3GPP TSG RAN WG1 Meeting #109e [R1-2205164](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2205164.zip)

**e-meeting, May 9th – 20th, 2022**

**Source: Moderator (CATT)**

**Title: FL Summary #2 for improved accuracy based on NR carrier phase measurement**

**Agenda item: 9.5.2.2**

**Document for: Discussion and Decision**

# Introduction

The Rel-18 SI “Study on expanded and improved NR positioning” was approved in RAN1#94e (RP-213588). One of the SI objective is:

* *Study solutions for accuracy improvement based on NR carrier phase measurements [RAN1, RAN4]*
  + *Reference signals, physical layer measurements, physical layer procedures to enable positioning based on NR carrier phase measurements for both UE-based and UE-assisted positioning [RAN1]*
  + *Focus on reuse of existing PRS and SRS, with new reference signals only considered if found necessary*

In this contribution, we summarize the related issues and proposals based on the contributions submitted to RAN1#109-e under agenda item 9.5.2.2 [1] – [23] for the following email discussion.

[109-e-R18-Pos-06] Email discussion on improved accuracy based on NR carrier phase measurement by May 20 – Ren (CATT)

* Check points: May 16, May 20

# SI Scope of Carrier Phase Positioning

## Background

The following proposals were submitted from interested companies related to SI scope of study of carrier phase based solutions, e.g., UE-based and UE-assisted positioning, DL/UL positioning, combination of carrier phase based solution with other measurements, etc.

***Submitted Proposals:***

* ***(Nokia,*** [***R1-2203178***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203178.zip)***[2]) Proposal 1:*** *RAN1 to study CP positioning for both DL and UL positioning based on the existing DL PRS and UL positioning SRS.*
* ***(Spreadtrum,*** [***R1-22-3333***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-22-3333.zip)***7[3]) Proposal 2:*** *Both UE-based and UE-assisted positioning should be considered for NR carrier phase positioning.*
* ***(ZTE,*** [***R1-2203626***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203626.zip)***[6]) Proposal 5:*** *Discuss whether LMF based or UE based solution or both is supported. Also discuss whether UL or DL carrier phase measurement or both is supported.*
* ***(ZTE,*** [***R1-2203626***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203626.zip)***[6]) Proposal 4:*** *Discuss whether carrier phase measurement is an independent positioning method or is configured under each legacy positioning method.*
* ***(China Telecom,*** [***R1-2203660***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203660.zip)***[9]) Proposal 2:*** *The carrier phase based solution can be combined with other measurements such as the TOA/TDOA to promote the accuracy.*
* ***(Samsung,*** [***R1-2203913***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203913.zip) ***[12]) Proposal 2:*** *Study and evaluate the performance of carrier-phase method for finer accuracy using detected phase.*
* ***(InterDigital,*** [***R1-2204134***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204134.zip)***[14])*** *Proposal 2: Study both stand-alone phase-based positioning and/or joint positioning methods, e.g., joint timing and phase-based measurements*
* ***(CMCC,*** [***R1-2204312***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204312.zip)***[15]) Observation 1:*** *The carrier phase positioning is shown with the following benefits ideally:*
  + *More accurate time of arrival can be obtained by measuring the phase change of the carrier;*
  + *More tolerant to bandwidth, a potential solution for Redcap positioning;*
* ***(NTT DOCOMO,*** [***R1-2204387***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204387.zip)***[16]) Observation 1:*** *In NR positioning, the carrier phase measurement can be used to adjust the measurement results of timing-based measurements such as RSTD and RTOA.*
* ***(Lenovo,*** [***R1-2204561***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204561.zip)***[18])Proposal 5:*** *Support UE-assisted and UE-based positioning modes for carrier phase positioning.*
* ***(Ericsson, R1-2204952[22]) Proposal 1:*** *Study the following: 1) whether a stand-alone positioning method for NR can be built from carrier phase measurements. 2) whether carrier phase measurements can be combined with any of the standardized Rel. 17 positioning methods to improve the accuracy.*

## Discussion

In FL’s understanding, UE-based and UE-assisted positioning, UL and DL carrier phase measurements should be included in SI scope for NR carrier phase positioning. Whether to combine the carrier phase measurements with other existing measurements may be up to the implementation. However, in general, similar to GNSS carrier phase positioning, it may not be good enough to use the carrier phase measurements only for carrier phase positioning, since in order to solve the integer ambiguity of the carrier phase measurements, there is a need to use other measurements to obtain the approximate UE’s location, which will narrow down the search space for the integer ambiguity. However, since NR is OFDM system, in FL’s view, it is also possible to combine the carrier phase measurements for a carrier frequency with the phase-differences (relative phases) of the subcarriers for NR carrier phase positioning, without the need to combine with other existing measurements, since the TOA can be determined based on the phase-differences (relative phases) of the subcarriers without the need to resolve the integer ambiguity.

Proposal 2-1

*The study of the NR carrier phase positioning in Rel-18 SI may include the following positioning methods:*

* *UE-based and UE-assisted carrier phase positioning,*
* *UL and DL carrier phase carrier phase positioning,*
* *Stand-alone NR carrier phase positioning with the carrier phase measurements of one (or more) carrier frequency and relative phase of the subcarriers),*
* *Combination of NR carrier phase positioning with any of the standardized Rel. 17 positioning methods.*

