

**R1-073755: E-UTRA Uplink Reference Signal Planning
and Hopping Considerations**
Agenda Item: 7.2.2

Current Working Assumption for PUSCH DM RS (Kobe)

- **Kobe (R1-072584)**
 - Group base sequences with one or more base sequences per group
 - Select a sequence in the group (planning) or sequence hopping (per slot/subframe) within group
 - Group (semi-)statically assigned to a cell or possibility for a cell to hop (on slot/subframe basis) between groups
- **Orlando**
 - Sequence and/or cyclic shift hopping for DM RS
 - Cyclic shifts
 - Possible use of multiple cyclic shifts within a cell is supported with UE assigned a cyclic shift as part of UL grant (up to 3 bits)
 - A cell may be assigned a subset of the available shifts (by higher layer signaling) with different shifts assigned to different cells of a Node-B (Kobe)
- **Sequence and/or cyclic shift hopping supported but can be disabled (planning)**

Cyclic Shift and Sequence Hopping for PUSCH DM RS

- **Cyclic shifts of the same root sequence**
 - Can provide a set of orthogonal RS, whereas different CAZAC root sequences are not orthogonal (regardless of length and construction method)
 - Can be used among cells of the same Node-B
 - Similar to the phase rotations defined for orthogonality of DL RS
 - Can be used among SDMA UEs in a cell
- **Cyclic Shift Hopping**
 - **Within a Node-B and adjacent Node-Bs: Coordination of shift values among the cells of a Node-B or adjacent Node-Bs is more effective than hopping**
 - Adjacent Node-Bs using the same root sequence but different shifts, both the shift assignments and the shift hopping patterns need to be coordinated among the Node-Bs
 - **Among non-adjacent Node-Bs:**
 - If propagation distance between Node-Bs using same root sequence is large, interference on a RS LB will include part of a data LB from the interferer and the benefit of shift hopping among Node-Bs is not clear
- **Shift/Sequence/Group hopping**
 - **Control should be by higher-layer signaling**
 - Can be disabled as agreed in Kobe, Orlando
 - **Should not be implicit from e.g. cell-ID to allow for planning/coordination of hopping patterns**
- **For case with no Sequence/Group hopping**
 - **Should be possible to select different base sequences within a group to allow for larger reuse distance with desired cross-correlation**

PUCCH DM RS

- **Agreements from Orlando, Kobe**
 - Sequence and/or cyclic shift hopping for PUCCH (ACK/NACK, CQI)
 - Cyclic shift hopping period per symbol
- **Orthogonal covering for ACK/NACK RS and LB control data**
- **Modulated ZC sequence for data LB**
 - Cyclic shift, sequence hopping applicable for data LBs as well

Orthogonal covering for PUCCH RS and LB data

- Orthogonal coding (e.g., Walsh, DFT) over 3 RS (and over 4 LB control data for ACK/NACK) agreed to provide adequate #users (e.g. up to 18) using one base sequence and a number (e.g. 6) of shifts
- Issue with using the same set of cyclic shift values (multiple of D samples) for the 3 orthogonal codes/groups of UEs (UE 1 to 6 in group 1 using code 1, UE 7 to 12 (13 to 18) in group 2 (3) using code 2 (3) on same RS)
 - **Degradation at high Doppler**
 - Inter-group interference (between group 1, 2, and 3 within a single LB) regardless of the delay spread – the interference cancellation relies completely on the collapsing (combining) of the pilots on all 3 RS LBs
 - **Careful selection of the shift values can mitigate the degradation**
 - **Cyclic shift values for second orthogonal code/group of users should be offset so that high Doppler only causes degradation when high delay spread is present**
 - By offsetting the cyclic shift values used by UEs in group 2 by $D/2$ relative to group 1 orthogonality *within* each LB (between group 2 and group 1/3) can be achieved at moderate delay spreads, thus significantly enhancing the tracking of high Doppler channels
- **Propose to offset cyclic shift values for one of the orthogonal codes by $D/2$ relative to other codes**
 - **Spacing between cyclic shifts = D samples**

Hopping for PUCCH RS and Control LBs (slide 1 of 2)

