

Source: CMCC
 Title: Discussion on remaining issues on PT-RS
 Agenda Item: 7.2.3.4
 Document for: Discussion and Decision

1. Introduction

In RAN1 NR #90bis meeting, the following agreements on PT-RS have been achieved [1]:

Agreement:

- For chunk-based pre-DFT PTRS insertion for DFTsOFDM with X chunks of size $K=\{2,4\}$, support the following
 - For $K=2$, the samples in DFT domain are divided in X intervals, and the chunks are located in each interval in samples n to $n+K-1$ where the n is FFS
 - For $K=4$, the samples in DFT domain are divided in X intervals, where in the first interval the chunk is placed in the Head (first K samples), in the last interval the chunk is placed in the Tail (last K samples), and in the rest of intervals the chunk is placed in the middle of each of the two intervals
 - For PTRS for DFT-s-OFDM, support a RRC parameter « *UL-PTRS-frequency-density-transform-precoding* » indicating a set of thresholds $T=\{N_{RBn}, n=0,1,2,3,4\}$, per BWP that indicates the values of X and K the UE should use depending on the scheduled BW according to the table below

Scheduled BW	X x K
$N_{RB0} < N_{RB} \leq N_{RB1}$	2x2
$N_{RB1} < N_{RB} \leq N_{RB2}$	2x4
$N_{RB2} < N_{RB} \leq N_{RB3}$	4x2
$N_{RB3} < N_{RB} \leq N_{RB4}$	4x4
$N_{RB} > N_{RB4}$	Yx4

- FFS default UE behaviour before RRC configuration, if needed
- FFS value of Y (if different than 4)
- FFS whether thresholds are MCS dependent
- Note: N_{RB0} can be equal to 0; when N_{RB0} is larger than 0, no PTRS is present for allocations less than or equal to N_{RB0}
- Note: The use of a specific pattern can be disabled by setting $N_{RBi}=N_{RBi+1}$ on the corresponding line in the previous table
- Possible PTRS presence/absence is configured through an RRC parameter « *UL-PTRS-present-transform-precoding* »

- Time-domain PTRS density is configured by an RRC parameter « UL-PTRS-time-density-transform-precoding » where supported time densities are $L_{\{PT-RS\}}=\{1,2\}$
 - Note: Time-domain pattern depends on DM-RS positions using the same principle as agreed for CP-OFDM PTRS mapping
- FFS: Whether to introduce ($K=1, X=16$) and the impacts on existing design. If supported, $K=\{1,2,4\}$ is supported and the following applies
 - The samples in DFT domain are divided in X intervals, and the chunks ($K=1$) are located in the middle of each interval
 - ($K=1, X=16$) applies when $N_{RB4} < N_{RB} \leq N_{RB5}$, and $X \times 4$ applies for $N_{RB} > N_{RB5}$

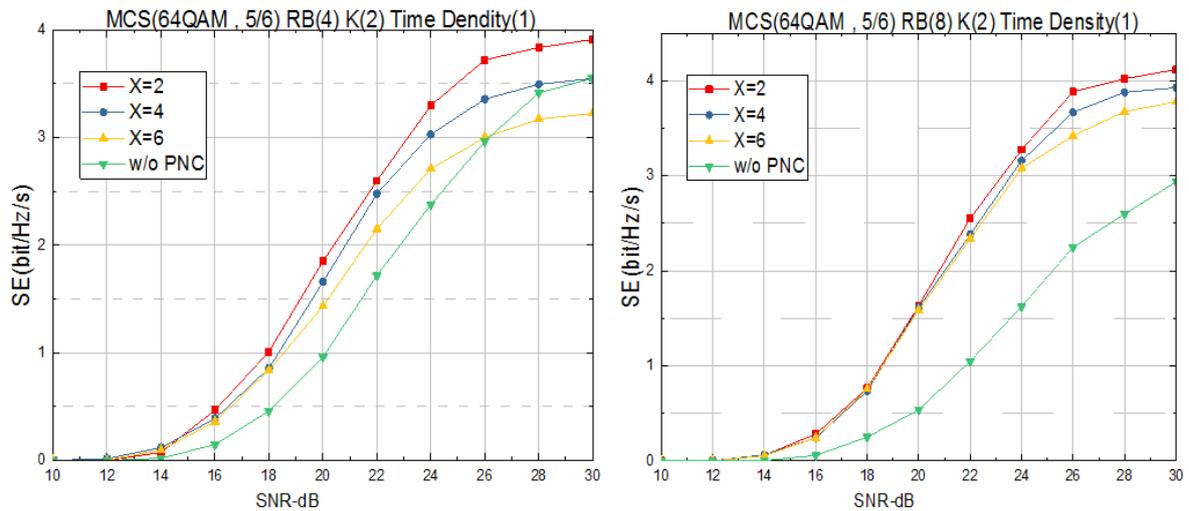
In this contribution, the remaining issues related to PT-RS design in DFT-s-OFDM systems are discussed, including the evaluation of X , K , $X \times K$ and n via extensive simulations. Then, a UCI transmission scheme for DFT-s-OFDM systems in high-frequency systems is proposed. Finally, the conclusions are given.