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| **Company** | **comments** |
| ZTE | We are generally fine with FL’s proposal. For good progress of this SI, the scope of the SI should be confined.  The third bullet is not clear enough from our side. For phase of the subcarriers, we don’t know whether absolute or relative phase should be reported yet, so we prefer to more generalize it as follows   * *Stand-alone NR carrier phase positioning with the carrier phase measurements of one (or more) carrier frequency ~~and relative~~ or phase of the subcarriers~~)~~,* |
| Huawei, HiSilicon | Regarding third bullet, we suggest to remove “and relative phase of subcarriers”.  It is not clear why “relative phase of the subcarriers” is related to carrier phase measurement, because it actually does not depend on carrier phase frequency.  In addition, we would like to have the following Note:  Note: The use of “carrier phase positioning” does not necessary mean it is a standalone positioning method.  In summary, we suggest to update the proposal as  *The study of the NR carrier phase positioning in Rel-18 SI may include the following positioning methods:*   * *UE-based and UE-assisted carrier phase positioning,* * *UL and DL carrier phase carrier phase positioning,* * *Stand-alone NR carrier phase positioning with the carrier phase measurements of one (or more) carrier frequency* * *Combination of NR carrier phase positioning with any of the standardized Rel. 17 positioning methods.* * *Note: The use of “carrier phase positioning” does not necessarily mean it is a standalone positioning method.* |
| Samsung | Fine to study UE-based and UE-assist carrier phase positioning. For channels to which carrier phase position applies, we would like to also include SL in addition to UL and DL.  For the last two sub-bullets it is not clear if stand-alone NR carrier phase positioning is sufficient to get positioning information. Suggest to update as follows:  *The study of the NR carrier phase positioning in Rel-18 SI may include the following positioning methods:*   * *UE-based and UE-assisted carrier phase positioning,* * *UL, ~~and~~ DL and SL carrier phase carrier phase positioning,* * *~~Stand-alone NR carrier phase positioning with the carrier phase measurements of one (or more) carrier frequency and relative phase of the subcarriers),~~* * *At least a combination of NR carrier phase positioning with any of the standardized Rel. 17 positioning methods.*   *FL: I assume SL carrier phase positioning is out scope of the SI.* |
| Nokia/NSB | We agree with Huawei that there is no need to include the part on relative phase of subcarriers. That can potentially be part of the study but is too detailed for this stage.  We are generally fine with the update from Huawei. One question for clarification on the 2nd bullet: do we mean that we will study DL carrier phase and UL carrier phase or we will also study DL+UL carrier phase?  FL: Here, it means “DL carrier phase positioning and UL carrier phase positioning” in my mind. I understand there are positioning methods that “DL+UL carrier phase”, but I assume it could be too advanced for R18. |
| Ericsson | Although we are supportive of the proposal, we have some concern with the scope of the last bullet. For the combination of NR carrier phase positioning with already standardized Rel. 17 positioning methods, we propose to restrict the combination to only the following methods: DL-TDOA, UL-TDOA and Multi-RTT. So we suggest to revise the last bullet as follows:   * *Combination of NR carrier phase positioning with the following positioning methods: DL-TDOA, UL-TDOA, and Multi-RTT.*   FL: In my view, it may be more reasonable that existing DL positioning methods (or DL measurements) are used together for DL *carrier phase positioning while* existing UL positioning methods (or UL measurements) are used together for UL *carrier phase positioning, since UE/TRP may provide the DL/UL carrier phase measurements together with other DL/UL positioning methods.* |
| CATT | We are in general fine with the proposal. |
| OPPO | First of all, we understand the relative phase of the subcarrier can be the difference between phase measured from two different frequency, which is one type of carrier phase measurement.  At the current moment, we do not need to restrict what kind of particular carrier phase measurement, which shall be part of our study work. In this proposal, we only need to say that stand-alone NR carrier phase positioning method is to be studied.  Lastly, the word of “*any of the standardized Rel. 17 positioning methods.”* is too vague. We suggest to list each particular positioning method. For that, we are fine with the suggestion by Ericsson.  *The study of the NR carrier phase positioning in Rel-18 SI may include the following positioning methods:*   * *UE-based and UE-assisted carrier phase positioning,* * *UL and DL carrier phase carrier phase positioning,* * *Stand-alone NR carrier phase positioning method ~~with the carrier phase measurements of one (or more) carrier frequency and relative phase of the subcarriers),~~* * *Combination of NR carrier phase positioning with the following positioning methods: DL-TDOA, UL-TDOA, and Multi-RTT.* |
| Apple | We are fine with the scope that has been identified in the proposal. We agree that the positioning methods for combination should be well defined. On the issue of adding SL to this, we think that at this point we should not mix two different issues that are being handled in different agenda items. |
| Xiaomi | We also have some concerns on “relative phase of the subcarriers” and prefer to remove it.  In addition, we are not sure stand-alone NR carrier phase positioning can work or not. We share same view as Samsung and prefer to remove it and add “at least” to the last bullet. While for the combination, we share same view as Ericsson, it is necessary to restrict the combination to only the DL-TDOA, UL TDOA and Multi-RTT. |
| NTT DOCOMO | Basically, we are fine with the proposal. Regarding the last bullet, we think timing-based methods would be beneficial to resolve the integer ambiguity, thus, we also support Ericsson’s update. |
| LGE | We are generally fine with the proposal.  We think the first and second bullet should be discussed in the SI phase and it would be useful to determine potential work scope for WI.  Regarding the third and the fourth bullet, we support to study both stand-alone and combination method to understand the pros and cons of each method. During the SI phase, it shall be investigated that not only the performance of each method but also other aspects, including resource/reporting efficiency and specification impact.  For the third bullet, although we are fine with current version but ZTE’s comment seems reasonable. |
| Fraunhofer | Okay in principle. In addition to suggestions above, some refinement on the proposal so second bullet can be misinterpreted as multi-RTT and suggest to remove positioning methods from the main bullet:  *The study of the NR carrier phase positioning in Rel-18 SI may include the following ~~positioning methods:~~*   * *UE-based and UE-assisted carrier phase positioning,* * *UL and/or DL [and SL] carrier phase ~~carrier phase~~ positioning,* * *…* |
| Lenovo | Fine with most bullets. For subbullet 3, we think "relative phase of subcarriers" could be replaced by "subcarrier phase difference" if it is kept. |
| InterDigital | We support the proposal. |
| **FL** | *It seems the main concern is related to the “relative phase” in 3rd bullet and the scope related to the combination of NR carrier phase positioning with other standardized Rel. 17 positioning methods.*  *The study of the NR carrier phase positioning in Rel-18 SI may include:*   * *UE-based and UE-assisted carrier phase positioning,* * *UL carrier phase positioning and DL carrier phase positioning.* * *NR carrier phase positioning with the carrier phase measurements of one carrier frequency or multiple frequencies* * *Combination of NR carrier phase positioning with another standardized Rel. 17 positioning method, e.g., DL-TDOA, UL-TDOA, etc.* * *Note: The use of “carrier phase positioning” does not necessarily mean it is a standalone positioning method.* |
| Locaila | We support Ericsson’s view.  In addition, we believe carrier phase method assisted with subcarrier measurement is sufficient to obtain initial position information and resolving integer ambiguity. Therefore, we want to limit the ‘combination’ approach in optional as below.  *Combination of NR carrier phase positioning with the following positioning methods: DL-TDOA, UL-TDOA, and Multi-RTT , if necessary.*  *FL: Suggest not limit to particular method(s) in this early stage.* |
| Intel | We are fine with the updated version from the FL, except the update to the third bullet – now, with “*one carrier frequency or multiple frequencies*” it is not clear if we are also including consideration of multiple carriers. Perhaps we could say “*one or more frequency/ies within a carrier*”  *FL: Similar view as commented by Qualcomm, it can be different frequencies with a carrier bandwidth, or different carrier frequencies.* |
| Qualcomm | We are generally ok with the latest FL update above.  In response to comments from Ericsson and Locaila that the scope of combination with existing methods can be limited to the timing based methods (DL/UL-TDOA and Multi-RTT), we think this scope limitation is too early at this stage. Specifically, angle-based methods may also be needed to address the issue of measured phase being a function of the AoD/AoA due to the phase-response of the antenna/array (we elaborate on this in our comments on proposal 6-1 and 8-1 below). The latest FL update above has not added this scope limitation, and we propose to keep it that way.  In response to Intel, “multiple frequencies” in general could cover (1) separate reporting (and use in position computation) of carrier phase for different subcarriers or groups of subcarriers, and (2) separate reporting of carrier phase for different positioning frequency layers. We think both these should be in scope, and we propose to keep the latest FL update as is. |

(Round 2) Proposal 2-1

*The study of the NR carrier phase positioning in Rel-18 SI may include:*

* *UE-based and UE-assisted carrier phase positioning,*
* *UL carrier phase positioning and DL carrier phase positioning.*
* *NR carrier phase positioning with the carrier phase measurements of one carrier frequency or multiple frequencies*
* *Combination of NR carrier phase positioning with another standardized Rel. 17 positioning method, e.g., DL-TDOA, UL-TDOA, etc.*
* *Note: The use of “carrier phase positioning” does not necessarily mean it is a standalone positioning method*

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| **Company** | **comments** |
| Huawei, HiSilicon | OK |
| Samsung | Add multi-RTT in forth bullet  We still think that carrier phase positioning is not excluded by the SID description. In the email disucssion of [109-e-R18-Pos-04] and in Proposal 3.1, the following is being discussed, we think that the note should also be included here.  Note: When the study of carrier phase positioning and the evaluations of sidelink positioning have progressed, it can be reviewed whether carrier phase for sidelink can be considered in further work. Checkpoint at RAN1#110-e-Bis to see if sufficient information is available for this review.  **Therefore, we propose the following update:**  *The study of the NR carrier phase positioning in Rel-18 SI may include:*   * *UE-based and UE-assisted carrier phase positioning,* * *UL carrier phase positioning and DL carrier phase positioning.* * *NR carrier phase positioning with the carrier phase measurements of one carrier frequency or multiple frequencies* * *Combination of NR carrier phase positioning with another standardized Rel. 17 positioning method, e.g., DL-TDOA, UL-TDOA, multi-RTT etc.* * *Note: The use of “carrier phase positioning” does not necessarily mean it is a standalone positioning method*   Note: When the study of carrier phase positioning and the evaluations of sidelink positioning have progressed, it can be reviewed whether carrier phase for sidelink can be considered in further work. Checkpoint at RAN1#110-e-Bis to see if sufficient information is available for this review.  FL:  For Samsung’s suggestion of adding “*multi-RTT”, I don’t have strong view, since it is icnldued in “e.g.” to given interested companies the freedom to provide the simulation results. From simulation effort point of view, I assume “multi-RTT” may need some more effort, since it needs to simulate both DL and UL.*  About Samsung’s suggestion of adding the Note, my preference is not to include it at least moment. Obviously, more discussion is needed to include SL carrier phase positioning. Ssince it is already under discussion in [109-e-R18-Pos-04] discussion, we could wait the conclusion of the discussion to see if we want to further discuss to ibclude the study of SL carrier phase positioning in this email thread. |
| Xiaomi | **Ok** |
| NTT DOCOMO | OK |
| ZTE | We are generally fine with FL's proposal. |
| LGE | We are fine with the proposal. |
| vivo | Even with the note, bullet 1, is more like study of carrier phase positioning as a standalone positioning method.  For us, the SID is about carrier phase measurement, how to position with carrier phase measurement can be discussed after carrier phase measurement is clear.  Maybe we can update the proposal as the following  *The study of ~~the NR carrier phase positioning~~ accuracy improvement based on NR carrier phase measurements in Rel-18 SI may include:*   * *UE-based and UE-assisted carrier phase positioning,* * *UL carrier phase positioning and DL carrier phase positioning.* * *NR carrier phase positioning with the carrier phase measurements of one carrier frequency or multiple frequencies* * *Combination of NR carrier phase positioning with another standardized Rel. 17 positioning method, e.g., DL-TDOA, UL-TDOA, etc.* * *Note: The use of “carrier phase positioning” does not necessarily mean it is a standalone positioning method*   FL: vivo’s suggestion is Okay to me. We can re-use the exact wording in SID “Study solutions for accuracy improvement based on NR carrier phase measurements” in the main bullet for covering different NR carrier phase positioning methods in this study. |
| InterDigital | We support the proposal from the FL. |
| Intel | Thanks for the clarifications from QC and FL to our earlier question. We’re fine with this version from the FL. |
| Qualcomm | We support the FL proposal |
| CATT | Support |
| **FL** | With the consideration of the comments, we may consider the following changes for Proposal 2-1  *The study of the accuracy improvement based on NR carrier phase measurements in Rel-18 SI may include:*   * *UE-based and UE-assisted carrier phase positioning,* * *UL carrier phase positioning and DL carrier phase positioning.* * *NR carrier phase positioning with the carrier phase measurements of one carrier frequency or multiple frequencies* * *Combination of NR carrier phase positioning with another standardized Rel. 17 positioning method, e.g., DL-TDOA, UL-TDOA, Multi-RTT, etc.* * *Note: The use of “carrier phase positioning” does not necessarily mean it is a standalone positioning method* |

