

Source: CMCC
Title: Phase-tracking reference signal design for DL CP-OFDM
Agenda Item: 7.1.2.4.3
Document for: Discussion and Decision

1. Introduction

In the last RAN1#88bis meeting, the following agreements on phase-tracking reference signal (PT-RS) for CP-OFDM has been achieved [1]:

Agreements:

- For CP-OFDM, the same PTRS to RE mapping and PTRS densities in time and frequency are available for DL and UL
- Distributed PTRS (non-consecutive subcarriers) in the frequency domain is used as default configuration
 - FFS: Support optional frequency-localized pattern with UE-specific explicit signaling. (e.g. higher MCS case)
- For single-user case, support orthogonal multiplexing among PTRS ports, if multiple PTRS antenna ports are supported.
 - FFS: how to multiplex multiple PTRS ports, e.g. FDM, TDM, CDM
 - FFS: Whether to support multiple PTRS ports or not (FFS: Max number of PTRS APs).
- Support orthogonal multiplexing between PTRS and data transmitted or received by a single UE.
- For MU-MIMO, non-orthogonal multiplexing of e.g. PTRS/PTRS and PTRS/data is possible but also orthogonal multiplexing to be considered
- FFS: Support multiplexing through multiple scrambling sequences for PTRS port(s)
- Support association between PTRS port and DMRS port group

In this contribution, for DL CP-OFDM, PT-RS design for different local oscillator (LO) configurations in high-frequency systems is given.

2. PT-RS design for different local oscillator (LO) configurations in high-frequency systems

For high frequency systems, massive MIMO is adopted to perform beamforming in order to compensate for the high path loss. Hybrid RF/analog + digital beamforming instead of full digital beamforming is proposed in high frequency bands, both at the base station and UE side, as a promising and practical architecture for optimal tradeoff between cost and performance. However, even hybrid RF architecture requires multiple RF channels to support multi-layer transmission, where different LO configurations that are adopted to complete up/down frequency conversion in different scenarios may affect the PT-RS design.

There are generally three LO configurations for high-frequency communication systems:

- ✧ **Case 1:** For all panels, a single high-frequency LO signal is generated centrally and distributes it throughout all the RF channels/antenna elements, as shown in Fig.1.

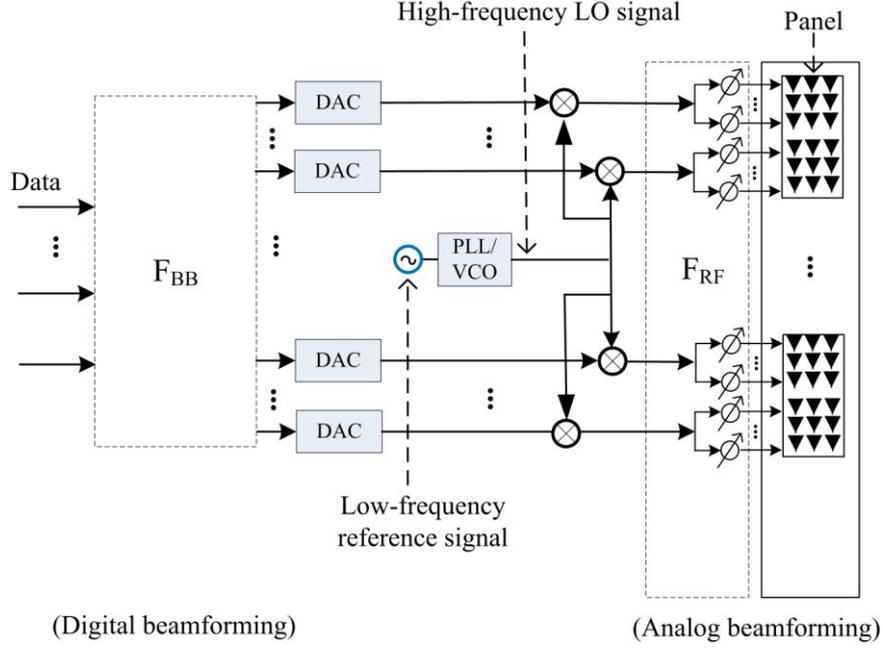


Fig.1. LO configuration for Case 1

For **Case 1**, there is only a single phase noise process generated across all panels.

