3GPP TSG RA WG1 Meeting #87 **R1- 1612632**
Reno, USA, November 14-18, 2016

Source: Cohere Technologies

Title: On UL RS for CSI Estimation

Agenda item: 7.1.3.2

Document for: Discussion and Decision

1. Introduction

The number of reference signals (RS) required for CSI estimation in the uplink (UL) is a function of the total number of streams supported by all the active UEs. With the increased number of UE antenna ports expected to be supported in NR, the number of RS that will need to be supported in NR is expected to be large. Furthermore, to support channel reciprocity, there will be a need to transmit UL reference signals for a period of time long enough to allow reasonable estimation of the channel for a given Doppler spread of the channels. On the one hand 3GPP is targeting to limit any persistent transmissions of any signal to guarantee forward compatibility, and on the other hand there is a recognition that there may be a need to send sounding reference signals (SRS) periodically and/or semi-persistently. This is expressed in the following agreements from RAN1 #86b:

- NR supports aperiodic SRS transmission triggered by the network
  - ➢ FFS on other trigger mechanism, e.g. event triggered
  - ➢ FFS on multi-shot SRS transmission, e.g. the UE transmits SRS multiple times with single trigger from network
- FFS: NR supports at least one of followings
  - ➢ Periodic SRS transmission
  - ➢ Semi-persistent SRS transmission

To support the large number of SRS and to minimize the duration of time that they have to be transmitted, an optimal packing of the SRS should be implemented in NR. In the following section we will discuss a way to achieve an optimal reference signal packing that can be used for SRS transmissions and may also be used for other reference signals.

2. Optimized Packing of Reference Signals

The number of RS that can be supported on a given time-frequency grid assigned for transmitting the RS is affected by the following parameters (see [1]):

- Delay and Doppler spreads of the channels.
- The distances in frequency and time between the time-frequency resource elements used for RS transmission. A denser grid improves the RS packing.
- The size of the receiver observation window in both time and frequency dimensions. The observation window in the time-frequency plane induces a convolution with a Dirichlet kernel (~ Sync function), increasing the energy of the received RS beyond its delay and Doppler spreads. As a result, a larger observation window will improve the RS packing.

As has been shown in [1], implementing the RS as delay-Doppler shifts of a 2D complex exponential basis function can achieve optimal RS packing. This implementation of the RS is equivalent to representing each RS as an impulse in the delay-Doppler plane as shown in the example of Figure 1.