(H)(Round 3) Proposal 2-1

*The study of the accuracy improvement based on NR carrier phase measurements in Rel-18 SI may include:*

* *UE-based and UE-assisted carrier phase positioning,*
* *UL carrier phase positioning and DL carrier phase positioning.*
* *NR carrier phase positioning with the carrier phase measurements of one carrier frequency or multiple frequencies*
* *Combination of NR carrier phase positioning with another standardized Rel. 17 positioning method, e.g., DL-TDOA, UL-TDOA, Multi-RTT, etc.*
* *Note: The use of “carrier phase positioning” does not necessarily mean it is a standalone positioning method*
* *FFS: whether SL carrier phase positioning is to be discussed in Rel-18 SI*

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| **Company** | **comments** |
| vivo | OK |
| ZTE | We are fine with FL's proposal. |
| MTK | ok |
| Huawei, HiSilicon | OK |
| Xiaomi | Ok |
| LGE | Fine with the proposal |
| CATT | Support |
| Nokia/NSB | Support. |
| Samsung | In reply to the FL comment: “About Samsung’s suggestion of adding the Note, my preference is not to include it at least moment. Obviously, more discussion is needed to include SL carrier phase positioning. Ssince it is already under discussion in [109-e-R18-Pos-04] discussion, we could wait the conclusion of the discussion to see if we want to further discuss to ibclude the study of SL carrier phase positioning in this email thread.”  We sugest adding the following note:  Note: Whether SL carrier phase positioning is supported in Rel-18 is under consideration/discussion in the SL positioning agenda item.  FL: I am not sure it may not be proper for this email thread to indicate the SL carrier phase positioning is under consideration/discussion in another AI. Maybe we could say “FFS: whether SL carrier phase positioning is to be discussed in Rel-18” to see if it is is acceptable. |
| Ericsson | Ok. |
| Intel | Support. |
| InterDigital | Support |
| **FL** | It seems we can use the latest verson with the last “FFS” bullet for Round 4 discussion to see if it is acceptable to all companies. |

### (Closed)(Round 4) Proposal 2-1

*The study of the accuracy improvement based on NR carrier phase measurements in Rel-18 SI may include:*

* *UE-based and UE-assisted carrier phase positioning,*
* *UL carrier phase positioning and DL carrier phase positioning.*
* *NR carrier phase positioning with the carrier phase measurements of one carrier frequency or multiple frequencies*
* *Combination of NR carrier phase positioning with another standardized Rel. 17 positioning method, e.g., DL-TDOA, UL-TDOA, Multi-RTT, etc.*
* *Note: The use of “carrier phase positioning” does not necessarily mean it is a standalone positioning method*
* *FFS: whether SL carrier phase positioning is to be discussed in Rel-18 SI*

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| **Company** | **comments** |
| Huawei, HiSilicon | OK. |
| LGE | We have concern on the added FFS bullet, and prefer previous version of round 3.  Since the study on SL positioning is just started in this meeting, we don’t have any baseline for implementing the carrier phase positioning to SL positioning. For example, we may need at least the information about reference signal and positioning procedure, but they are objectives of study in Rel-18 SL positioning item. Moreover, there are already many issues that shall be studied and may be required to be resolved for the carrier phase measurement for normal UEs. Hence, we do prfer to focus on the carrier phase positioning for normal UEs and not to discuss SL carrier phase positioning.  FL: Understand the concern. The last bullet it is under “FFS:”, it simple gives the companies more time to consider the issue. |
| Samsung | OK |
| CATT | OK |
| Intel | Support. |
| Xiaomi | Support |
| NTT DOCOMO | Support |
| Qualcomm | OK. We have similar views as LGE on the last bullet, but we’re ok with the FFS, as the FL commented in reply. |
| Ericsson | We share similar understanding as LGE and QC about the last bullet. But we are ok to keep it FFS. |
| **FL** | The proposal is endorsed to stable. Seem no revision is needed. |

# Reference Signals for Carrier Phase Measurements

## Background

As described in the SID [24], the SI will “*Focus on reuse of existing PRS and SRS, with new reference signals only considered if found necessary”.* The following proposals were submitted from interested companies on whether to introduce new reference signals for carrier phase measurements.

***Submitted Proposals:***

* ***(Nokia,*** [***R1-2203178***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203178.zip)***[2])******Proposal 1:*** *RAN1 to study CP positioning for both DL and UL positioning based on the existing DL PRS and UL positioning SRS.*
* ***(Spreadtrum,*** [***R1-22-3333***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-22-3333.zip)***7[3])Proposal*** *3: Polarization should be considered for implementing NR carrier phase positioning.*
* ***(CATT,*** [***R1-2203469***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203469.zip)***[4])Proposal 1****: R18 SI should focus on reuse of existing R16 PRS and SRS first for reference signal.*
* ***(vivo,*** [***R1-2203568***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203568.zip)***[5]) Proposal 3:*** 
  + *Support evaluating the carrier phase performance with the existing signal first, and comparing the performance gain with the existing NR method.*
  + *Don’t introduce a new signal for the carrier-phase measurement without the necessary reason.*
* ***(ZTE,*** [***R1-2203626***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203626.zip)***[6]) Proposal 6:*** *Discuss how the carrier phase estimation can be achieved based on the existing PRS or SRS, e.g. from frequency domain channel estimation or time domain channel estimation.*
* ***(Locaila,*** [***R1-2203634***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203634.zip)***[7]) Proposal 1****: Study new reference Signalling efficient for supporting phase-based measurement method*
* ***(DanKook,*** [***R1-2203635***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203635.zip)***[8]) Proposal 1.*** *To improve the positioning performance of 5G NR by applying the carrier phase positioning method, a new PRS signal efficient for phase measurement must be studied.*
* ***(DanKook,*** [***R1-2203635***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203635.zip)***[8]) Proposal 2:*** *Further study on the benefit of the block type continuous PRS sequence as proposed in the formula (1)*
* ***(China Telecom,*** [***R1-2203660***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203660.zip)***[9]) Proposal 1:*** *For the reference signal determination of the carrier phase based positioning solution, consider reusing the existed PRS/SRS-Pos or introducing the pure carrier wave of sinusoidal signal.*
* ***(MediaTek,*** [***R1-2203753***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203753.zip)***[10]) Proposal 2-1:*** *The new RS is not needed for carrier phase measurement under OFDM system*
* ***(Xiaomi,*** [***R1-2203824***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203824.zip)***[11]) Proposal 1:*** *Study the potential solution for integer ambiguity and considering the impacts on UE RF with reusing of PRS/SRS and other specification impacts.*
* ***(OPPO,*** [***R1-2203966***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203966.zip)***[13])Proposal 1:*** *The study of NR phase measurement-based positioning shall be based on the existing DL PRS and SRS for positioning.*
* ***(InterDigital, R1-2204134[14]) Proposal 5:*** *Study new PRS designs for carrier phase measurements for UL and DL*
* ***(InterDigital, R1-2204134[14]) Proposal 6:*** *A method to differentiate multiple PRSs, if they are transmitted in the same time-frequency resource, should be identified*
* ***(NTT DOCOMO,*** [***R1-2204387***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204387.zip)***[16]) Observation 3:*** *The current PRS should be reused unless evaluation results shows that the PRS does not provide accuracy improvement gain of NR carrier phase measurement.*
* ***(LGE, R1- 2204524[17]) Proposal 1:*** *Performance evaluation of the carrier phase measurement with existing PRS and SRS structure should be prioritized.*
* ***(Lenovo,*** [***R1-2204561***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204561.zip)***[18])Proposal 3:*** *RAN1 to further discuss the feasibility of the PT-RS like design for supporting carrier phase measurements.*
* ***(Ericsson, R1- 2204952[22]) Proposal 8:*** *Study methods to obtain the carrier phase from PRS and SRS.*
* ***(Qualcomm,*** [***R1-2205040***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2205040.zip)***[23]) Proposal 1:*** *Reuse Rel-16/17 PRS and SRS-for-positioning waveforms, and do not introduce a lower-BW positioning reference signal for carrier phase positioning.*

## Discussion

Based on the feedbacks, it seems the majority view is that the study of NR carrier phase positioning should be based on existing DL PRS and UL positioning SRS (e.g., [2][4][6][10][22][23]) and new reference signals may only be introduced when it is necessary (e.g., [7][8][14][18]). However, some companies believe introducing new reference signals is needed (e.g., [5][9][16][17]). Companies are invited to further provide their opinions whether existing DL PRS and UL positioning SRS are good enough for supporting NR carrier phase positioning in Rel-18, or there is need to introduce new DL/UL positioning reference signals for supporting NR carrier phase positioning.

