**3GPP TSG RAN WG1 #109-e R1-2205173**

**e-Meeting, May 9th – 20th, 2022**

**Source: Moderator (Intel Corporation)**

**Title: Summary#1 of AI: 9.9.1 NR PDCCH reception in symbols with LTE CRS REs**

**Agenda item: 9.9.1**

**Document for: Discussion and Decision**

# Introduction

In RAN#94-e meeting a work item on enhanced MIMO support was agreed for Rel-18 [1]. The objectives of the WID include enhancements to NR PDCCH reception as shown below:

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| The following objectives shall be included for improvement of NR spectrum efficiency for LTE-NR co-existence (RAN1):• Study and if needed specify NR PDCCH reception in symbols with LTE CRS REs. [RAN1] |

This document contains summary of the companies’ and moderator’s proposals.

# Review and observations

The following are observations from the FL based on tdoc review. This is not meant for agreement.

Multiple companies point out that the following existing methods enabling NR PDCCH capacity for DSS:

* UE supporting FG 3-2, FG 3-5, or the newly introduced Rel-16 UE capability to support monitoring PDCCH within the first 4 symbols.
* Rel-17 SCell PDCCH scheduling P(S)Cell PDSCH/PUSCH

Multiple companies point out the following consideration for UE implementation:

* Increase in UE complexity for channel estimation due to irregular DM-RS patterns for certain types of puncturing. The DMRS mapping/pattern may depend on the LTE-CRS pattern/configuration or PDCCH monitoring occasion.

Performance related:

* Multiple companies point out that enabling NR PDCCH reception in symbols with LTE CRS REs bring additional symbols for NR PDCCH allocation which contributes to NR PDCCH system capacity gain (e.g. 2 NR PDCCH symbols overlapped with 1 CRS symbol with puncturing improves the PDCCH capacity compared with 1 NR PDCCH symbol)
	+ For individual link performance a UE using a higher AL with puncturing (AL=2X) compared to the case with no puncturing and lower AL (AL=X) show gains. Higher AL compensates for loss due to puncturing.
	+ At least one company points out that the extent of gain over the existing capability of monitoring PDCCH in the first 4 symbols without puncturing may not be significant
* Multiple companies point out that the benefits of a potential Rel-18 solution depend on various factors including the ratio of UEs supporting legacy FGs, co-existence of LTE PDCCH/PCFICH/PHICH, number of LTE CRS ports and CRS BW relative to NR system BW.

# Enhancements for NR-PDCCH for DSS

## Possible specifications impact

Some companies have mentioned new or modified DMRS patterns for NR-PDCCH but given the TUs for this WID, such option is not included in this round. Pls. comment if you feel otherwise. The intention of Proposal #1 is to list few (reasonably complete) proposals in this meeting and check support. If you have alternative wording to suggest pls. also feel free to mention in comments.

**Proposal #1:**

* Consider the following Tx procedures: In the REs comprising an OFDM symbol that is overlapped between a NR-PDCCH candidate and LTE-CRS:
	+ Option-1: No NR-PDCCH-DMRS is transmitted, NR-PDCCH is transmitted on REs not colliding with LTE-CRS, NR-PDCCH is punctured on REs colliding with LTE-CRS, NR-PDCCH must span at least 2 consecutive symbols with at least 1 symbol not overlapping with LTE-CRS
	+ Option-2: NR-PDCCH or NR-PDCCH-DMRS is transmitted on REs not colliding with LTE-CRS, NR-PDCCH and NR-PDCCH-DMRS is punctured on REs colliding with LTE-CRS
	+ Option-3: NR-PDCCH or NR-PDCCH-DMRS is transmitted on REs colliding as well as not colliding with LTE-CRS (superposition)
* Consider the following applicability conditions (in addition to UE feature):
	+ Case-1: Applicable to NR-PDCCH candidate spanning 2 [or 3] consecutive symbols where the first 1 [or 2] symbol is overlapping with LTE CRS
	+ Case-2: Applicable to NR-PDCCH reception within the first 3 [or 4] consecutive symbols in a slot
	+ Case-3: Not applicable to Type-0/0A/1/2 CSS SS-sets reception
	+ Case-4: No additional applicability restrictions
* Consider the following NR-PDCCH reception with LTE CRS REs: A UE is expected to monitor a PDCCH candidate where at least one RE of the candidate is overlapping with LTE-CRS according to one of the following options (other options not precluded):
	+ Option-1: Tx procedure option-1 + Applicability cases-1, 2, 3
	+ Option-2: Tx procedure option-2 + Applicability case-4
	+ Option-3: Tx procedure option-2 and 3 + Applicability cases-1, 2