- For SU-MIMO transmission, since phase noise estimation result can be shared among layers, only a single PT-RS port is enough to track this single phase noise process (note that each PTRS port aims to estimate the phase variation incurred by an independent LO). This single PT-RS port could be transmitted on a single layer or multi layer. If the single PT-RS port is transmitted on a single layer, the corresponding REs on other layers can either be nulled (no interference to PT-RS port) or can be used to transmit data (produce interference to PT-RS port). If the single PT-RS port is transmitted on multi-layers, the REs used to map PT-RS on these layers need not to be orthogonal, e.g., they can be identical to each other.
- For MU-MIMO transmission, since phase noise estimation result cannot be shared among UEs, even though there is only a single phase noise process, a single PT-RS port is required for each UE. Furthermore, in order to avoid interference among UEs, the PT-RS ports among UEs should be orthogonal (FDM, TDM or CDM). However, if perfect space division multiplexing among UEs can be achieved by using beamforming, non-orthogonal multiplexing of PTRS/PTRS among UEs maybe supported.
- **Proposal 1:** For **Case 1** SU-MIMO transmission, consider to support non-orthogonal multiplexing of PTRS/PTRS among layers, e.g., PT-RS can be transmitted on only one layer.
- **Proposal 2:** For **Case 1** MU-MIMO transmission, support orthogonal multiplexing of PTRS/PTRS among UEs, i.e., PT-RS should be orthogonally transmitted on each layer. Non-orthogonal multiplexing of PTRS/PTRS among UEs is FFS. The specification impact of PT-RS in MU-MIMO is FFS.
- ✧ **Case 2:** All the RF channels/antenna elements/panels share one single low-frequency reference signal as **Case 1**, but separate PLLs + VCOs are used to independently generated high-frequency LO signals for each panel, as shown in Fig.2.

For **Case 2**, a single phase noise process is generated for each panel. However, some kind of correlations may exist among those phase noise processes since a shared low-frequency reference signal is adopted. Genie phase noise estimation and compensation schemes may take advantages of such phase noise characteristic to facilitate and simplify PT-RS design.