Comments

|  |  |  |  |
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| **Company** | **New RS** | | **Additional comments** |
| **yes** | **NO** |
| ZTE |  | No | For good progress of this SI, the first step is, to re-use existing signal(s). If it is not sufficient to the requirement target (e.g., some commercial requirement), we can investigate new signal. |
| Vivo |  | No | we prefer not to introduce new signal for carrier phase measurement in Rel-18 |
| Huawei, HiSilicon |  | No | We do not want to expand the scope given that the existing RS already provided sufficient accuracy. |
| Samsung |  | No | Reference signals for carrier phase should strive to reuse DL PRS in the DL direction and Positioning SRS in the UL direction. |
| Nokia/NSB |  | No | The SID is already clear that we should focus on existing RS if possible. We are not sure that any agreement is even needed at this stage as the SID objective is there. |
| Ericsson |  | No | The feasibility/accuracy of a carrier phased positioning method depends on many different error sources such as the possibility to compensate for initial phase errors, oscillator drift, doppler, etc. In relation to these other error sources, the accuracy of the carrier phase measurements appears to be very good for both PRS and SRS. Consequently, the study must focus on how to tackle the much more significant error sources.  Most companies suggest carrier phased positioning as a means to enhance existing positioning methods. The combination with another positioning method may be needed to resolve the integer ambiguity problem. If carrier phased positioning is used with other methods then they should also use the same reference signals. |
| CATT |  | No | Suggest focusing on reuse of existing R16 PRS and SRS first for reference signal |
| Apple |  | No | We should use the existing signals. |
| Xiaomi |  | No | We prefer to reuse existing PRS and SRS for R18 carrier phase positioning. |
| NTT DOCOMO |  | No | Our 1st preference is to reuse the existing signals. |
| LGE |  | No | As described in the SID, we need to focus on reusing existing PRS and SRS. After investigation of the carrier phase measurement implementation using the existing PRS and SRS, the study on new reference signal might be started if necessary (e.g. only if any critical problem is observed from the carrier phase measurement with existing PRS/SRS).  Furthermore, it is our understanding that introducing a new RS will lead huge standard works, the necessity of it should be carefully considered. |
| Fraunhofer |  | No | Focus only on enhancements for existing positioning RS. |
| InterDigital | Yes |  | In our view, the existing RS for positioning (e.g., DL-PRS and UL-PRS) does not support contiguous RS transmission across multiple OFDM symbols and in order to obtain accurate phase measurement, such contiguous transmission is necessary. Therefore, a new RS (e.g., the RS with contiguous transmission in multiple OFDM symbols) may be necessary for phase measurement. However, if the majority of the companies want to work with the existing PRS, we are fine with the direction. |
| **FL** |  |  | Based on the feedbacks, most companies, except one, do not support introducing new RS for the moment. Maybe we can just confirm the SI objectives: “*Focus on reuse of existing PRS and SRS, with new reference signals only considered if found necessary”.* If there is indeed a need to new RS, we can further discuss it. |
| Dankook University | Yes |  | We strongly suggest to introduce new PRS.  We have achieved 15% to 20% higher performance using new continuous PRS design.  SNR is improved by accumulating phase information using the continuous waveform.  Rel-17 staggered PRS is only efficient for TdoA, not for the carrier phase positioning. |
| Locaila | Yes |  | We think Ericsson’s view is actually speaking the reason why we need new PRS signal. We had a lot difficulty in synchronizing TRPs in early stage of our field experiment. We were able to stabilize PLLs after we introduced continuous signal.  New PRS design, such as continuous signal, is necessary for efficient tracking of signal, synchronization of TRPs and improving the phase measurement accuracy. Couple of companies also addressed that current PRS is not good for the purpose of PLL training.  We need a form of continuous waveform reference signal for coarse/fine locking of PLL.  Performance gain in the phase measurement is another benefit.  We suggest to continue to discuss this issue with brining more experiment evidence of comparison between PRS design. |
| Intel |  | No | Same understanding as described by Ericsson that DL-PRS and UL-SRS have been shown to provide good potential for CP positioning, and the key challenges for CP positioning arises from a multitude of practical challenges/impairments. Unless a clear need is established, we prefer to focus on existing PRS options. |
| Qualcomm |  | No | There has to be a compelling need before we can agree to a new RS. In response to the comments about the need for “continuous PRS”, we think that (1) a fully ‘continuous PRS’ is not even possible in TDD and even in FDD may be quite challenging for the UE in the light of events like DRX and the need to be mindful of power consumption, and further (2) the motivations of the proponents of ‘continuous PRS’ may likely be met even without a fully ‘continuous PRS’ – what is really essential there is ‘phase continuity’ even if the transmission itself was not necessarily continuous – i.e., even though the transmission may cease and resume later, the phase when it resumes has a well-defined relation to the phase during/at the beginning/end of the previous transmission. |
| **FL** |  |  | Based on the feedbacks, most companies, except three, do not support introducing new RS for the moment. Again, in FL view, we can confirm the SI objectives: “*Focus on reuse of existing PRS and SRS, with new reference signals only considered if found necessary”.* It does not exclude introducing the new RS, but new RS will only be considered “*if found necessary”*. |

### (Closed) Proposal 3-1

*Confirm that during the SI, it will “Focus on reuse of existing PRS and SRS, with new reference signals only considered if found necessary”.*

|  |  |
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| **Company** | **comments** |
| Locaila | We disagree. |
| vivo | Support |
| Intel | Support |
| Qualcomm | Support |
| Huawei, HiSilicon | Support. |
| Samsung | It is not necessary to have a proposal to confirm the SI. We should be following what’s in the SI without having to confirm! This proposal is already captured in the SI (the part marked in yellow)   * + Study solutions for accuracy improvement based on NR carrier phase measurements [RAN1, RAN4]     - Reference signals, physical layer measurements, physical layer procedures to enable positioning based on NR carrier phase measurements for both UE-based and UE-assisted positioning [RAN1]     - Focus on reuse of existing PRS and SRS, with new reference signals only considered if found necessary |
| ZTE | Support |
| Nokia/NSB | We agree with Samsung. We should not reconfirm something that is crystal clear in the SID. No need for this proposal. |
| CATT | Support |
| **FL** | The motivation of the proposal was to address the pproposals of supporting new RS for carrier phase positioning, since at least one company proposes “*a new PRS signal efficient for phase measurement* ***must be*** *studied*”[8]. So, it would be better to check the views from all interested companies on this. From the comments received, it seems the majority responses is that we will follow the description in the SID. For that, I would agree with Samsung/Nokia that we may not need new agreement on it. Thus, I would suggest closing the discussion of the proposal. I assume any proposal related to the change of the SID can be discussed in plenary meeting. |

# NR Carrier Phase Measurements

## Background

3GPP has so far not defined the carrier phase measurements obtained from wireless communication systems. Thus, for the study of NR carrier phase positioning, we may first need to have a clear definition on NR carrier phase measurements.

If we follow the similar way as GNSS carrier phase positioning, the carrier phase should be defined as a measure of the range between a transmitter (e.g., a TRP or a UE) and a receiver (a UE or a TRP) expressed in units of cycles of the carrier frequency. The carrier phase measurement may include an integer ambiguity (i.e., unknown integer cycles). From the carrier phase measurements obtained from different transmitter and/or receivers, single/double differential operations may be performed to remove the carrier phase errors associated with the transmitter and/or receivers, such as transmitter and/or receiver clock offset, for cm-level positioning.

In addition, UE/TRP may also provide or use the phase-differences between multiple Tx/Rx antennas (or Tx/Rx antenna elements) for the determination of AOA/AOD. For example, for UL-AOA, one of the commonly used method for TRP to obtain the UL-AOA is to use the phase-differences between multiple Rx antennas (or Rx antenna elements in Rx antenna array) to estimate UL-AOA. Similarly, using the phase-differences between multiple TRP Tx antennas and the UE Rx antenna may be used to determine the DL-AOD.

Furthermore, since NR is an OFDM system, a UE/TRP may also provide the phase measurements for each subcarriers, or the phase-difference between the subcarriers and the reference carrier frequency. The phase-difference can be used for positioning purpose, e.g., determining the TOA.