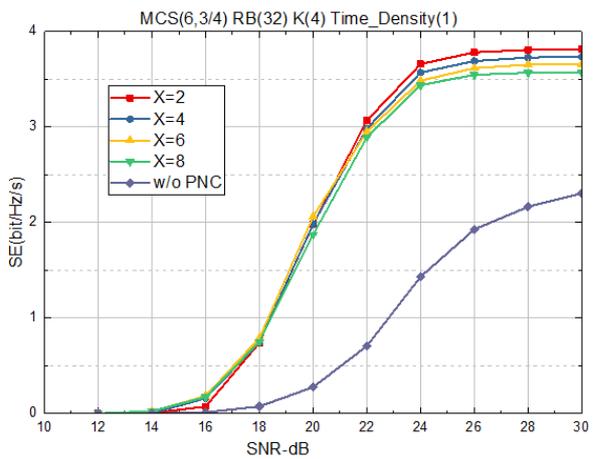
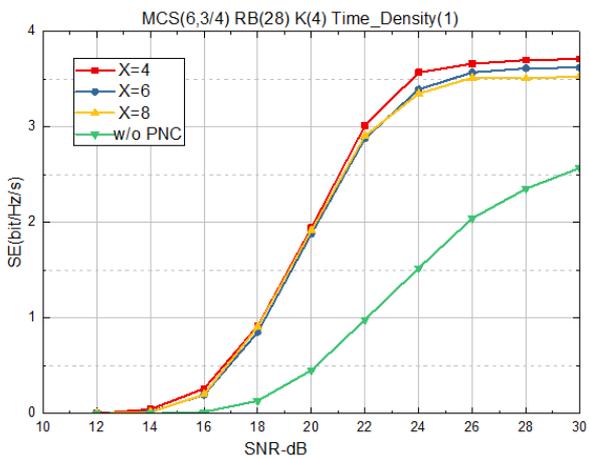
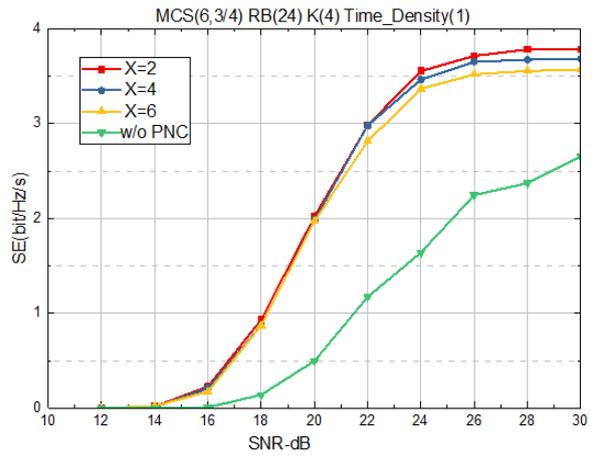
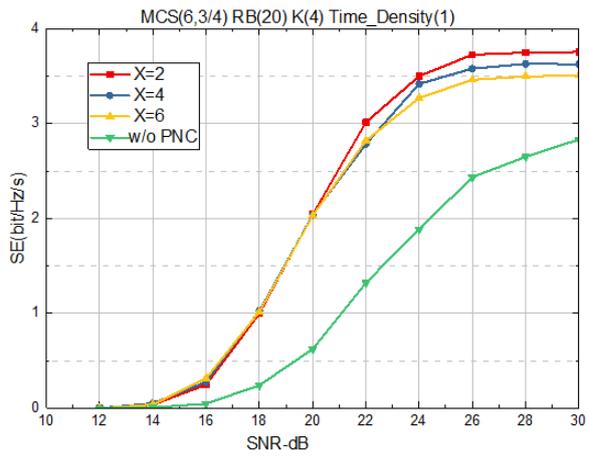
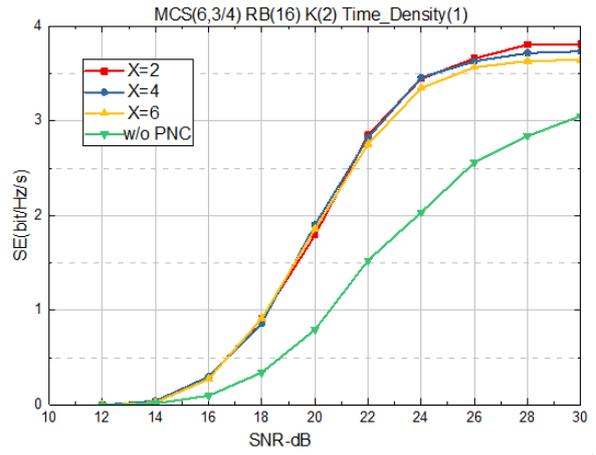
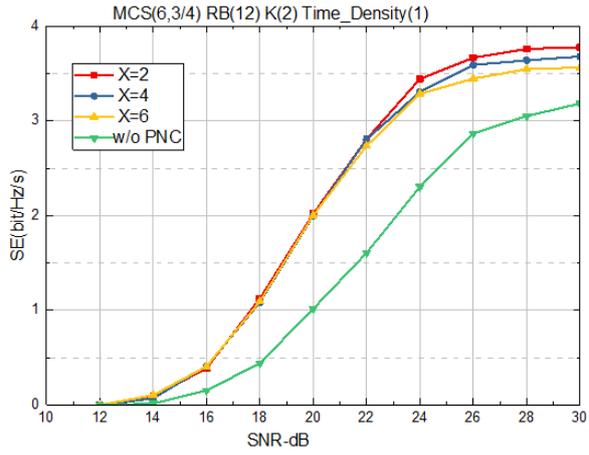
2. Remaining issues on PTRS for DFT-s-OFDM

