coding gain → Same Shared Control Channel FER as for TDM pilot
 - No practical impact on Shared Data Channel throughput
 - Example: Shared Control Channel occupies 1/2 OFDM Symbol → Coding loss for Shared Data Channel due to coding gain of Shared Control Channel is only 0.01-0.07 dB.
- Scattered Pilot can Offer Same Shared Control Channel FER as TDM Pilot - No Effect on Shared Data Channel Throughput

UE Power Savings in Micro-Sleep Mode

- UE RF shut down possible at most for 3-4 OFDM symbols
 - Shared Control Channel and Pilot sub-carriers on first OFDM Symbol
- Scattered Pilot Allows More Shared Control Channel Sub-carriers
- 1 Tx Antenna
 - With TDM Pilot, number of shared control channel sub-carriers on 1st OFDM symbol may be inadequate → increase decoding time, less power savings
 - Alternatively, less scheduled UEs per TTI with TDM pilot → throughput loss
 - 1.25 MHz example: TDM pilot → 37-38 shared control sub-carriers (probably not enough for a single UE !), Scattered pilot → 56-57 (~50% more)
- 2 or 4 Tx Antennas
 - TDM pilot with acceptable frequency density cannot support Shared Control Channel on first OFDM symbol
 - Same Shared Control Channel decoding latency if TDM pilot on 2nd OFDM symbol – UE RF shut down possible for at most 2-3 OFDM Symbols

→ Scattered Pilot May Offer 33%-50% More UE Power Savings

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Complexity Issues

- UE dedicated pilots needed with TDM Pilot Format
- Node B signaling to UE regarding transmission of dedicated pilots
 - Additional shared control channel overhead
 - Doubling of TTI structures
 - Non-uniform pilot formats
 - Frequency scheduling implications in specification of sub-bands
- UE support for channel estimation and TTI structures with and without dedicated pilots
 - Additional implementation complexity
 - Possible performance degradation due to different pilot densities in different sectors/cells

→ **TDM Pilot Leads to Larger System, Node B, and UE Complexity**

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Conclusions: Scattered Pilot versus TDM Pilot

- **Shared Data Channel Throughput**
 - **Scattered Pilot offers larger throughput**
 - **Shared Control Channel FER**
 - **Same FER performance for Scattered Pilot and TDM Pilot**
 - **UE Power Savings**
 - **Scattered Pilot may offer 33%-50% larger power savings**
 - **Complexity**
 - **Scattered Pilot offers smaller System, Node B, and UE Complexity**
- => Scattered Pilot Format Preferred for E-UTRA Downlink**

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