***Submitted Proposals:***

* ***(Huawei,*** [***R1-2203166***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203166.zip)***[1]) Proposal 3:*** *For the downlink positioning methods, a reference TRP can be selected and the phase difference of other TRPs compared to the reference TRP can be reported.*
* ***(Nokia,*** [***R1-2203178***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203178.zip)***[2])******Proposal 4:*** *RAN1 to study and identify necessary measurements to support CP positioning for both DL-based positioning and UL-based positioning.*
* ***(Spreadtrum,*** [***R1-22-3333***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-22-3333.zip)***7[3])Proposal 1****: Differencing the measurements between base stations or UEs should be used for eliminating clock bias errors in NR.*
* ***(CATT,*** [***R1-2203469***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203469.zip)***[4])Proposal 2****: Candidate DL/UL measurements for NR CPP may include the carrier phase measurement (Phase Of Arrival, POA), differential carrier phase measurement (Phase Difference Of Arrival, PDOA) and measurement quality indication. The PDOA can be the POA difference between different gNB/TRPs or the POA difference between different antennas of same UE. The measurement quality indication can include one or combination of following items: LOS/NLOS indicator, Rician factor, SINR, and variance of CPP measurement, etc.*
* ***(CATT,*** [***R1-2203469***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203469.zip)***[4])Proposal 5****: Both time-domain and frequency-domain methods for carrier phase measurement with non-continuous signal can be studied.*
* ***(vivo,*** [***R1-2203568***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203568.zip)***[5]) Proposal 1:*** 
  + *Focus on NR carrier phase measurements in the study of carrier phase positioning.*
  + *The selected measurement method and corresponding phase measurement performance should be provided by companies .*
* ***(ZTE,*** [***R1-2203626***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203626.zip)***[6]) Proposal 3:*** *Consider to specify carrier phase measurement based positioning in Rel-18.*
* ***(ZTE,*** [***R1-2203626***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203626.zip)***[6]) Proposal 4****: Discuss whether carrier phase measurement is an independent positioning method or is configured under each legacy positioning method.*
* ***(MediaTek,*** [***R1-2203753***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203753.zip)***[10]) Proposal 2-2:*** *RAN1 to discuss whether carrier phase measurement under the OFDM (multicarrier) system could be equivalent to the usage of high resolution receiver. Then the specification impact may be minimized*
* ***(Xiaomi,*** [***R1-2203824***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203824.zip)***[11]) Proposal 3: Study relative carrier phase measurement between different TRPs or different times.***
* ***(InterDigital,*** [***R1-2204134***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204134.zip)***[14]) Proposal 7: Study contents of the measurement report for phase-difference based positioning.***
* ***(LGE, R1- 2204524[17]) Proposal 2:*** *Study pros and cons of candidate estimation methods for NR carrier phase measurement including UE complexity.*
* ***(Intel,*** [***R1-2204807***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204807.zip)***[20])Proposal #2:*** *Study new RSTD measurement based on the carrier phase difference measurement of the DL PRS signal at the kth subcarrier frequency for the target and reference TRPs normalized by the carrier frequency (œâc + œâk) corresponding to the LOS path.*
* ***(Intel,*** [***R1-2204807***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204807.zip)***[20])Proposal #5:*** *Study RSTD measurement for the multi element TX antenna array, which requires TX beamforming phase difference estimation for the reference and target TRPs.*
* ***(Intel,*** [***R1-2204807***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204807.zip)***[20])Proposal #7:*** *Study RSTD measurement for the multi element RX antenna array, which requires RX beamforming phase difference estimation for the reference and target TRPs.*
* ***(Intel,*** [***R1-2204807***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204807.zip)***[20])Proposal #8:*** *Study new RTOA measurement based on the carrier phase measurement of the UL SRS signal at the kth subcarrier frequency normalized by the carrier frequency (œâc + œâk) corresponding to the LOS path.*
* ***(Intel,*** [***R1-2204807***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204807.zip)***[20])Proposal #10:*** *Study RTOA measurement for the multi element TX antenna array, which requires TX beamforming phase difference estimation for the reference and target TRPs.*
* ***(Intel,*** [***R1-2204807***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204807.zip)***[20])Proposal #11:*** *Study RTOA measurement for the multi element RX antenna array, which requires RX beamforming phase difference estimation for the reference and target TRPs.*
* ***(Fraunhofer,*** [***R1-2204836***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204836.zip)***[21]) Proposal 1:*** *The carrier phase shall be determinable for different components of the channel impulse response and shall be measured in the delay domain*
* ***(Fraunhofer,*** [***R1-2204836***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204836.zip)***[21]) Proposal 5:*** *Allow the double difference phase reporting for phase based positioning enhancements*
* ***(Ericsson, R1- 2204952[22]) Proposal 7:*** *Any definition of carrier phase measurements should consider the aspect of multipath propagation. I) One option is to assume that the measurement is for the first path. Ii) Another option is to define carrier phase measurements for additional paths.*

## Discussion

To make the discussion easier and avoid confusion, the FL suggests to have a discussion on the definitions related to *carrier phase measurements, single/double differential phase measurements, phase-difference measurements, etc.*

Proposal 4-1

* *For NR downlink and/or uplink carrier phase positioning, the carrier phase (CP) measurement between a transmitter and a receiver is defined as a measure of the signal propagation time from an Tx antenna of a transmitter (e.g., a TRP or a UE) to a Rx antenna of a receiver and a receiver (e.g., a UE or a TRP) expressed in units of cycles of a reference carrier frequency.* 
  + *Note: There can be an unknown integer of cycles in a carrier phase measurement.*
  + *FFS: whether to have introduce definitions of the carrier phase measurement for the 1st path and the additional paths*