In RAN1#90, the chunk-based pre-DFT PTRS insertion for DFT-s-OFDM systems has been agreed. The exact number of chunk X and the chunk size K are still left to be decided. It has been agreed in RAN1 NR#3 that the supported values for X (number of chunks/DFT-s-OFDM symbol) are at least 2 and 4. In RAN1#90bis, it has been agreed that for $K=2$, the samples in DFT domain are divided in X intervals, and the chunks are located in each interval in samples n to $n+K-1$ where the n is FFS. In this section, extensive simulations are performed to evaluate X , K , $X \times K$ and n . The simulation parameters are summarized in Appendix.

➤ The number of chunk X

In the simulation, $X = 2, 4, 6$ are selected to evaluate the performance. The simulation results are presented as follows:





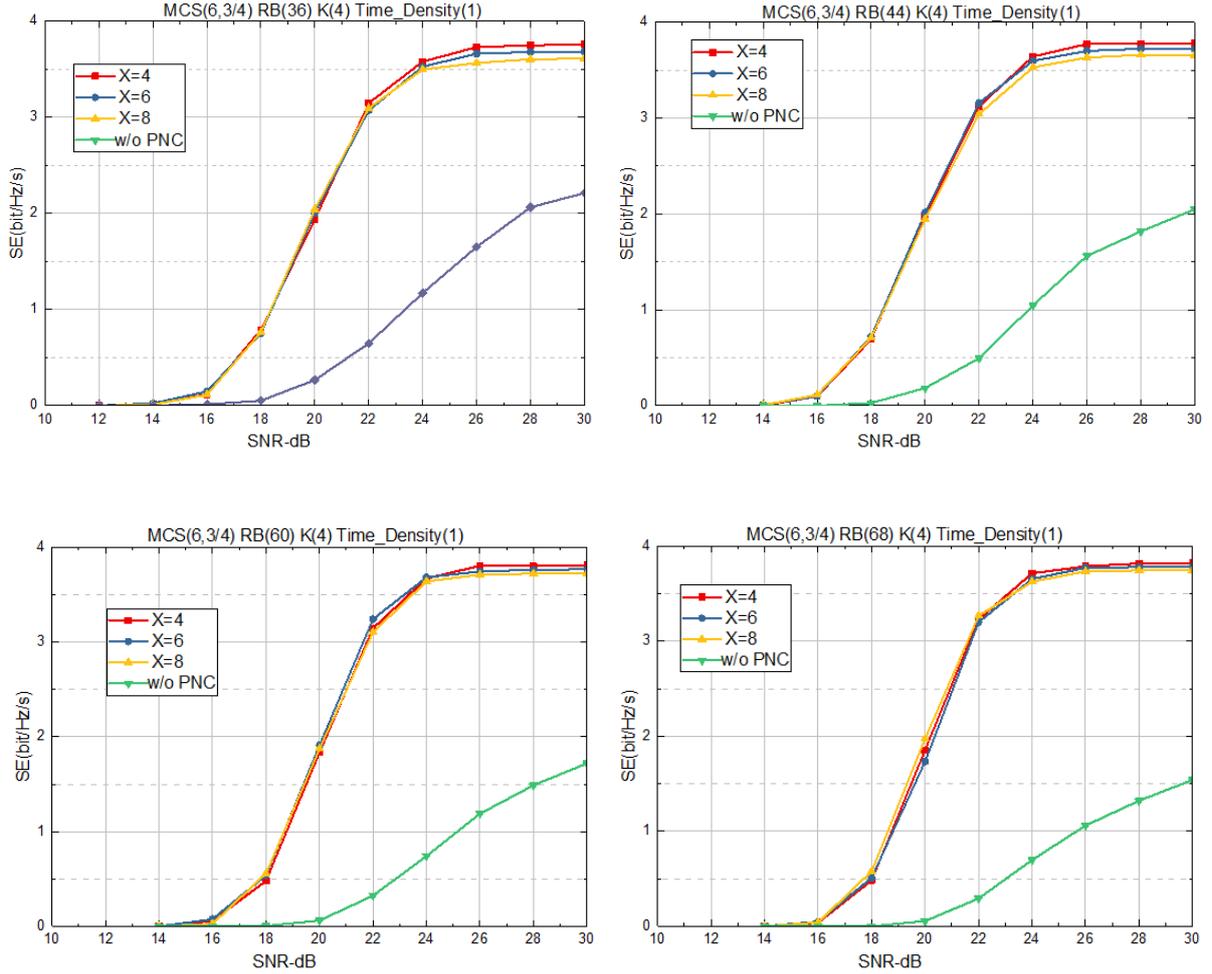


Fig. 1 The evaluation of X

It can be seen from Fig.1 that for $BW < 12RB$, $X=2$ obtains the best performance; for $12RB \leq BW < 32PRB$, $X=4$ obtains the best performance and for $32 PRB \leq BW$, $X=6$ achieves the best performance. The relationship between scheduled BW and X is summarized in the following Table 1.

Table 1: The relationship between scheduled BW and X

Scheduled BW	The number of chunk X
$0 \leq N_{RB} < 12 RB$	2
$12RB \leq N_{RB} < 32PRB$	4
$32 PRB \leq N_{RB}$	6

– **Proposal 1:** The relationship between scheduled BW and X according to Table 1 should be supported.

➤ **The chunk size K**

In the simulation, $K = 2, 4, 6, 8$ are selected to evaluate the performance. The simulation results are presented as follows:

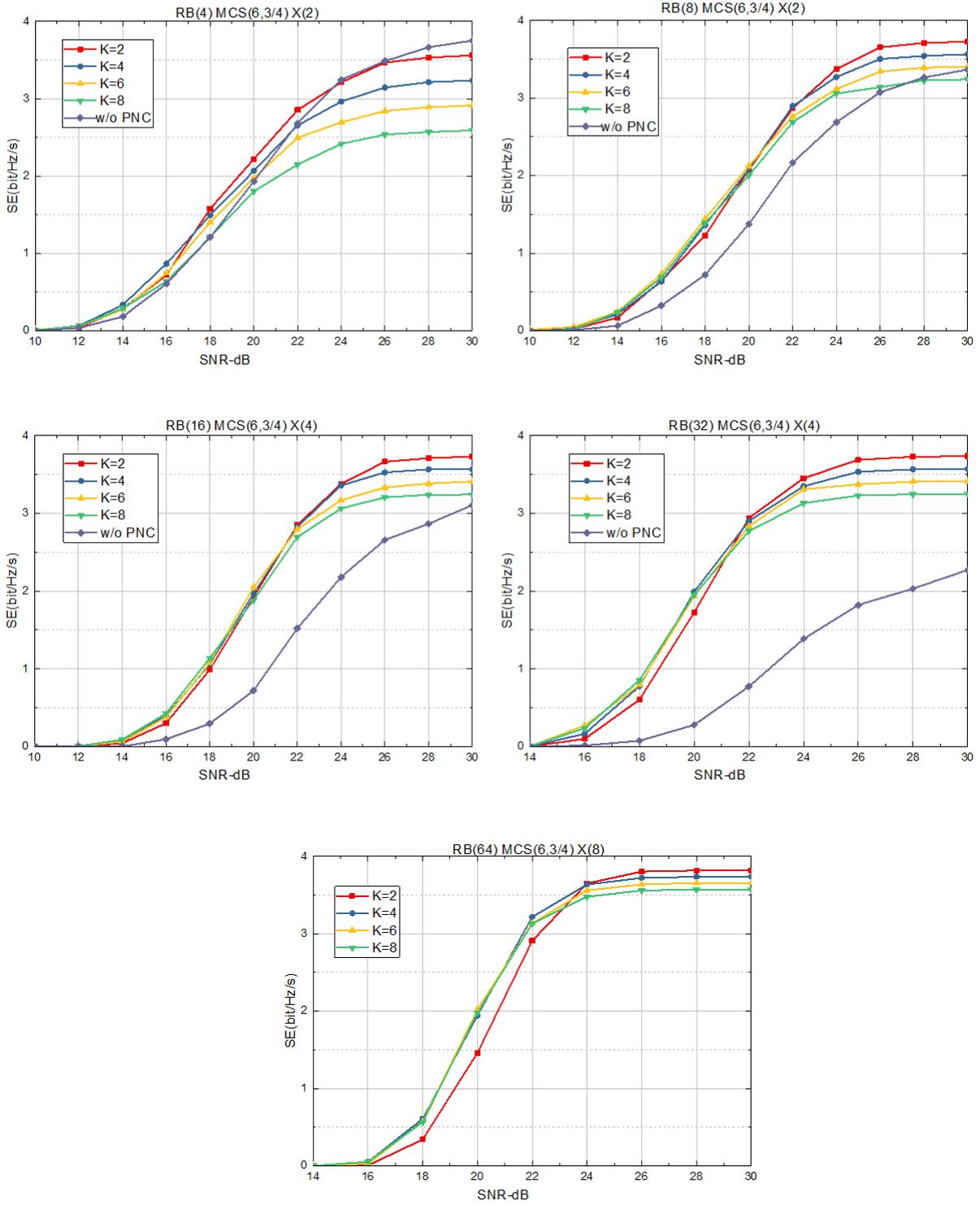


Fig. 2 The evaluation of K

Table 2: The relationship between scheduled BW and K

Scheduled BW	The chunk size K
$0 \leq N_{RB} < 8$ RB	2
$8PRB < N_{RB}$	4

It can be seen from Fig.2 that when $RB = 4$, $K = 2$ is the best. When $RB = 8, 16, 32, 64$, $K=2$ is the worst when $SNR < 22dB$. For $20 < SNR < 24$, which is likely the working SNR range for 64QAM, $K=4$ achieves the best tradeoff between the performance and overhead. The relationship between scheduled BW and K is summarized in Table 2.

- **Proposal 2:** The relationship between scheduled BW and K according to Table 2 should be supported.

➤ **The X x K table**

Based on the simulation results from Fig. 1 and 2, the relationship between scheduled BW and $X \times K$ is summarized in the following Table 3.

Table 3: The relationship between scheduled BW and $X \times K$

Scheduled BW	$X \times K$
$0 < N_{RB} < 8 RB$	2x2
$8RB \leq N_{RB} < 12PRB$	2x4
$12RB \leq N_{RB} < 32PRB$	4x4
$32 PRB \leq N_{RB}$	6x4

- **Proposal 3:** The relationship between scheduled BW and $X \times K$ according to Table 3 should be supported.

➤ **The evaluation of n**

It has been agreed in RAN1#90bis that for $K=2$, the samples in DFT domain are divided in X intervals, and the chunks are located in each interval in samples n to $n+K-1$ where the n is FFS. It can be seen from Fig. 3 that when $n=0, X/2$ and $X/4$, it represents alt2, alt3 and alt4, respectively.