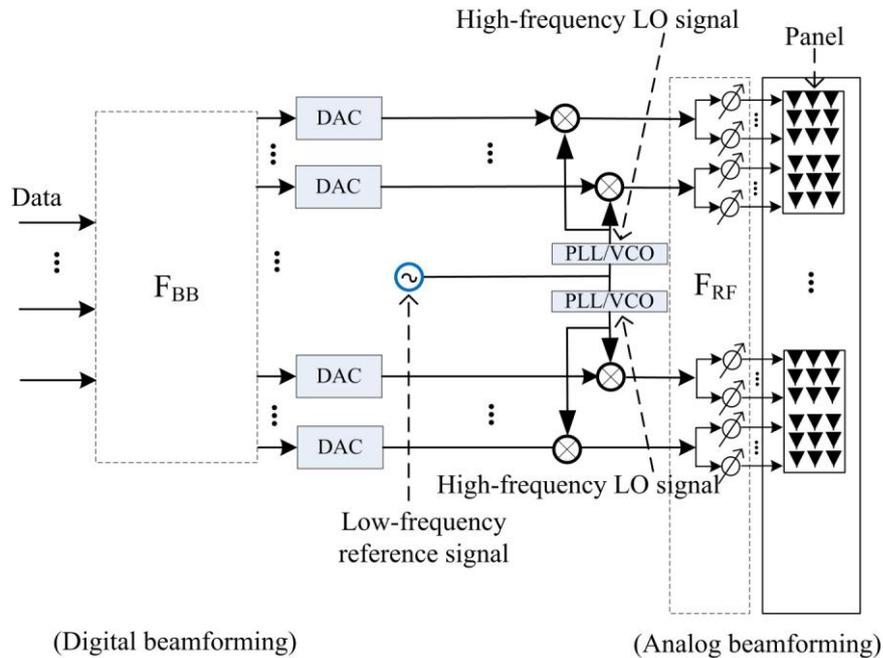


Fig.2. LO configuration for Case 2

- For SU-MIMO transmission, if only a single panel is adopted, the scenario is the same as **Case 1 SU-MIMO** transmission. If multi panel is adopted, a single PT-RS port is required for each panel. However, considering that some kind of correlations may exist among those phase noise processes, these PT-RS ports for multiple panels may not strictly orthogonal.
- For MU-MIMO transmission, if only a single panel is adopted, the scenario is the same as **Case 1 MU-MIMO** transmission. If multi panel is adopted and each panel is used to support one UE, even though some kind of correlations may exist among those phase noise processes, phase noise estimation result cannot be shared among UEs. Therefore, in order to avoid interference among UEs, the PT-RS ports among UEs should be orthogonal, i.e., transmitted on each layer, FFS FDM, TDM or CDM.
- **Proposal 3:** For **Case 2 SU-MIMO** transmission, consider to support non-orthogonal multiplexing of PTRS/PTRS among layers.
- **Proposal 4:** For **Case 2 MU-MIMO** transmission, support orthogonal multiplexing of PTRS/PTRS among UEs. Non-orthogonal multiplexing of PTRS/PTRS among UEs is FFS. The spec impact due to MU-MIMO is FFS.
- ✧ **Case 3:** Each panel uses its own low-frequency reference signal + PLL + VCO to generate its own high-frequency LO signal, as shown in Fig.3.

For **Case 3**, a single phase noise process is generated for each panel and these phase noise processes among panels are completely independent.

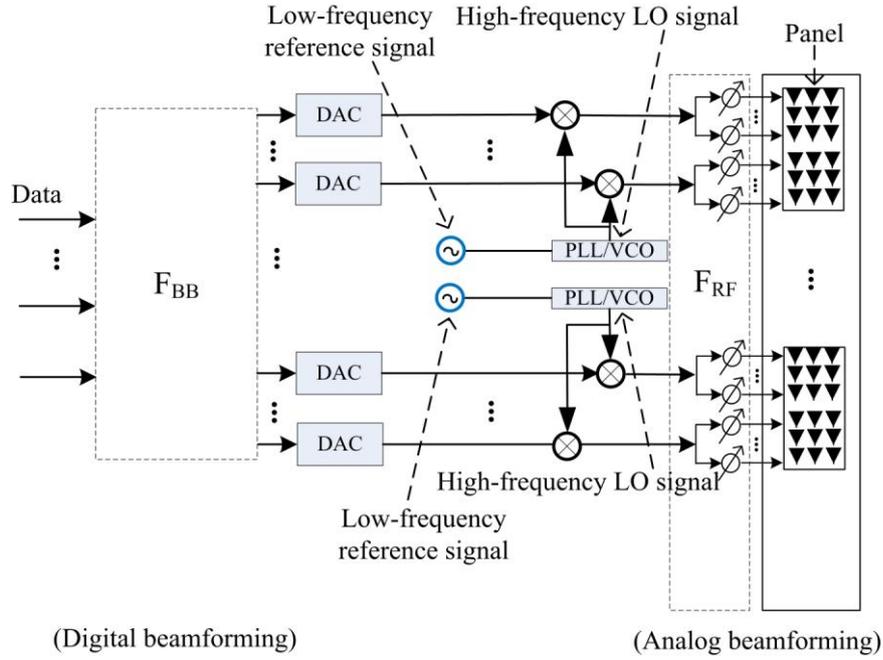


Fig.3. LO configuration for Case 3

- For SU-MIMO transmission, if only a single panel is adopted, the scenario is the same as **Case 1** SU-MIMO transmission. If multi panel is adopted, a single PT-RS port is required for each panel. These PT-RS ports should be orthogonal to avoid interference.
- For MU-MIMO transmission, no matter single panel or multi panel is adopted, since phase noise processes among panels are completely independent, The PT-RS ports among UEs should be orthogonal to avoid interference (FDM, TDM or CDM). The PT-RS due to multiple panels should be orthogonal as well.
- **Proposal 5:** For **Case 3** SU-MIMO transmission, if only a single panel is adopted, consider to support non-orthogonal multiplexing of PTRS/PTRS among layers. If multi panel is adopted, support orthogonal multiplexing of PTRS/PTRS among layers.
- **Proposal 6:** For **Case 3** MU-MIMO transmission, support orthogonal multiplexing of PTRS/PTRS among UEs. Non-orthogonal multiplexing of PTRS/PTRS among UEs is FFS. The spec impact due to MU-MIMO is FFS.