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| **Company** | **comments** |
| MTK | 1, To express specifically in unit of cycles may not be needed. We prefer to give a more general description:  “the carrier phase measurement may be defined as a measure of the phase change from an TX antenna of a transmitter to a RX antenna of a receiver expressed as the frequency of a (sub-)carrier times the propagation time”  2, we suggest to have a general discussion first, on whether we treat the “carrier phase measurement” under OFDM as the phase measurement over a single carrier? Or it is a joint phase measurements over subcarriers? And our proposal is to consider joint phase measurements over subcarriers so that the high resolution receiver applies |
| ZTE | MTK’s revision seems clearer to us.  Furthermore, we think whether the integer part of units of cycles should be measured/reported in some cases. Hence, we prefer to add one more study bullet as:  **FFS phase measurement includes the integer part of units of cycles** |
| vivo | More clarification is needed, do you mean the carrier phase measurement includes the number of integer N?  And we also agree with the view of MTK, how to measure the fraction integer needs to be studied first |
| Huawei, HiSilicon | Some corrections/clarifications below:   * *For NR downlink and/or uplink carrier phase positioning, the carrier phase (CP) measurement at a RF frequency between a transmitter and a receiver is a function of the signal propagation time from an Tx antenna reference point of a transmitter (e.g., a TRP or a UE) to a Rx antenna reference point of a receiver (e.g., a UE or a TRP) expressed in units of integer cycles and a fractional part of the wavelength of the RF frequency.*    + *Note: The integer cycles may be unknown.*   + *FFS: whether to have introduce definitions of the carrier phase measurement for the 1st path and the additional paths*   Carrier phase measurement should be defined in a way to obtain the measurement from signals, similar to the measurement defined TS 38.215.  To MTK, for OFDM system, it should also allow to have a centre frequency for the transmission, which is used for extract the carrier phase measurement. |
| Samsung | The proposal is not very clear. What is the meaning of carrier phase measurement between transmitter and receiver? How can this be measured? In our view, the carrier phase is measured at the receiver. The carrier phase measurement at the receiver is just a measure of the phase of the received signal relative to a reference at the receiver. Strictly speaking, the carrier phase at the receiver doesn’t measure the signal propagation time, except if the receiver and transmitter are phase-synchronized. |
| Nokia/NSB | We should not already be “defining” a measurement at this stage in the SID in our view. Huawei’s suggestion to call it a function is better but we should also remove the word “measurement” from the first line. |
| Ericsson | We do not agree with the proposal and we think that the FL description of the corresponding GNSS measurement is incorrect: In GNSS, the carrier phase measurement is the difference between the phase of an internal oscillator of the receiver and the phase of the incoming signal. That is of course related to the propagation time and an integer number of complete cycles as the proposal say, but the measurement should not include that.  Regarding multipath, we think multipath propagation may have a large impact on the accuracy. It is easy to formulate a measurement definition that takes the aspect of multipath in consideration, we think that this is preferable.  We agree with the comment from Nokia/NSB that it is too early to be defining the measurement at this stage of the study item. |
| CATT | Huawei’s modification is okay for us. |
| OPPO | We have concern on this proposal. Is its intention to define measurement for 38.215? The description in the proposals seem not. And furthermore, it is too early to define that, as commented by Nokia/NSB, which we agree.  And for the discussion purpose, we agree with the comment by MTK that we should consider the phase measurement under OFDM signal, instead of a very general description. |
| Apple | We do think that it may be a bit early to have a detailed definition of a measurement at this time. Defining the measurement as a function of something as proposed by Huawei may be a good way forward. |
| Xiaomi | We have some confusion on the proposal. First, for UE side, the carrier phase measurement should be the phase difference between the reference phase at UE side and the incoming signal, since UE doesn’t know the phase of the transmitter unless phase synchronization between transmitter and receiver. Second, the measurement results can only include a fractional part. |
| NTT DOCOMO | At this stage, we prefer high level proposal since there is no conclusion how to support NR carrier phase measurement. |
| LGE | Overall, it seems like further discussion is required to make consensus on the definition of the carrier phase measurement.  Different companies seem to have different understandings on the definition of the carrier phase measurement is and points of interest in.  Also, it seems like the proposed definition only cares about the signal propagation delay. Since this definition affects the following proposals, it would be better to add a note for phase error terms. For example, it would be worth to clarify that phase offset due to the tx/rx clock error can be included in the carrier phase measurement.  We tend to agree with MTK that fraction of cycles should be included in the carrier phase measurement but it is not clearly stated in the proposal  Regarding FFS point, we don’t see needs for defining the carrier phase measurement for multiple paths. As far as we concern, the carrier phase measurement would be useful in LOS scenario. Thus, tt can be discussed further if we found benefits from the carrier phase measurement for the additional paths. |
| Fraunhofer | Share views that is early to discuss the measurement. We propose to agree on possible methods to determine the carrier phase that can be further evaluated during the study item; namely: carrier frequency recovery, frequency domain or derived from the channel response in time. |
| Lenovo | We share other views that such a discussion is too early, and we think the discussion may sidetrack RAN1 from progressing in the other aspects. Apart from that we agree that the measurement is based on the incoming signal and a local/internal phase reference. We also agree that RAN1 should address and resolve Mediatek's question 2. |
| InterDigital | We support having definitions of different measurements (e.g., carrier phase, single/double differential phase measurement, phase-different measurement, etc.) for study/discussion purpose only. In our view, for phase measurement, fraction of cycles is critical, and it should be added in the definition. |
| **FL** | Based on the feedbacks, it seems it is too early to discuss the definition of the carrier phase measurements. We may leave the discussion of carrier phase measurements in future meetings. Maybe we can have a description on what *a carrier phase (CP) measurement represents. By the way, an integrating description of the GNSS* carrier phase measurements is available in the link:[*https://www.insidegnss.com/auto/julaug10-solutions.pdf*](https://www.insidegnss.com/auto/julaug10-solutions.pdf)  The following is a suggestion of the revision of the proposal for further discussion.  **For discussion purposes:**   * *For NR downlink and/or uplink carrier phase positioning, a carrier phase (CP) measurement at a RF frequency represents the signal propagation time from an Tx antenna reference point of a transmitter (e.g., a TRP or a UE) to a Rx antenna reference point of a receiver (e.g., a UE or a TRP) expressed in units of integer cycles and a fractional part of the wavelength of the RF frequency.*    + *Note: The integer cycles may be unknown.* |
| Locaila | We suggest to discuss this issue later. There are some unclear concepts mixed in the proposed text.  As Ericsson pointed out, we never know the distance from tx to rx. We can only measure the difference of phase between rx signals or between local oscillator and rx signal phase. In this view, the proposed definition is somewhat confusing. |
| vivo | Based on the link from FL, we also find “but the whole number of cycles between satellite and receiver is not measurable”. So, in our view, the fractional part of the wavelength can be measured, and maybe it can be defined as a measurement parameter. But the integer N is more like a location parameter and can be obtained by solving in the position equation according to ZTE, Qc Tdoc. So, we wonder whether integer N can be seen as a measurement.  FL: It is correct that “the whole number of cycles between satellite and receiver is not measurable”, although it could be estimated. I think this is clear with the “Note: The integer cycles may be unknown”.  So, we propose Proposal 4-1 For the purpose of study of NR downlink and/or uplink carrier phase positioning, carrier phase (CP) measurement may include:   * a fractional part of the wavelength measurement * FFS *integer cycle N measurement* * FFS whether *a carrier phase (CP) measurement at a RF frequency can be represented as the signal propagation time from an Tx antenna reference point of a transmitter (e.g., a TRP or a UE) to a Rx antenna reference point of a receiver (e.g., a UE or a TRP) expressed in units of integer cycles and a fractional part of the wavelength of the RF frequency*   FL: Not sure why we want to add the “FFS” here. It seems the intention to proposal is lost if we put these FFSs. |
| Intel | The updated version from FL, without the word “measurement”, could be in the right direction. However, as Ericsson, we too think that the definition should be qualified further to distinguish LOS vs. NLOS in multipath scenarios.  FL: The propogration time here can be any path, not limited to LOS. |
| Qualcomm | We generally support the latest FL updated version, and feel it has addressed many of the issues pointed out in the prior comments by multiple companies. However, we also suggest the following further clarifications:  We understand the word ‘represents’ [in ‘…. carrier phase (CP) measurement … represents the signal propagation time…’] to mean the following: ‘a carrier phase measurement… is a measurement of a phase that depends on the signal propagation time..’, and suggest to replace ‘represents’ with ‘is a measurement of a phase that depends on’. An equivalent alternative to ‘depends on’ here could be ‘is a function of’, which has also been proposed earlier by Huawei and supported by others in previous comments.  Also, the latest FL update indicates that the phase represents a propagation time, but it mentions the fractional part as a fraction of the wavelength (which is a distance). This inconsistency could be addressed and clarified by (1) replacing ‘fractional part of the wavelength of the RF frequency’ with ‘fractional part of a cycle of the RF frequency’, and (2) adding another subbullet saying: “Note: the fractional part can equivalently be expressed in terms of a phase P in range [0, 2π], a distance d=λ\*[P/(2π)], or a time t=d/c where c is the speed of light and λ is the wavelength of the RF frequency”  FL: With the consider the suggestions of wording changes, we may revise the proposal as follows:  **For discussion purposes:**   * *For NR downlink and/or uplink carrier phase positioning, a carrier phase (CP) measurement at a RF frequency is a measure of a phase of the signal propagation time from an Tx antenna reference point of a transmitter (e.g., a TRP or a UE) to a Rx antenna reference point of a receiver (e.g., a UE or a TRP) expressed in units of integer cycles and a fractional part of a cycle of the RF frequency.*    + *Note: The integer cycles may be unknown.*   In response to Intel and Ericsson on multipath, the latest FL proposal already captures multipath in the sense that the signal propagation time will depend on the path, and will be different for each path in a multipath channel. |

(Round 2) Proposal 4-1

* *For NR downlink and/or uplink carrier phase positioning, a carrier phase (CP) measurement at a RF frequency is a measure of the phase of the signal propagation time from an Tx antenna reference point of a transmitter (e.g., a TRP or a UE) to a Rx antenna reference point of a receiver (e.g., a UE or a TRP) expressed in units of integer cycles and a fractional part of a cycle of the RF frequency.* 
  + *Note: The integer cycles may be unknown.*