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| **Company** | **Comment** |
| OPPO | First, we are not sure which one of the following is the intention of proposal 1. * RAN1 further discusses Options listed in the last bullet, targeting the WID term of “Study and if needed specify”.
* The agreement of the proposal means RAN1 agrees to specify something for NR-PDCCH reception with LTE CRS REs, with possible solutions from Options {1,2,3}.

Could FL please clarify the intention?Secondly, the Options {1,2,3} are not defined per UE behavior for reception, but based on gNB behavior for transmission. This makes the proposal unclear to us. For example, does “Option-3: Tx procedure option-2, 3” mean the UE would monitor PDCCH (including using DMRS) in the same legacy way, which at least works for Tx option-3 (superposition) but maybe questionable for Tx Option-2 (puncturing)?  |
| Qualcomm | Considering the limited time until the completion, we suggest the following:1. In this meeting, RAN1 picks up a possible solution that is understood as feasible from various angles (UE implementation, performance)
2. In the next meeting, RAN1 will make a decision whether to support it or not.
	* For this, LLS and SLS assumptions are to be agreed in this meeting.

Regarding the above “a possible solution”, we are OK to move forward if it is Option-1 of the Tx procedure in the FL proposal. Option-2 and Option-3 would require UE to smartly handle irregular DMRS pattern(s) or superimposed DMRS. Different handling would be necessary for different CRS pattern configurations (v-shift, # of antenna ports, bandwidth, carrier frequency). This will be further serious problem if we consider overlapped/non-overlapped multiple LTE CRS patterns that overlaps with the PDCCH, where each CRS pattern has its own parameters. There are certain operational points where basic receiver (the receiver processing PDCCH as if it is a legacy PDCCH without overlapping CRS) works, as reported by some contributions. However, it would not be possible to say that basic receiver is sufficient and advanced receiver is not necessary. Once we decide to go with Option-2 or Option-3, we have to accommodate various receiver types for various scenarios in the end.From both UE and NW points of view, any possible solution is anyway a new type of PDCCH. Even with the basic receiver, the UE behavior and implementation have to be not the legacy one. With that said, we propose to consider Option-1 only.Some other aspects, e.g., whether to support Type-0/0A/1/2 CSS sets, can be concluded after the major decisions are made. |
| Moderator | To OPPO: the intention is the first bullet. yes – I have same understanding that for Tx procedure option 3 UE monitors in legacy way and Tx procedure option-2 is one way of puncturing |
| vivo | TX procedure: option1, option2* According to our simulation, option3 suffers serious loss if UE use the RE colliding CRS for estimation or PDCCH decoding, thus it is not supported.
* With modifications to UE side, i.e., nulling the CRS REs during the channel estimation or PDCCH decoding, option2 achieves significant PDCCH capacity gain but it may lead to irregular DMRS patterns as commented by Qualcomm, in which case it is not possible to use AL=1 to achieve 1% BLER requirement for PDCCH decoding. Option1 has no irregular DMRS issue, and provides better performance than option2. Thus, we think option1/2 should be considered for further down-selection.

applicability conditions:* In our understanding, the target scenario of the WID is case2. We are also open to case 3 to avoid impacts to common PDCCH performance of idle UE.
* Besides, we think it should be clarified if the case with two CRS patterns should be considered in this AI. If not, an additional condition as below should be introduced.
	+ Case-5: Applicable to NR-PDCCH candidate when there is only one LTE CRS pattern list
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| Nokia, NSB | We are in principle OK with all the suggested branches, but as suggested by Oppo, perhaps it would be better to formulate the Rx processing* PDCCH and PDCCH DMRS REs overlapping with CRS are ignored (puncturing)
* PDCCH and PDCCH DMRS REs overlapping with CRS are processed as if there was no overlap
	+ Tx could still puncture the PDCCH/PDCCH DMRS overlapping with the CRS, or it could superposition the two.
	+ If the UE is able to puncture in the Rx, then it of course should be told if these REs are not transmitted.

