R1-073988: E-UTRA Uplink DM RS Issues

Agenda Item: 6.2.2

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)
  - 3 bits in the UL grant (on PDCCH) indicate up to 8 cyclic shifts per sequence
  - Shift hopping within the subset of shifts assigned to cell
  - CS Hopping pattern function of (Base group #, slot #, SFN)
  - Hopping pattern cell-specific and not UE-specific
- **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
- **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 Athens, Orlando, Kobe**
  - 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
- **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 = mod(j + hopping offset pattern, # 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**
  - **Base sequence/shift/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 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
  - **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)