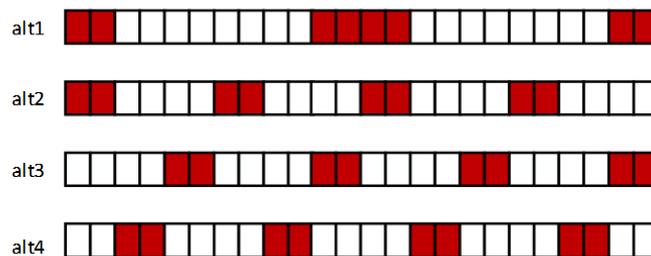
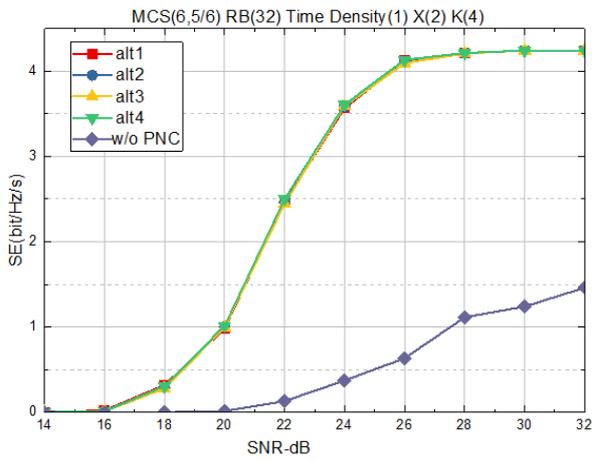
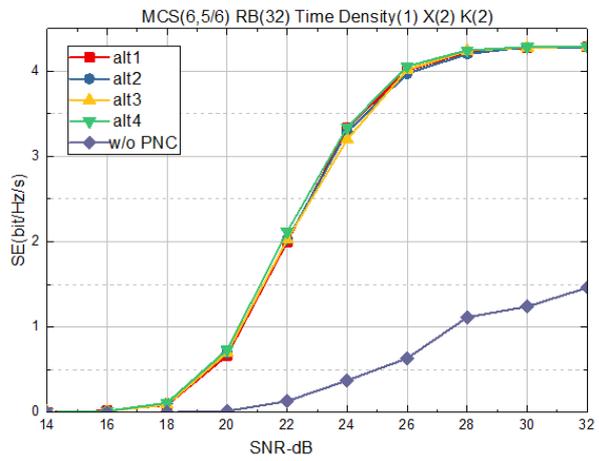
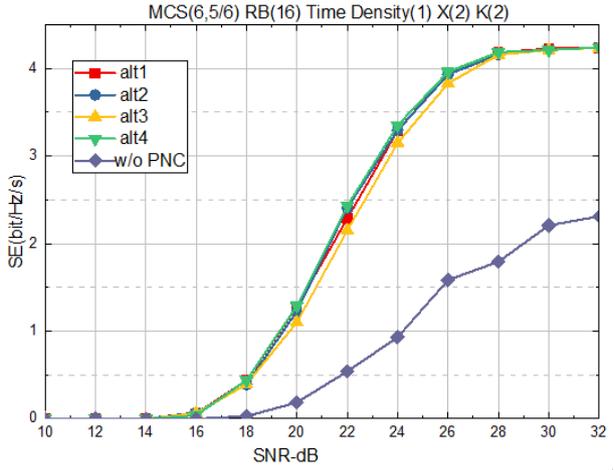
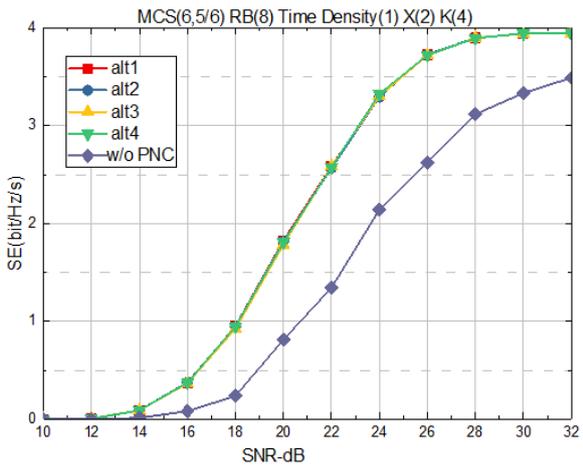