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| **Company** | **comments** |
| MTK | 1, from receiver point of view the propagation time in resided in the phase of a carrier and subcarriers, ans also the frequency of the carrier and subcarriers is resided in the phase. For the wording proposed by FL that “the phase of the signal propagation time”, it seems better to change “of” to “as a function of”   * *For NR downlink and/or uplink carrier phase positioning, a carrier phase (CP) measurement at a RF frequency is a measure of the phase as a function of the signal propagation time from an Tx antenna reference point of a transmitter (e.g., a TRP or a UE) to a Rx antenna reference point of a receiver (e.g., a UE or a TRP) expressed in units of integer cycles and a fractional part of a cycle of the RF frequency.*    + *Note: The integer cycles may be unknown.*   FL: It seems OK to use “as a function”.  2. in our view, the phase may provide better granularity for finding the propagation time for a TOA measurement. So the intrinsic property for carrier phase measurement is still related to TOA measurement  FL: Yes. Carrier phase measurement is related to signal propagation time.  3, from several companies’ math derivation (HW QC CATT MTK…), at the receiver view, the phase within a carrier actually contains several impairment terms, as Samsung mentioned above “*Strictly speaking, the carrier phase at the receiver doesn’t measure the signal propagation time, except if the receiver and transmitter are phase-synchronized*”  The initial phase at TX and RX residing in the received phase can actually be removed when observing more subcarriers  4, if single differential or double differential apply, it is still to do the “phase difference”. This happens when measuring the phase of a particular carrier between a TRP and a UE. Then for the companies who want to reject section 7, we also want to understand whether to support single/double differential? |
| Huawei, HiSilicon | “Measure” should be changed “measurement”.  We agree with MTK’s comment 1 to add “as a function”.  Reply to MTK comment 4: There are multiple differentials:  1. Same UE between two TRP  2. Same TRP between two UEs  3. Same UE-TRP pair between two subcarriers  4. Same UE-TRP pair between two Tx (or two resources)  Single differential is 1 (similar to TDOA) to cancel the sync error between UE and TRP, and double differential is 1+2 to cancel the sync error between UE and TRP and between TRPs.  The diferential between subcarriers is totally up to UE/TRP implementation on how to get a finer abservation of ToA, and UE/TRP can on its own resolve this so-called “integer ambiguity” among subcarriers, which is already considered in Rel-16/Rel-17 evaluation and even the product implementation. Otherwise, how can we reach 0.2m (<2ns ToA error) accuracy in Rel-17 with only 100MHz bandwidth? |
| Samsung | *For discussion purposes*   * *For NR downlink and/or uplink carrier phase positioning, a carrier phase (CP) measurement ~~at a~~ of an RF frequency is a measure of the phase of the received signal relative to a reference signal at the receiver.* * *The CP measurement depends on the propagation time from an Tx antenna reference point of a transmitter (e.g., a TRP or a UE) to a Rx antenna reference point of a receiver (e.g., a UE or a TRP) expressed in units of integer cycles and a fractional part of a cycle of the RF frequency.*    + *Note: The integer cycles may be unknown.*   FL: For the change “of an RF frequency”, I don’t have strong view. It seems to me “at an RF frequency” may be more precise”. But, it seems fine either way. For the suggestion of carrier phase (CP) measurement is “measure of the phase of the received signal relative to a reference signal at the receiver” is unclear to me. I am not sure if this refers to how the PLL locks the carrier signals. But, I’ve seen the definition that the carrier phase measurement is the received signal relative to a reference signal. Maybe Samsung can point out the reference on the definition. The 2nd change “depends on … ” may have same meaning “a function of”; |
| Xiaomi | We support the latest Proposal 4-1 in principle. But for the note, from our understanding, the integer cycles is not unknow. It is can be known by calculation, it is just not measurable. So we prefer the following modification for the note:   * + *Note: The integer cycles is not measurable.*   FL:While I would agree “The integer cycles cannot be directly measured”, my suggestion is to keep “The integer cycles may be unknown.” The reason is that we are trying to have the common understanding on what carrier phase measurement is, but not how it is measured. So, we simple to sate the factor that “The integer cycles may be unknown”. |
| NTT DOCOMO | We are fine with the FL proposal in principle and also support Samsung’s updates. |
| ZTE | We more prefer MTK’s update. The phase is a function of propagation time. |
| LGE | We have similar view with MediaTek that it would be better add “as a function” in the main bullet. The measured phase may include the phase error (e.g. due to the unsynchronized phase), and signal propagation time cannot be expressed by the phase measurement itself without differencing technique.  FL: Yes. Measured phase normally has errors, which will be further discussed in the following sections. |
| Vivo | We would like to confirm whether the integer N is included in the carrier phase measurement or not based on the proposal?  In our view, at least for UE-assisted carrier phase measurement, only a fractional part of a cycle can be achieved and reported. So, in this case, we think “units of integer cycles” is unclear to us:  FL: When the PLL initialliy locks the carrier signal, the initial phase carrier phase measurement is a fractional part of a cycle. After that, PLL needs to track the changes of the signal cycles, thus, in general phase carrier phase measurement is not limited to a fractional part of a cycle.  And we also think the carrier phase measurement… is a measurement of a phase that depends on the signal propagation time..’, not equal to the signal propagation time.  FL: Using “*as a function” may addres the concern.*  So, we propose (Round 2) Proposal 4-1  * *For NR downlink and/or uplink carrier phase positioning, a carrier phase (CP) measurement at a RF frequency is a measure of the phase as a function of the signal propagation time from an Tx antenna reference point of a transmitter (e.g., a TRP or a UE) to a Rx antenna reference point of a receiver (e.g., a UE or a TRP) expressed in ~~units of integer cycles and~~ a fractional part of a cycle of the RF frequency.*    + *Note: The integer cycles may be unknown.* |
| Nokia/NSB | We still feel that this is a bad approach and the word measurement or should not be in any part of this proposal in our view. Otherwise later it may be interpreted as a measurement definition. This discussion may not bring much value to the SI. If others feel it is really necessary we propose the following change:  FL: NR “Carrier phase” is a new to 3GPP. At this discussion helps the group to have better understanding on what the Carrier phase means for positioning. Round 2) Proposal 4-1  * *For NR downlink and/or uplink carrier phase positioning, ~~a~~the carrier phase (CP) ~~measurement~~ at a RF frequency ~~is a measure of~~ can be seen as representing the phase of the signal propagation time from an Tx antenna reference point of a transmitter (e.g., a TRP or a UE) to a Rx antenna reference point of a receiver (e.g., a UE or a TRP) expressed in units of integer cycles and a fractional part of a cycle of the RF frequency.*    + *Note: The integer cycles may be unknown.*   FL: Okay. Let us remove “measurement” to see if it helps. |
| InterDigital | We are generally fine with the proposal if “For discussion purposes:” is added in the main bullet. |
| Intel | Generally fine, with the suggestion from MTK to add “a function of”. Also, prefer to delete “measurement” in first line to avoid unintended interpretations as a UE measurement definition, but keeping the rest including “is a measure of” is fine. |
| Qualcomm | We suggest the following, in an attempt to address some of the comments above. Specifically, the motivation is to try to ensure that we are not formally defining a measurement, but we need some general understanding of what we mean by ‘carrier phase’. There could be multiple different specific meanings, but we think all potential meanings discussed so far share these general characteristics – (1) carrier phase is a phase, and (2) the phase depends on the propagation time. In response to vivo, the below attempts to make the integer part something analogous to FFS/optional.   * *For the purposes of discussion, for ~~For~~ NR downlink and/or uplink carrier phase positioning, a carrier phase (CP) measurement at a RF frequency is a ~~measure of the~~ phase measurement that is a function of the signal propagation time from an Tx antenna reference point of a transmitter (e.g., a TRP or a UE) to a Rx antenna reference point of a receiver (e.g., a UE or a TRP) expressed in units of ~~integer cycles and~~ a fractional part of a cycle of the RF frequency and possibly a number of integer cycles.*   *~~Note: The integer cycles may be unknown~~*  *FL: The suggested changes looks fine. It may be clear to has the Note, saying “The exact a number of integer cycles may be unknown.”* |
| CATT | For Qualcomm’s suggestion, “*possibly a number of integer cycles*”, we may add that it may not be “*the exact number of integer cycles of the signal propagation time.”* |
| **FL** | Based on the comments, let us try to see if the following changes have address the comments. (Round 2) Proposal 4-1  * *For the purposes of discussion, for NR downlink and/or uplink carrier phase positioning, a carrier phase (CP) measurement at a RF frequency is the phase measurement that is a function of the signal propagation time from an Tx antenna reference point of a transmitter (e.g., a TRP or a UE) to a Rx antenna reference point of a receiver (e.g., a UE or a TRP) expressed in a fractional part of a cycle of the RF frequency and possibly a number of integer cycles, which may not be the exact number of integer cycles of the signal propagation time.* |

(H)(Round 3) Proposal 4-1

* *For the purposes of discussion, for NR downlink and/or uplink carrier phase positioning, a carrier phase (CP) measurement at a RF frequency at a receiver is the phase measurement that is a function of the signal propagation time from an Tx antenna reference point of a transmitter (e.g., a TRP or a UE) to a Rx antenna reference point of the receiver (e.g., a UE or a TRP).*
  + *The propogation time can be expressed in a fractional part of a cycle of the RF frequency and a number of integer cycles, but the CP measurement may be independent from the number of integer cycles.*