- **Cyclic shift hopping within a slot (for RS and control LBs)**
 - **If orthogonal covering used (ACK/NACK)**
 - Cyclic shift (CS) hopping within the same orthogonal code
 - Same starting cyclic shift and orthogonal code index for RS and control LBs
 - Same Hopping offset pattern for all (e.g. 6) cyclic shifts of a orthogonal code
 - CS Hopping offset pattern function of (Cell ID, Sub-frame #, SFN)
 - CS Hopping offset pattern possibly of length-N (N=# of SC-FDMA symbols/slot)
 - CS Hopping pattern for initial-shift $j = \text{mod}(j + \text{hopping offset pattern}, \# \text{ of cyclic shifts})$
 - CS Hopping offset pattern for RS/control-LB subset (e.g. first 3/4 elements) of the hopping offset pattern
 - Same hopping offset patterns for different orthogonal codes
 - **Without orthogonal covering (e.g. CQI)**
 - CS Hopping offset pattern function of (Cell ID, Sub-frame #, SFN)
 - Same pattern as with orthogonal covering case
- **Cyclic shift hopping between slot 0 and slot 1**
 - Different starting cyclic shift but same hopping offset pattern as slot 0
 - Starting cyclic shift in slot 1 function of (starting-shift in slot 0)
- **Orthogonal code index hopping between slot 0 and slot 1**
 - Hopping offset pattern function of (Cell ID, Sub-frame #, SFN)
- **Hopping offset pattern cell-specific and not UE-specific**

Hopping for PUCCH RS and Control LBs (slide 2 of 2)

- **If PUSCH base sequence/group hopping enabled**
 - Sequence/Group Hopping between LBs of a slot and between slots (for both RS and control LBs)
 - Base Sequence/group Hopping pattern same as that for PUSCH
 - Starting base sequence index same as that for PUSCH, if PUSCH data was transmitted instead of control in the current sub-frame
 - Hopping pattern not function of cell-ID to allow for planning/coordination of hopping patterns

Conclusions

- **PUSCH DM RS**

- Hopping can be enabled, but an operator should be able to plan if desired
- **Base sequence/group hopping pattern not function of cell-ID to allow for planning/coordination of hopping patterns**
 - Explicit signaling through D-BCH
- **For case with no Sequence/Group hopping**
 - Should be possible to select different base sequences within a group to allow for larger reuse distance with desired cross-correlation

- **PUCCH DM RS and control LBs**

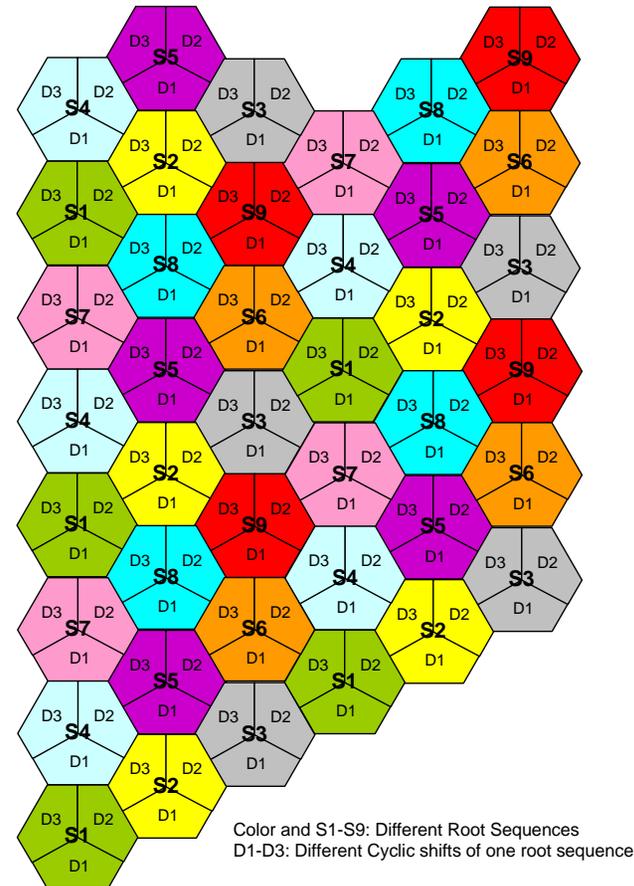
- **Offset the cyclic shift values for one or more of the orthogonal codes (e.g., Walsh, DFT) to enhance tracking of high Doppler channels at moderate delay spreads**
- **Cell-specific cyclic shift hopping pattern**
 - Same Hopping offset pattern for all (e.g. 6) cyclic shifts and different orthogonal codes
- **Orthogonal code index hopping (ACK/NACK) between slots**
- **Sequence Hopping pattern same as that for PUSCH, if sequence hopping is enabled**
 - Hopping between LBs of a slot and between slots (for both RS and control LBs)

RS and Cyclic Shift Planning Examples

Reference Signal Planning (1)