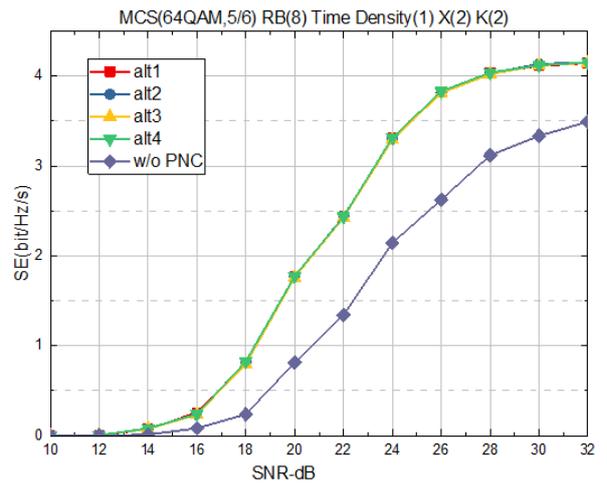
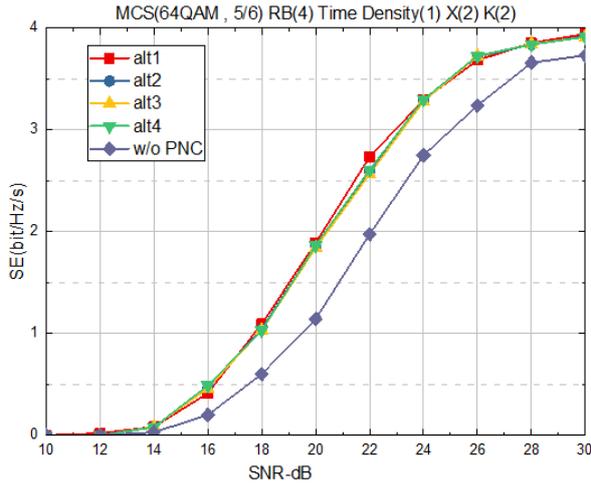


Fig. 3. Four possible alternatives when $X=2, K=2$

The simulation results comparing the four alternatives are presented as follows:

- For 120KHz SCS



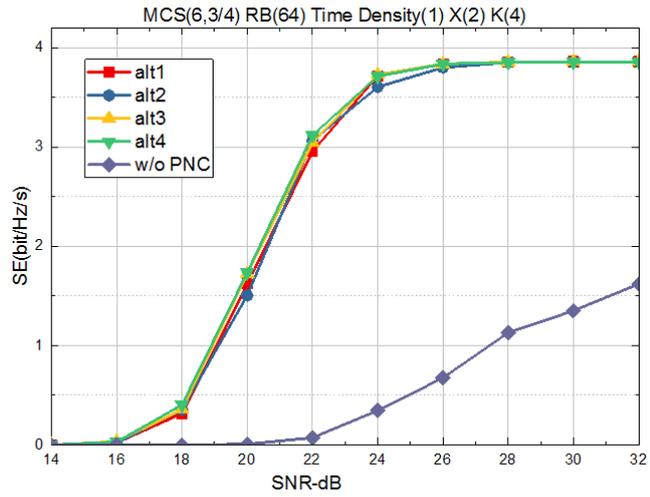
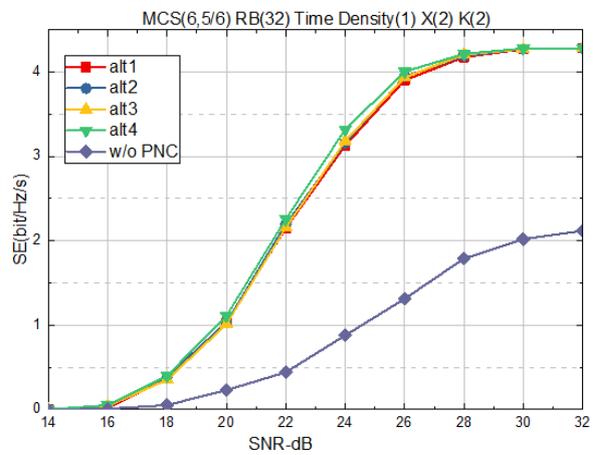
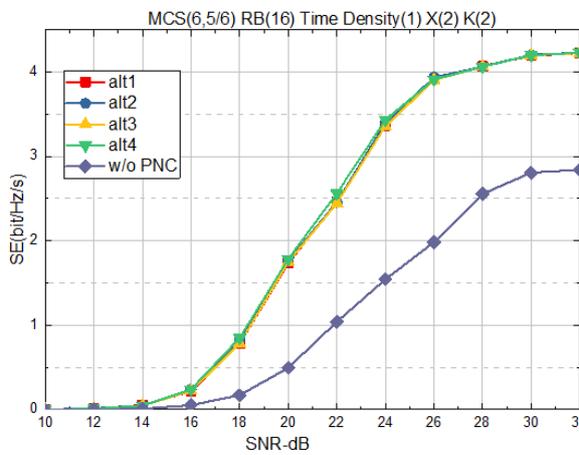
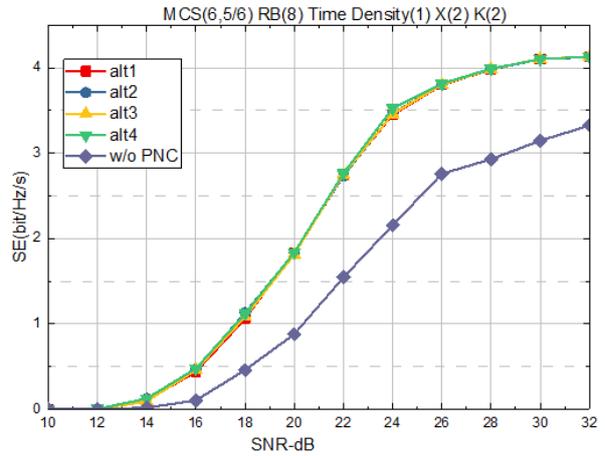
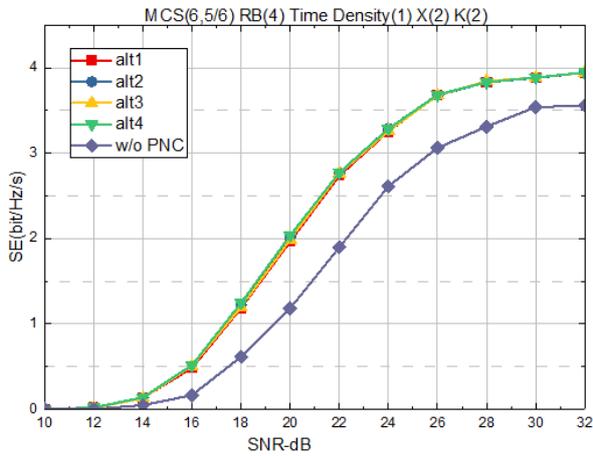


Fig. 4. Comparing four alternatives when SCS = 120KHz

● For 60KHz SCS



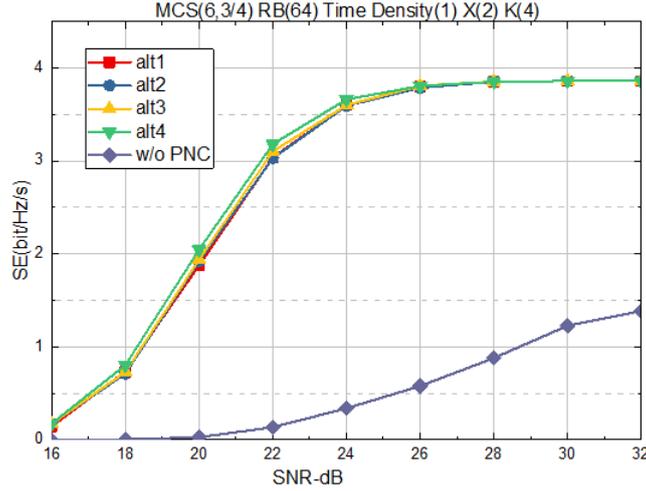


Fig. 5. Comparing four alternatives when SCS = 60KHz

It can be seen from Fig. 4 and Fig. 5 that alt4 performs better than others for both 60KHz and 120KHz cases. Therefore, alt4 is preferred, i.e., $n = X/4$ should be supported.