**@Qualcomm, Vivo**: Superpositioning doesn’t require any changes to the UE PDCCH processing, and it actually seems to work better than puncturing with higher aggregation levels, while with low Als it would not work (would need to opt for puncturing or just not use low ALs if the UE doesn’t support puncturing). We can do superpositioning today with idle mode UEs (just as we can do puncturing, where UE still assumes the REs to be present), but because of PDCCH candidate dropping we can’t configure a connected mode UE with CRS RM pattern overlapping with PDCCHs.Sure, the UE could do better if it wanted to, it could try to mitigate the CRS interference if it knows for sure that both CRS and PDCCH are superpositioned, or it could puncture the overlapping REs in the receiver. These could be different UE implementation alternatives. The UE would also be free to do channel estimation only based on the non-overlapping symbol or use DMRS from both overlapping and non-overlapping symbols.On scenarios, our understanding is that case 1 is the target.On ruling out CSS, this would be counterproductive, as it is today very bad that the UE drops PDCCH candidates overlapping with LTE CRS when it has been told that CRS is there. So if we want PDCCH we can’t configure CRS RM patter, but if want PDSCH with RM, we can’t have PDCCH. This is a pointless and counter-productive configuration restriction in Rel-15 preventing the network to find a compromise operational point without ANY impact to the UE implementation. |
| MediaTek | Thanks to Moderator’s further clarification. However, it is still not clear to us what is the next step after we choose some of the combination of options+cases. Is it for further study and the simulation should consider the chosen combination or is it to ignore the study and specify the feature directly? Based on the WID, I guess Moderato’s intention is to further study the selected combinations? If so, we suggest to add the wording “**For the purpose of study**” in each of the main bullets or simply add the wording in the beginning of proposal: **Proposal #1: For the purpose of study,**Regarding the options, we think at least option-3 might not be within the scope of WID where puncturing is specified:* Study and if needed specify NR PDCCH reception in symbols with LTE CRS REs. [RAN1]
	+ Investigate enabling LTE CRS to puncture NR PDCCH, including the impact to NR PDCCH DMRS if there is the performance gain from the additional PDCCH resources.

Regarding the cases, we think case-3 should be separated as a conclusion and not as an study candidate. It’s not clear to us how gNB should handle cell-specific CSS coexistence between legacy UEs and Rel-18 DSS UEs. As for case-1 and case-2, we support to study case-2 only. As pointed out by other companies, the necessity of considering puncturing in case-1 is not clear when UE can monitor other symbols in addition to the first 3 or 4 symbols. Also, due to the limited TU, it is preferred to focus on the basic feature first in order to converge the discussion faster. Therefore, we support to study * + Option-4: Tx procedure option-1 and 2 + Applicability case-2

