

R1-080065: Uplink DM RS – Open Issues
Agenda Item: 6.1.2

RS Sequence Hopping for PUSCH and PUCCH

- **Agreements from RAN1#50bis**
 - One bit in D-BCH indicates whether sequence hopping is enabled or not
 - The selection applies to both PUCCH and PUSCH (not necessarily the same hopping pattern)
 - If hopping is disabled, the sequence group is indicated (5 bits for 30 groups)
 - If hopping is enabled, the signaling of the hopping pattern is FFS (e.g. on D-BCH or cell-specific)
 - One sequence per group for allocations of up to 5 RBs
- **Agreements from RAN1#51**
 - The number of hopping patterns for the base sequence groups is 504
 - Number of sequences per base sequence group for allocations larger than 5 RBs:
 - One sequence could be selected in case of base sequence group hopping.
 - In case of planning: 2 sequences to enable sequence hopping within the sub-frame – this hopping can also be disabled
- **For Planning with no Sequence and Group hopping**
 - Should be possible to select one of the two base sequences for larger than 5RBs to allow for larger reuse distance with desired cross-correlation
 - Can re-use bits used for signaling the group hopping pattern and/or sequence hopping pattern within a group when hopping is enabled

Cyclic Shift and Sequence Hopping for PUSCH DM RS

- **Cyclic Shift hopping**
 - 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, RAN1#49)
 - 3 bits in the UL grant (on PDCCH) indicate up to 8 cyclic shifts per sequence
 - Cyclic Shift (CS) hopping within the subset of shifts assigned to cell
 - CS Hopping pattern (for a given RB allocation BW) function of (Base group #, slot #, SFN)
 - Same CS hopping pattern for all UEs with the same allocation BW within a cell
- **Shift/Sequence/Group hopping**
 - Should not be implicit from e.g. cell-ID to allow for planning/coordination of hopping patterns
 - Coordination of shift values among the cells of a Node-B or adjacent Node-Bs using the same root sequence/group

PUCCH DM RS

- **Agreements from Athens, Orlando, Kobe**
 - Support for sequence and/or cyclic shift hopping for PUCCH (ACK/NACK, CQI)
 - Cyclic shift hopping period per symbol
 - Orthogonal covering hopping per slot for PUCCH ACK/NAK sub-frames
- **Agreements from Jeju (#51)**
 - PUCCH sequence hopping is per slot
 - revisit if there is a problem with respect to BER performance on ACK/NACK
 - PUCCH Cyclic Shift and Orthogonal Cover Hopping
 - PUCCH cyclic shift hopping (per symbol) is always enabled
 - PUCCH orthogonal cover hopping (per slot) is always enabled
- **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

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

- **Cell-specific 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)
- **Cell-specific 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**
 - PUCCH sequence hopping is per slot (agreement from Jeju)
 - PUCCH Base Sequence/group Hopping pattern same as that for PUSCH
 - Hopping pattern not function of cell-ID to allow for planning/coordination of hopping patterns

Cyclic shift Values for PUSCH, PUCCH and SRS

- For PUSCH, 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, RAN1#49)
- Can define a sets of possible cyclic shift increment values
 - e.g. \sim [2.78us, 3.71us, 4.167us, 5.55us, 8.33us, 11.11us, 16.67us, 22.22us, 33.33us] corresponding to [24, 18, 16, 12, 8, 6, 4, 3, 2] possible cyclic shifts
 - The extreme values can be reserved for normal and extended CP respectively requiring 3-bits to indicate the CS increment
- Define a set of possible fractional cyclic shift offset values
 - e.g. \sim [0 1/3 1/2 2/3] - 2 bits to indicate the CS offset
- Thus, the set of cyclic shifts that can be assigned to UEs in a cell
 - possible cyclic shifts = (cyclic shift offset + k) * cyclic shift increment, k = 0 to [24, 18, 16, 12, 8, 6, 4, 3, 2] -1
 - Can support less than 8 cyclic shifts with maximum separation
- Example: Node-B with 3 cells and 8 cyclic shifts/cell with spacing (increment) = 8.33us
 - Cell A: fractional offset = 0, shifts = 0, 8.33, 16.67, 25, 33.33, 41.67, 50, 58.33 us
 - Cell B: fractional offset = 1/3, shifts = 2.78, 11.11, 19.45, 27.78, 36.11, 44.45, 52.78, 61.11us
 - Cell C: fractional offset = 2/3, shifts = 5.55, 13.89, 22.22, 30.56, 38.89, 47.22, 55.56, 63.89us
- Cell broadcasts (D-BCH) cyclic shift offset and cyclic shift increment

Cyclic shift Values cont.

- For PUCCH, as has been agreed in Shanghai (R1-074491), different orthogonal covers can have different fractional cyclic shift offset
- Cyclic shift indicator (3 bits) in UL Grant indicate the cyclic shift assigned to a UE
- For specifying the cyclic shift in 36.211, section 5.5.1
 - $s_i = [24, 18, 16, 12, 8, 6, 4, 3, 2]$, possible cyclic shift increment values
 - $s_o = [0, 1/3, 1/2, 2/3]$, possible fractional cyclic shift offsets
 - Phase $\alpha = 2\pi(s_o + k)/s_i$
 - Where k is the 3-bit cyclic shift (in decimal) signaled to the UE

Conclusions

- **PUSCH DM RS**

- **For Planning with no Sequence and Group hopping**

- Should be possible to select one of the two base sequences for larger than 5RBs to allow for larger reuse distance with desired cross-correlation
 - Can re-use bits used for signaling the group hopping pattern and/or sequence hopping pattern within a group when hopping is enabled

- **Base sequence/shift/group hopping pattern not function of cell-ID to allow for planning/coordination of hopping patterns**

- Explicit signaling through D-BCH

- **PUCCH DM RS and control LBs**

- **Cell-specific cyclic shift hopping pattern**

- Same Hopping offset pattern for all (e.g. 6) cyclic shifts and different orthogonal codes

- **PUCCH Base Sequence/group Hopping pattern same as that for PUSCH**

- **Cyclic Shift Values for PUSCH, PUCCH, and SRS**

- **Cell broadcasts (D-BCH) cyclic shift offset and cyclic shift increment**

- possible cyclic shift increment values [2.78us, 3.71us, 4.167us, 5.55us, 8.33us, 11.11us, 16.67us, 22.22us, 33.33us]

- possible fractional cyclic shift offset values [0 1/3 1/2 2/3]

- possible cyclic shifts = (cyclic shift offset + k) * cyclic shift increment