- **Proposal 4:** When $K=2$, the samples in DFT domain are divided in X intervals, and the chunks are located in each interval in samples n to $n+K-1$, where $n = X/4$.

3. UCI transmission for DFT-s-OFDM in high-frequency systems

In LTE, UCI is placed around DMRS to guarantee its demodulation performance. In NR uplink DFT-s-OFDM, both UCI and PTRS are inserted before DFT operation. It is noted that in NR, DMRS occupies a whole DFT-s-OFDM symbol just as DMRS in LTE, and PTRS is inserted before DFT in the time domain along with data in PUSCH symbols. Since reliable phase estimate can be obtained via both DMRS and PTRS, UCI should be placed around both DMRS and PTRS to guarantee its demodulation performance, as shown in Fig. 6.

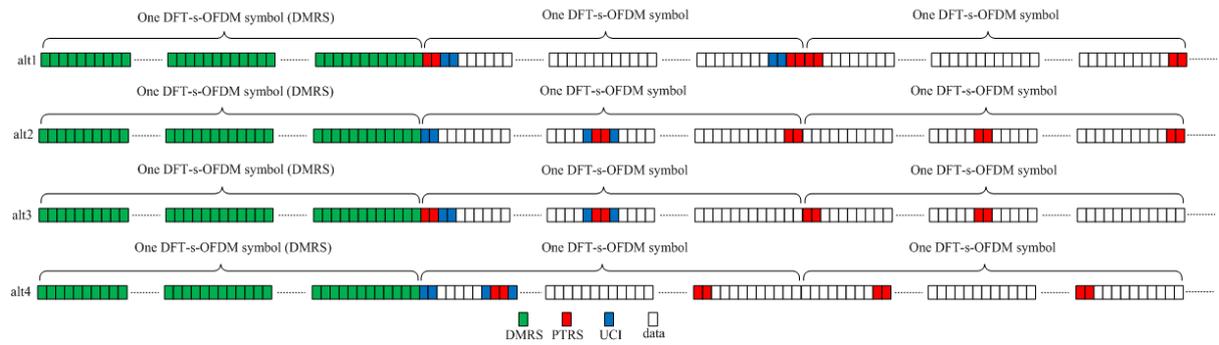


Fig. 6. Proposed UCI transmission scheme for four possible PTRS alternatives ($X=2, K=2$)

More specifically, assuming one front-loaded DMRS symbol is transmitted and PTRS exists in every other symbols, then for alt1, UCI is placed next to the front/tail PTRS in the symbol next to the DMRS; for alt2, UCI is placed next to the front-loaded DMRS and the middle PTRS in the symbol next to the DMRS; for alt3, UCI is placed next to front/middle PTRS in the symbol next to the DMRS; for alt4, UCI is placed next to the front-loaded DMRS and the middle of first of the 2 equally-sized parts of the DFT-s-OFDM symbols containing

PTRS, which is next to the DMRS. By doing so, both the channel estimation accuracy of DMRS symbol and the phase noise estimation accuracy of PTRS can be utilized, and meanwhile no extrapolation is needed.

Proposal 5: UCI should be placed around both DMRS and PTRS to guarantee its performance.

4. Conclusions

In this contribution, CMCC's consideration of uplink PT-RS design in DFT-s-OFDM systems is presented. The following proposals are achieved:

- **For the number of chunk X:**
 - *Proposal 1: The relationship between scheduled BW and X according to Table 1 should be supported.*
- **For the chunk size K:**
 - *Proposal 2: The relationship between scheduled BW and K according to Table 2 should be supported.*
- **For the X x K table:**
 - *Proposal 3: The relationship between scheduled BW and X x K according to Table 3 should be supported.*
- **For the evaluation of n:**
 - *Proposal 4: When K=2, the samples in DFT domain are divided in X intervals, and the chunks are located in each interval in samples n to n+K-1, where n= X/4.*
- **For UCI transmission for DFT-s-OFDM in high-frequency systems:**
 - *Proposal 5: UCI should be placed around both DMRS and PTRS to guarantee its performance.*

References

[1] 3GPP, Chinaman's Notes RAN1_90bis_final, RAN WG1 Meeting 90bis, October 2017.

Appendix

Parameters	Values or assumptions
Carrier frequency	28GHz
Channel model	CDL-B, 100ns
Subcarrier Spacing	120KHz
Allocated bandwidth	100MHz
Coding scheme	Turbo
Channel estimation	MMSE
Receiver	MMSE-IRC
Phase noise	Phase noise only at Tx