and separate case-3 into a proposed conclusion:Conclusion: NR PDCCH reception in symbols with LTE CRS Res is not applicable to Type-0/0A/1/2 CSS SS-sets.  |
| Apple | For Tx procedure Option-1, we are not sure this option can work properly, i.e., PDCCH occupies two symbols but only one symbol has the DMRS. The third symbol in the slot would be used by PDCCH for legacy UEs, only second symbol in the slot is available for Rel-18 DSS UE, but there is no DMRS in this symbol.Similarly for applicability conditions, Case-1/2/4 is the scenario that no legacy UEs are in the network; otherwise only one symbol, i.e., the second symbol in the slot, is available for Rel-18 NR-PDCCH. |
| NTT DOCOMO | Our understanding is that the objective of this AI includes Tx procedure option 1 and 2. Considering the UE processing complexity and limited time, only option 1 may be sufficient.Regarding applicability conditions, as other companies have said, we see little need to support PDCCH reception in symbols that overlap with CRS other than the first 3 or 4 symbols. |
| Ericsson1 | In terms of analyzing benefit, we suggest using below case as baseline for study. Many companies have evaluated at least this case and it should help simplify the discussions. Companies can also bring up other cases but it is good to have at least one case that everyone studies.Some companies mentioned FG 22-12 but we do not see it being relevant for current discussion as it does not help reclaim sym#1 for NR PDCCH when LTE PDCCH is not used there.Which additional symbols to support (i.e., sym#0, #4 etc.) can be later point of discussion.We prefer Nokia proposed formulation for Rx processing. The two cases i.e., “PDCCH and PDCCH DMRS REs overlapping with CRS are ignored (puncturing)” and “PDCCH and PDCCH DMRS REs overlapping with CRS are processed as if there was no overlap” (aka basic receiver in our contribution) can used as baseline to analyze the benefit. According to our analysis, if a two-symbol CORESET (sym#1+sym#2) is used, then it is beneficial to use PDCCH-DMRS in both sym#2 and sym#1 (in spite of some REs being punctured) for channel estimation compared to only using REs in sym#2. This can also be considered.Then on QC proposed option (i.e., *-- in the REs comprising an OFDM symbol that is overlapped between a NR-PDCCH candidate and LTE-CRS -- no NR-PDCCH-DMRS is transmitted, NR-PDCCH is transmitted on all REs not colliding with LTE-CRS, NR-PDCCH is punctured on REs colliding with LTE-CRS, NR-PDCCH must span at least 2 consecutive symbols with at least 1 symbol not overlapping with LTE-CRS*), we are open to consider if there is support. However, considering the additional spec impact (effectively a new (no) PDCCH-DMRS pattern introduced in specs for sym#1), we do not think it is justified to consider it as the only option. This especially when other (arguably simpler) approaches are shown to be viable. |
| Huawei/Hisi | **1,** For the 1st proposal, we share the same view with Qualcomm that only Option-1 is a practical way for UE channel estimation. UE cannot perform basic legacy channel estimation based on Option 2 irregular DMRS pattern. To address Ericsson’s concern, we do not see a new DMRS pattern is necessary in spec (as seen in Understanding 1 in below). For Option 3, wouldn’t the superposition NR DMRS interfere the LTE CRS for channel estimation/measurement? Such degradation of the legacy RAT is not desired.In addition, the meaning of ‘No NR-PDCCH-DMRS is transmitted, NR-PDCCH is transmitted on REs not colliding with LTE-CRS’ in Option-1 needs clarified:**Understanding 1:** No NR-PDCCH-DMRS transmitted only on the overlapped REs with CRS. In other words, DMRS is still transmitted on other non-overlapped REs on the overlapped symbol (red spot in the left figure). UE will not use them for estimation though.**Understanding 2:** No NR-PDCCH-DMRS transmitted on any RE of the overlapped symbol. In other words, these REs can be 1) blank, or 2) used for carrying PDCCH payload (striped purple in right figure).

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**2,** If the intention of Proposal#1 is to set the simulation assumptions and for the purpose of performance comparison/analysis, then we suggest the baselines (legacy PDCCH on clean symbols) are needed. E.g.:* **Baseline** 1: 1 OS (3rd OS)
* **R18 Alt.1 (Case-1, or Case-2 with 3 OS monitoring)**: 2OS (2nd OS + 3rd OS), i.e. 1OS overlap + 1OS clean

* **Baseline 2**: 1 OS (3rd OS+4th OS)
* **R18 Alt.2 (Case-2 with 4 OS monitoring):** 3OS (2nd OS + 3rd OS + 4th OS), i.e. 1OS overlap + 2OS clean

We are OK with Case-3, Case-4 in applicability cases. For the combination (3rd bullet), as we only prefer Option-1, then only the 1st combination (Option-1) is valid. |
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# Evaluation assumptions

