

## R1-081278: Cyclic Shift values for UL RS Agenda Item: 6.1.2

# Cyclic Shift Agreements

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- **PUSCH**
  - Different shifts may be used for different cells of the same eNode B (e.g. if same group assigned to the cells) and needed for UL SDMA (MU-MIMO)
  - Cell may be assigned a subset of the available shifts (by higher layer signaling) - Kobe, RAN1#49
  - 3 bits in the UL grant (on PDCCCH) indicate up to 8 cyclic shifts per sequence
- **SRS**
  - Cyclic shift: 3 bits. FFS how to support less than 8 cyclic shifts with maximum separation
- **In this contribution, we present a flexible way for signaling the CS values with maximum CS spacing/separation (depending on deployment)**

# Proposal: Cyclic shift Values

- Define a set of CS increment (spacing) values
  - e.g. ~[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
    - 2.78us reserved for normal CP, 33.33us reserved for extended CP
  - Can have a reduce set each for normal CP and extended CP
    - Normal CP [5.55us, 8.33us, 11.11us, 16.67us] corresponding to [12, 8, 6, 4] possible cyclic shifts
    - Extended CP [11.11us, 16.67us, 22.22us, 33.33us] corresp. to [6, 4, 3, 2] possible cyclic shifts
    - 4 possible values requiring 2-bits to indicate the CS increment
- Define a set of fractional cyclic shift offset values
  - ~[0 1/3 1/2 2/3] - 2 bits to indicate the CS offset
- Thus, set of cyclic shifts assigned to a cell
  - Assignable Cyclic Shifts = (cyclic shift offset + k) \* cyclic shift increment, k = 0 to [24, 18, 16, 12, 8, 6, 4, 3, 2] -1
  - Can support different number of cyclic shifts with maximum separation
- Cell broadcasts cyclic shift increment (2 bits) and fractional cyclic shift offset (2 bits)
  - Can be different for PUSCH and SRS due to different CS requirements and/or CS co-ordination b/w cells
  - To reduce signaling overhead, SRS uses the same CS values as PUSCH
    - Group of PUSCH CS values <= 33.33us on each SRS comb
    - Same CS values on each SRS comb

## Example of Cyclic shift Values

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- **PUSCH**
  - **3 cells of a Node-B with 8 cyclic shifts/cell and max CS separation**
    - CS spacing (increment) = 8.33us
    - Cell A: fractional CS offset = 0, shifts = 0, 8.33, 16.67, 25, 33.33, 41.67, 50, 58.33 us
    - Cell B: fractional CS offset = 1/3, shifts = 2.78, 11.11, 19.45, 27.78, 36.11, 44.45, 52.78, 61.11us
    - Cell C: fractional CS offset = 2/3, shifts = 5.55, 13.89, 22.22, 30.56, 38.89, 47.22, 55.56, 63.89us
    - 2.78us spacing b/w the different cells
  - **3 cells of a Node-B with 4 cyclic shifts/cell and max CS separation**
    - CS spacing (increment) = 16.67us
    - Cell A: fractional CS offset = 0, shifts = 0, 16.67, 33.33, 50 us
    - Cell B: fractional CS offset = 1/3, shifts = 5.55, 22.22, 38.89, 55.56us
    - Cell C: fractional CS offset = 2/3, shifts = 11.11, 27.78, 44.45, 61.11us
    - 5.55us spacing b/w the different cells

## SRS Examples

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- **SRS (for each comb)**
  - **4 cyclic shifts / comb**
    - CS spacing (increment) = 8.33us, fractional CS offset = 0
  - **2 cyclic shifts / comb**
    - CS spacing (increment) = 16.67us, fractional CS offset = 0

## Specification of the cyclic shifts in 36.211 (sec 5.5.1)

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- To enable efficient UE/eNode-B implementation, CS value in samples (@ 30.72MHz) should be a multiple of 16
- Cyclic shift increment
  - Normal CP:  $N_{cs} = [12, 12, 8, 4]$  represent possible number of cyclic shifts
  - Extended CP:  $N_{cs} = [6, 4, 3, 2]$  represent possible number of cyclic shifts
  - cyclic shift increment,  $CS_{incr} = N/N_{cs}$ ,  $N=2048$
  - 4 possible values requiring 2-bits to indicate the CS increment
- $CS_{offset} = [0 \ 1/3 \ 1/2 \ 2/3]$ , possible fractional cyclic shift offsets
- $CS_{samples} = \text{round}(CS_{incr} * (k + CS_{offset}) / 16) * 16$ 
  - Where k is the 3-bit cyclic shift (in decimal) signaled/assigned to the UE
- $\text{Phase alpha} = 2\pi * cs_{samples}/N$

## Conclusions - CS Values for PUSCH and SRS

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- **Cell broadcasts (D-BCH) cyclic shift increment/number of cyclic shifts (2 bits) and cyclic shift offset (2 bits)**
- **Cyclic shift increment**
  - Normal CP:  $N_{cs} = [12, 12, 8, 4]$
  - Extended CP:  $N_{cs} = [6, 4, 3, 2]$
  - cyclic shift increment,  $CS_{incr} = N/N_{cs}$ ,  $N=2048$
- **$CS_{offset} = [0 \ 1/3 \ 1/2 \ 2/3]$**
- **Possible cyclic shifts = (cyclic shift offset + k) \* cyclic shift increment**
  - k is the 3-bit cyclic shift (in decimal) signaled/assigned to the UE
- **Cyclic shift in samples should be multiple of 16 to enable efficient UE implementation**
- **SRS uses the same CS values as PUSCH**
  - PUSCH CS values  $\leq 33.33\mu s$  on each SRS comb
  - Same CS values on each SRS comb
  - No CS offset between combs