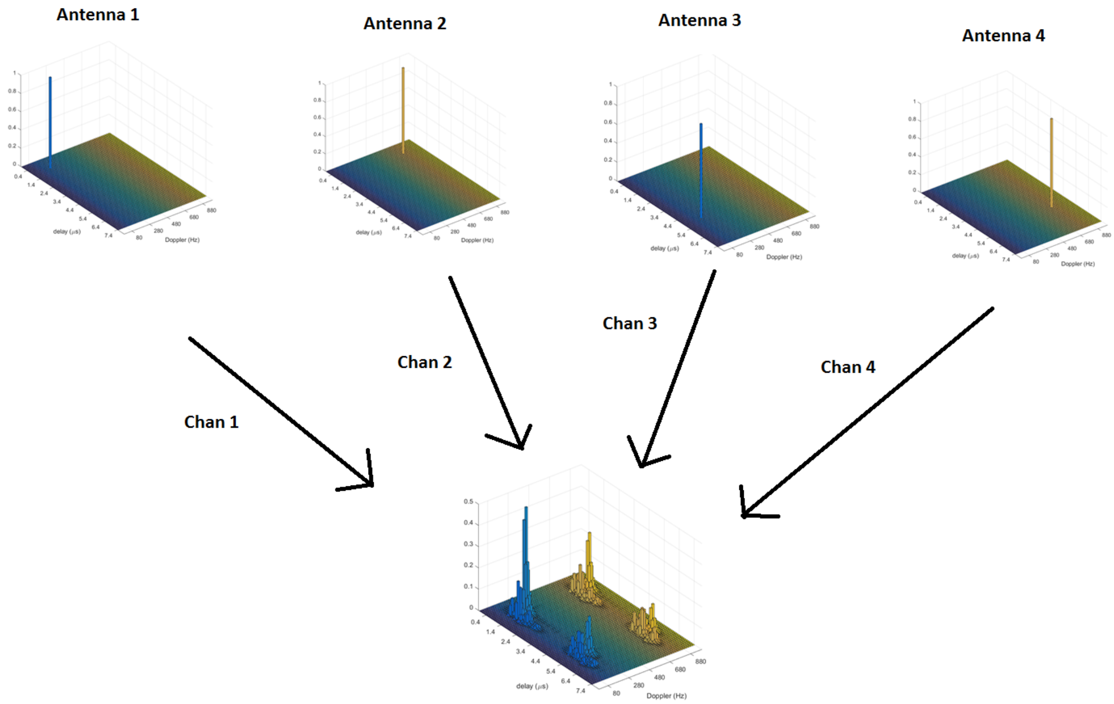

Figure 1: Reference signals multiplexed in the delay-Doppler domain

For a given time-frequency grid assigned to the RS, the maximum number of RS that can be simultaneously supported and still keep their orthogonality after going through their channels, assuming infinite bandwidth and observation time, is given by $N^P_{\max\_\tau} \cdot N^P_{\max\_\nu}$ where $N^P_{\max\_\tau}$ and $N^P_{\max\_\nu}$ are given by:

$$N^P_{\max\_\tau} = \lfloor C^P_\tau / \Delta_\tau \rfloor$$
$$N^P_{\max\_\nu} = \lfloor C^P_\nu / \Delta_\nu \rfloor \qquad (1)$$

Where $C^P_\tau = 1/M_0\Delta_f$, Δ_f is the subcarrier spacing, M_0 is the number of subcarriers between the RS grid points, Δ_τ is the delay spread of the channel, $C^P_\nu = 1/N_0\Delta_t$, Δ_t is the time distance between the OFDM symbols, N_0 the distance in number of OFDM symbols between the RS grid points, Δ_ν is the Doppler spread of the channel. An example of a time-frequency RS grid is shown in Figure 2.

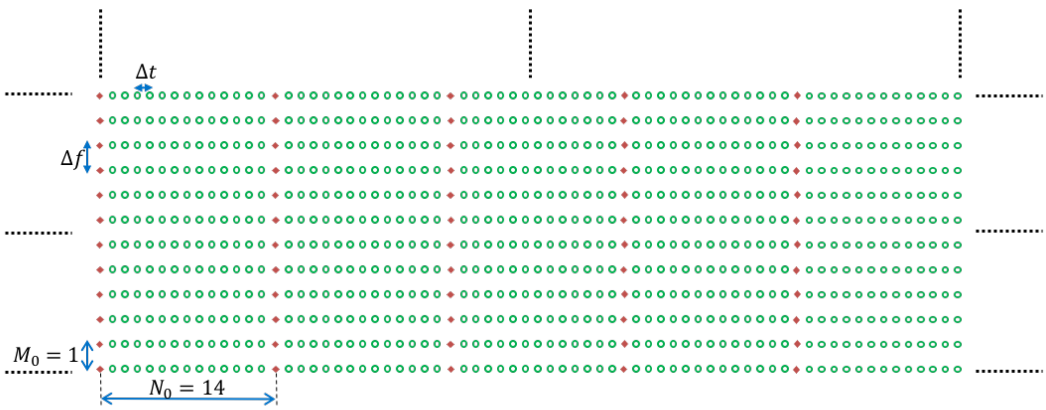

Figure 2: Time-frequency reference signal grid example.

For the time-frequency grid of Figure 2, and assuming that all the channels observed by the different RS have delay spread of $5\mu s$ and Doppler spread of $100Hz$ (maximum Doppler frequency of $50Hz$), the maximum number of RS that can be supported is $\lfloor 66.67/5 \rfloor \cdot \lfloor 1000/100 \rfloor = 13 \cdot 10 = 130$. Actual numbers will be lower depending on the observation window in frequency and time.

Using the 2D complex exponentials as RS provides the following benefits over using time and/or frequency multiplexing:

- Ability to optimally support the simultaneous estimation of channels with different delay and/or Doppler spreads.
- More flexibility in packing the RS, as the RS can be placed anywhere in the continuous delay-Doppler plane as opposed to the finite grid selection available in the time-frequency plane. This flexibility results in a more optimized packing of the RS.

Based on the discussion above, we propose the following:

Proposal Reference signals generated as delay-Doppler shifts of a 2D complex exponential base reference signal shall be considered as candidates for at least SRS

3. Conclusion

Based on the discussion in this contribution we have the following proposal:

Proposal Reference signals generated as delay-Doppler shifts of a 2D complex exponential base reference signal shall be considered as candidates for at least SRS

4. References

[1] R1-163619, “OTFS Modulation Waveform and Reference Signals for New RAT,” Cohere Technologies, AT&T, CMCC, Deutsche Telekom, Telefonica, Telstra, TSG RAN WG1 #84b, Busan, South Korea, April 2016.