## LLS assumptions

**Proposal #2:** LLS simulations assumptions:

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| **Parameters** | **Values** |
| Carrier frequency | 2 GHz |
| SCS | 15 kHz  |
| Bandwidth  | 10 MHz |
| Channel model | TDL-C 300-100 |
| Correlation | Low |
| Number of BS antennas | 4 Tx (Two cross-polarized antenna pairs) |
| Number of UE antennas | 2 Rx (One cross-polarized antenna pair) |
| DCI payload (excluding CRC) | 60 bits |
| Interleaving | Non-Interleaved |
| Precoding | Precoder cycling per REG bundle |
| REG bundle size | 6 PRBs |
| CRS | 4 port CRS |
| Channel estimation | practical – companies to report details |
| CORESET configuration | companies to report |

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| **Company** | **Comment** |
| OPPO | We think the typical BW for NR is 20MHz (to align with SLS in Proposal 3), and the BW for LTE could be smaller than that of NR. In addition, the number of LTE CRS ports in case of LTE-NR coexistence can be 2.  |
| vivo | Same view as OPPO BW should be 20MHz. For number of BS antennas, we suggest adding 2TX, companies can select one between 2TX and 4TX.  |
| Nokia, NSB | The proposal is in principle agreeable. We would also suggest 20 MHz carrier BW to be added. |
| MediaTek | For channel bandwidth, we would like to add 5 MHz as a candidate. For CRS, 4 port CRS should be the only candidate for the study, which is the motivation of this object. Moreover, more than 1 CRS pattern should be considered in the evaluation.For channel estimation, we suggest to list some candidates to facilitate the discussion. Otherwise, it might be difficult to align the results from different companies. Also, this aspect might also have impact on the demodulation requirement in RAN4 and we prefer to align companies’ views on how to handle punctured DMRS in RAN1 discusison.For CORESET configuration, it is not clear to us the meaning of this field. Is it for the CORESET symbol duration (2 symbols, 3 symbols)? Or the locations of PDCCH monitoring symbols (first 3 symbols, first 4 symbols in a slot)?  |
| Apple | Number of symbols for PDCCH need to be specified, i.e., 1 or 2. |
| NTT DOCOMO | We are fine with the proposal. |
| Ericsson1 | Providing input for both link and system simulation assumptions here in one place. Suggest aligning carrier frequency and BW (i.e., use 2GHz and 20MHz) for both link and system level simulation assumptions.4Tx-2Rx (gNB-UE) antennas is OK. Perhaps good to clarify antenna configuration as below if not already common understandinggNB: (M,N,P,Mg,Ng;Mp,Np)= (1,2,2,1,1;1,1)UE: (M,N,P,Mg,Ng;Mp,Np)= (1,1,2,1,1;1,1)On DCI payload, we think 60bits is on higher side considering the scheduling is for a 20MHz FDD carrier with above antenna configuration (i.e., no need for TCI indication etc.) and considering UL grants (DCI 0\_1 based which are expected to be smaller) are sent along with DL assignments. We propose to include both 50bits and 60 bits in the evaluation.Prefer to keep UMa as proposed by Moderator.Finally, on Nokia comment on relevance of SLS, we somewhat agree. In our understanding the SLS assumptions (if used) are just to arrive at static SINR -> CCE aggregation level distributions and not for dynamic system level simulations. |
| Huawei/Hisi | We have following changing suggestions:1, Bandwidth 🡪 20MHz. In addition, 5MHz/10MHz can also be optionally considered, as it is typical combination of narrow band 5MHz/10MHz LTE + wideband 20MHz NR for the re-farming scenarios. To ease the simulation, the simulation of NR runs on 5MHz/10MHz, while the capacity can be calculated by considering 20MHz (only 5MHz/10MHz part contributes capacity gain).2, UE Speed should be added with 30km/h to be aligned with SLS EVM outdoor; in addition, a high speed case is also beneficial, e.g., 120km/h, 350km/h. |
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## SLS assumptions