In summary, for the above-mentioned three Cases, the following proposal can be achieved:

- **Proposal 7:** For DL CP-OFDM SU-MIMO transmission, consider to transmit PT-RS only on one spatial layer (non-orthogonal PT-RS). For DL CP-OFDM MU-MIMO transmission, PT-RS is transmitted on each spatial layer (orthogonal PT-RS). Non-orthogonal multiplexing of PTRS among UEs is FFS. The spec impact due to MU-MIMO is FFS.
- **Proposal 8:** For **Case 1**, one PT-RS port per UE is supported. For **Case 3**, the number of PT-RS port per UE equals to the number of independent LO associated with the UE. For **Case 2**, the number of PT-RS port per UE maybe in between **Case 1** and **Case 3** (depending on specific phase noise estimation and compensation algorithm), and non-orthogonal multiplexing of PT-RS between different layers can be considered.

3. Conclusions

In this contribution, CMCC's consideration of PT-RS design for high frequency DL CP-OFDM is presented. The following proposals are achieved:

- **Proposal 1:** For **Case 1** SU-MIMO transmission, consider to support non-orthogonal multiplexing of PTRS/PTRS among layers, e.g., PT-RS can be transmitted on only one layer.
- **Proposal 2:** For **Case 1** MU-MIMO transmission, support orthogonal multiplexing of PTRS/PTRS among UEs, i.e., PT-RS should be orthogonally transmitted on each layer. Non-orthogonal multiplexing of PTRS/PTRS among UEs is FFS. The specification impact of PT-RS in MU-MIMO is FFS.
- **Proposal 3:** For **Case 2** SU-MIMO transmission, consider to support non-orthogonal multiplexing of PTRS/PTRS among layers.
- **Proposal 4:** For **Case 2** MU-MIMO transmission, support orthogonal multiplexing of PTRS/PTRS among UEs. Non-orthogonal multiplexing of PTRS/PTRS among UEs is FFS. The spec impact due to MU-MIMO is FFS.
- **Proposal 5:** For **Case 3** SU-MIMO transmission, if only a single panel is adopted, consider to support non-orthogonal multiplexing of PTRS/PTRS among layers. If multi panel is adopted, support orthogonal multiplexing of PTRS/PTRS among layers.
- **Proposal 6:** For **Case 3** MU-MIMO transmission, support orthogonal multiplexing of PTRS/PTRS among UEs. Non-orthogonal multiplexing of PTRS/PTRS among UEs is FFS. The spec impact due to MU-MIMO is FFS.

In summary, the following proposal can be achieved:

- **Proposal 7:** For DL CP-OFDM SU-MIMO transmission, consider to transmit PT-RS only on one spatial layer (non-orthogonal PT-RS). For DL CP-OFDM MU-MIMO transmission, PT-RS is transmitted on each spatial layer (orthogonal PT-RS). Non-orthogonal multiplexing of PTRS among UEs is FFS. The spec impact due to MU-MIMO is FFS.
- **Proposal 8:** For **Case 1**, one PT-RS port per UE is supported. For **Case 3**, the number of PT-RS port per UE equals to the number of independent LO associated with the UE. For **Case 2**, the number of PT-RS port per UE maybe in between **Case 1** and **Case 3** (depending on specific phase noise estimation and compensation algorithm), and non-orthogonal multiplexing of PT-RS between different layers can be considered.

References

- [1] 3GPP, R1-1706676, "Merged WF on PTRS structure", Ericsson, Panasonic, Huawei, HiSilicon, etc., RAN WG1 Meeting #88bis, April 2017.