- **Single RB contains 12 subcarriers on LB**
 - **Worst-case RS sequence length = 12**
 - **RS design option 1: Length 13 CAZAC truncated to length 12 (frequency domain)**
 - 12 root sequences available
 - Nearest conventional reuse patterns are 12-cell (if all sequences used) or 9-cell (if 9 lowest CM sequences are chosen)
 - **RS design Option 2: Length 11 CAZAC sequence cyclically extended (frequency domain)**
 - 10 Root sequences available
 - Nearest conventional reuse plan is 9-cell
 - **One base sequence per group**
- **Example 9-sequence/group reuse plan shown**
 - **All cells of the same Node-B use the same sequence**
 - **Cyclic shifts of the same root sequence can be used among cells of the same Node-B**
 - Only 3 cyclic shifts used in this example (more than 3 cyclic shifts are available)
 - **Remaining cyclic shifts (up to 4) for SDMA UEs in a cell**

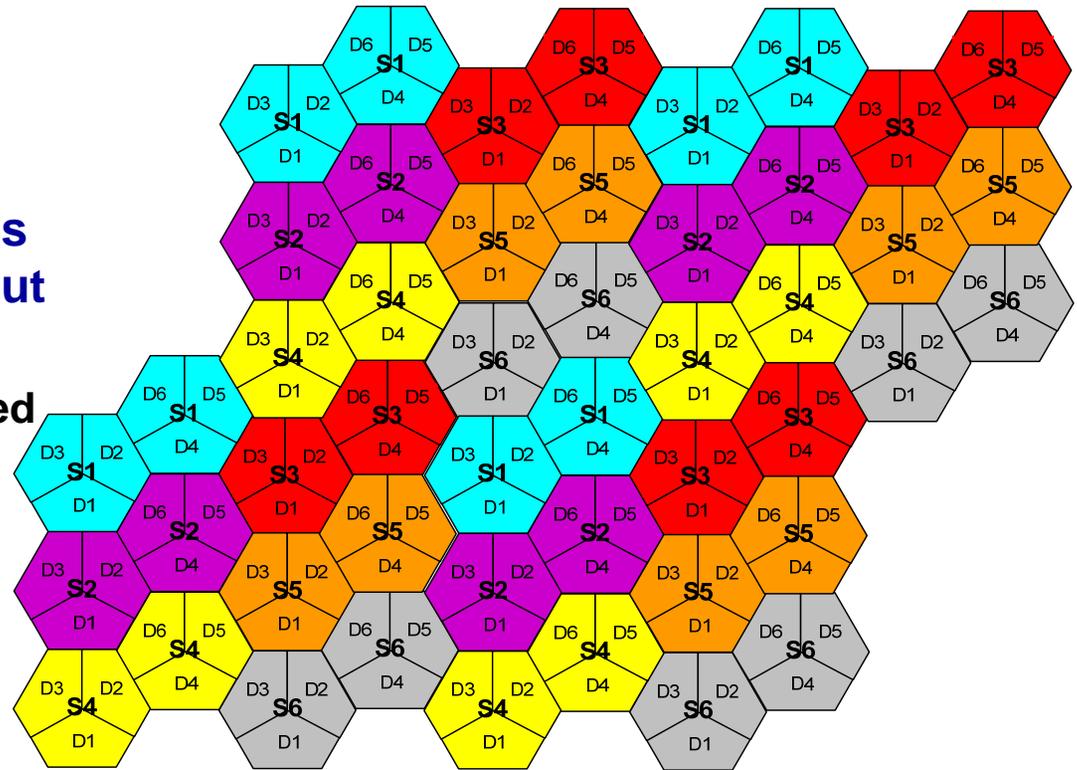
Example Reuse Plan using 9 root sequences with 3 cyclic shifts per Node-B



Reference Signal Planning (2)

- **Example: 6-sequence, 6 cyclic shifts reuse plan shown**
 - 6 sequences with $CM < QPSK$
 - All cells of the same Node-B use the same sequence
- **In addition, 2 adjacent Node-Bs use the same root sequence but different shifts**
 - Half of the available shifts used in each Node-B
- **Remaining cyclic shifts of the same root sequence can be used among cells of the 2 adjacent Node-B**
 - e.g. 2 shifts per cell for UL MIMO/SDMA

Example Reuse Plan using 6 root sequences with 6 cyclic shifts split among 2 adjacent Node-B



Color and S1-S6: Different Root Sequences
D1-D6: Different Cyclic shifts of one root sequence