**Proposal #3:** SLS simulations assumptions:

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| **Parameters** | **Values** |
| Carrier frequency | 2.1 GHz |
| SCS | 15 kHz |
| Simulation bandwidth  | 20 MHz |
| BS antenna height | 25 m |
| UE height | 1.5m  |
| TRP transmit power | 49 dBm 20 MHz |
| Scenario | Urban Macro |
| ISD | 500m |
| Device deployment | 80% indoor, 20% outdoor  |
| UE speeds | Indoor users: 3km/h |
| Outdoor users (in-car): 30 km/h |
| BS noise figure | 5 dB |
| BS antenna element gain | 8 dBi |
| UE noise figure | 9 dB |
| Thermal noise level | -174 dBm/Hz |
| Traffic | Full Buffer |
| Macro sites | 19 |
| Downtilt | 102° |
| Minimum BS to UE distance | 35m |

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| **Company** | **Comment** |
| OPPO | The above evaluation assumptions do not seem to account for the challenging condition in which some of the PDCCH DMRS REs are missing, for example, * In time domain, for Tx option-1, PDCCH DMRS may occur only on one symbol (if the number of CRS ports is 4), then a low UE speed (up to 30km/h, which is roughly a school-zone limit in some area) could be in favor of the sparse DMRS density in time domain.
* In frequency domain, the puncturing of PDCCH DMRS effectively makes the frequency domain channel selectivity to be less trackable by DMRS. For this issue, our understanding is that the RMa channel model may suffer more than UMa.
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| Nokia, NSB | Mix of indoor/outdoor is not recommended. In general we would aim to avoid a SLS sim campaign in a 2-meeting WI. |
| Huawei/Hisi | We are fine with the SLS table, with one suggestion that RMa can be considered also, since 2.1GHz is used for wide area coverage by many operators. Considering the SLS CDF of geometry is easy to be obtained, it will not add big efforts on simulation. |
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# References

[1] RP-213575, New WI: Enhancement of NR Dynamic spectrum sharing (DSS), Ericsson, 3GPP TSG RAN Meeting #94e, Electronic Meeting, Dec. 6 - 17, 2021.

[2] R1-2203137, Discussion on NR PDCCH reception in symbols with LTE CRS REs Huawei, HiSilicon

[3] R1-2203210 Discussion on NR PDCCH reception for DSS ZTE

[4] R1-2203344 Discussion on NR PDCCH reception in symbols with LTE CRS Res Spreadtrum Communications

[5] R1-2203581 Discussion on PDCCH reception on CRS symbol vivo

[6] R1-2203648 Evaluation of NR PDCCH overlapping with LTE CRS InterDigital, Inc.

[7] R1-2203834 Discussion on NR PDCCH reception in symbols with LTE CRS REs xiaomi

[8] R1-2203923 Considerations on PDCCH receptions in symbols with LTE CRS Samsung

[9] R1-2204024 Discussion on NR PDCCH reception in symbols with LTE CRS REs OPPO

[10] R1-2204260 Discussion on NR PDCCH reception in symbols with LTE CRS REs Apple

[11] R1-2204323 Discussion on NR PDCCH reception in symbols with LTE CRS REs CMCC

[12] R1-2204395 Discussion on NR PDCCH reception in symbols with LTE CRS REs NTT DOCOMO, INC.

[13] R1-2204630 Discussion on NR PDCCH reception in symbols with LTE CRS REs LG Electronics

[14] R1-2204709 Discussion on NR PDCCH reception in symbols with LTE CRS REs MediaTek Inc.

[15] R1-2204815 Discussion on NR PDCCH reception in DSS Intel Corporation

[16] R1-2204823 NR PDCCH overlapping with LTE CRS Nokia, Nokia Shanghai Bell

[17] R1-2204885 NR PDCCH reception in symbols with LTE CRS REs Ericsson

[18] R1-2205049 NR PDCCH reception in symbols with LTE CRS REs Qualcomm Incorporated

# Appendix (Summary of the agreements)

The agreements made in RAN1#TBD meetings are provided below.