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| **Company** | **comments** |
| vivo | Based on the reply from FL, “FL: When the PLL initialliy locks the carrier signal, the initial phase carrier phase measurement is a fractional part of a cycle( vivo: we agreed). After that, PLL needs to track the changes of the signal cycles, thus, in general phase carrier phase measurement is not limited to a fractional part of a cycle（vivo: tracking may need more discussion based on proposal 13-3）. ”, so, we suggest putting “*and possibly a number of integer cycles*” into bracket since we are still concerned whether the tracking can be supported and integer part belong to phase measurement.  FL: It could be a wayford with the bracket. But, hopefully, the latest changes of Round 3 discussion based on the comments from other companies can address vivo’s concern. |
| ZTE | We are fine with FL's proposal. |
| MTK | The wording doesn’t help  “*and possibly a number of integer cycles, which may not be the exact number of integer cycles of the signal propagation time.”*  The integer cycles may not be measured. It needs to be estimated or by trial and error. Since we are talking about carrier phase **measurement** , we also prefer to remove this sentence  *expressed in a fractional part of a cycle of the RF frequency ~~and possibly a number of integer cycles, which may not be the exact number of integer cycles of the signal propagation time~~.* |
| Huawei, HiSilicon | To vivo/MTK: how about the following change?   * *For the purposes of discussion, for NR downlink and/or uplink carrier phase positioning, a carrier phase (CP) measurement at a RF frequency is the phase measurement that is a function of the signal propagation time from an Tx antenna reference point of a transmitter (e.g., a TRP or a UE) to a Rx antenna reference point of a receiver (e.g., a UE or a TRP).* * *The propogation time can be expressed in a fractional part of a cycle of the RF frequency and possibly which may not be the exact number of integer cycles of the signal propagation time.*    + *, but the CP measurement may be independent from the number of integer cycles.*   FL: It seems there is a duplication of “propagation time” in the second bullet. The version from MTK below seems to be better. |
| Xiaomi | Support the latest version with ‘*but the CP measurement may be independent from the number of integer cycles.*’ |
| LGE | Fine with the proposal. If it is not agreeable, we also fine with HW’s revised version as a compromise view. |
| CATT | Support the proposal. |
| MTK | The desired phase at receiver is 2pi \*fc\* propagaton time = 2pi \*propagation distance/wavelength = 2pi\*(an integer + a fraction) = 2pi\*(a fraction). Then we may remove “possibly”. Integer cycles are there, just may not be measurable   * + *The propogation time can be expressed in a fractional part of a cycle of the RF frequency and ~~possibly~~ a number of integer cycles, but the CP measurement may be independent from the number of integer cycles.*   FL: I think the description is good. |
| Nokia/NSB | Sorry but our previous comments on removing the word measurement have not been addressed. As such we can’t support the current proposal. We still feel it reads way too much like we are defining a measurement.  FL: Okay. I assume here we are not try to define the physical layer measuremens for TS 38.215, but what the carrier phase measurement means. |
| CATT | TS 103 246-1 V1.3.1 (2020-10), it has the following definition:  **carrier phase measurement:** measure of the range between the satellite and receiver expressed in units of cycles of the carrier frequency  FL: A simple way may re-use the definition in TS 103 246-1 V1.3.1 (2020-10) by replacing the “satellite” with the “transmitter”, i.e.,  **carrier phase measurement:** measure of the range between the transmitter and receiver expressed in units of cycles of the carrier frequency |
| Samsung | For progress we can accept the updated version from Huawei and MediaTek. With one additional update as described below:   * *For the purposes of discussion, for NR downlink and/or uplink carrier phase positioning, a carrier phase (CP) measurement at a RF frequency at a receiver is the phase measurement that is a function of the signal propagation time from an Tx antenna reference point of a transmitter (e.g., a TRP or a UE) to a Rx antenna reference point of ~~a~~ the receiver (e.g., a UE or a TRP).*   + *The propogation time can be expressed in a fractional part of a cycle of the RF frequency and ~~possibly~~ a number of integer cycles, but the CP measurement may be independent from the number of integer cycles.* |
| **FL** | *It seems the discussion start converging now. (H)(Round 3) Proposal 4-1 is modified with the consideration of the latest suggestion from Samsung for further discussion.* |
| Ericsson | Ok |
| Intel | Support the latest version. |
| InterDigital | Ok with the latest version |
| **FL** | It seems we can use the latest verson of round 3 can be used for Round 4 discussion to see if it is acceptable to all companies. |

(H)(Round 4) Proposal 4-1

* *For the purposes of discussion, for NR downlink and/or uplink carrier phase positioning, a carrier phase (CP) measurement at a RF frequency at a receiver is a phase measurement that is a function of the signal propagation time from an Tx antenna reference point of a transmitter (e.g., a TRP or a UE) to a Rx antenna reference point of the receiver (e.g., a UE or a TRP).*
  + *The propogation time can be expressed in a fractional part of a cycle of the RF frequency and a number of integer cycles, but the CP measurement may be independent of the number of integer cycles.*

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| **Company** | **comments** |
| vivo | Generally okay for us |
| Huawei, HiSilicon | OK |
| LGE | Fine with the proposal |
| Samsung | OK |
| Lenovo | Support the proposal |
| CATT | Support |
| Intel | Support. |
| Xiaomi | Support |
| NTT DOCOMO | Support |
| Qualcomm | Support. Couple of grammatical changes proposed below (on the first one, we are saying ‘***a*** carrier phase measurement is… ‘ so we should say ‘…is ***a*** phase’. Other alternative is to replace both ‘a’ with ‘the’, but this is not the desired direction because we are only giving a general understanding of what carrier phase is, not a precise definition).   * *For the purposes of discussion, for NR downlink and/or uplink carrier phase positioning, a carrier phase (CP) measurement at a RF frequency at a receiver is ~~the~~a phase measurement that is a function of the signal propagation time from an Tx antenna reference point of a transmitter (e.g., a TRP or a UE) to a Rx antenna reference point of the receiver (e.g., a UE or a TRP).*   *The propogation time can be expressed in a fractional part of a cycle of the RF frequency and a number of integer cycles, but the CP measurement may be independent of~~from~~ the number of integer cycles.*  FL: Thanks for the suggested grammatical changes. I have include the changes into Proposal. |
| MTK | Thanks QC for the grammar class. Yes, the revision by QC makes sense |
| Ericsson | ok |
| **FL** | It seems most companies are fine with the proposals. The proposal is revised with the consideration of following Nokia’s comemntsin email reslector:  Nokia:   * We multiple times raised our concern with using the word measurement in proposal 4-1. It was replied that we are not defining a measurement but then we simply don’t understand why then there is insistence to keep the word measurement throughout the proposal. We recognize that many companies seem to feel this proposal brings some value (though to be honest it seems trivial from our side). For sake of progress we suggest the following update, removing all “measurement” instances, which we can accept:   + For the purposes of discussion, for NR downlink and/or uplink carrier phase positioning, thecarrier phase (CP) at a RF frequency at a receiver is the a phase which is a function of the signal propagation time from an Tx antenna reference point of a transmitter (e.g., a TRP or a UE) to a Rx antenna reference point of the receiver (e.g., a UE or a TRP).     - The ropagation time can be expressed in a fractional part of a cycle of the RF frequency and a number of integer cycles, but the CP may be independent of the number of integer cycles. |

(H)(Round 4) Proposal 4-1

### (Closed)(Round 5) Proposal 4-1

* *For the purposes of discussion, for NR downlink and/or uplink carrier phase positioning, the carrier phase (CP) at a RF frequency at a receiver is a phase that is a function of the signal propagation time from an Tx antenna reference point of a transmitter (e.g., a TRP or a UE) to a Rx antenna reference point of the receiver (e.g., a UE or a TRP).*
  + *The propogation time can be expressed in a fractional part of a cycle of the RF frequency and a number of integer cycles, but the CP measurement may be independent of the number of integer cycles.*

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| **Company** | **comments** |
| Fraunhofer | Okay |
| Samsung | OK |
| InterDigital | Ok |
| MTK | okay |
| LGE | Ok.  Minor comment: It seems like “measurement” in the sub-bullet should be removed as well.  *The propogation time can be expressed in a fractional part of a cycle of the RF frequency and a number of integer cycles, but the CP ~~measurement~~ may be independent of the number of integer cycles.*  FL: Okay. |

### Proposal 4-2

* *For NR downlink and/or uplink carrier phase positioning,* 
  + *the single differential carrier phase (SD-CP) measurement is defined as the difference of the CP measurements between either one transmitter and two receivers, or two transmitters and one receiver;*
    - *E.g., DL SD-CP can be obtained for differencing CP measurements between two TRPs and one UE;*
  + *the double differential carrier phase (DD-CP) measurement is defined as the difference of the two SD-CPs between two transmitters and two receivers.*
    - *E.g., DL DD-CP of two UEs and two TRPs can be obtained for differencing the SD-CP between one UE and the two TRPs and the SD-CP between another UE with and same two TRPs.*

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| **Company** | **comments** |
| MTK | Too early for having such definition. We suggest to discuss first about whether we treat the “carrier phase measurement” under OFDM as the phase measurement over a single carrier? Or it is a joint phase measurements over subcarriers?  Under a same distance, different frequency may arrive at different phase. So it seems to us that under OFDM signal, the propagation time measurement has been sufficient because the phase measurements over certain number of subcarriers is to derive a single propagation time |
| ZTE | We are doubting about whether the differential value is required. The positioning calculation end (e.g., LMF, UE) can generate a differential value (if more than one original values of carrier phase are reported / generated). Hence, it should be make clear before this proposal. |
| vivo | Too early for us |
| Huawei, HiSilicon | It is too early to “define the measurement”, which implies that it will be specified in TS 38.215. Actually, the differential between two receivers may not be possible if the two receivers are not in the same node.  Suggested revision as below   * *For NR downlink and/or uplink carrier phase positioning,*    + *the single differential carrier phase (SD-CP) measurement is the difference of the CP measurements between either one transmitter and two receivers, or two transmitters and one receiver;*     - *E.g., SD-CP can be obtained from differencing CP measurements between two TRPs and one UE;*   + *the double differential carrier phase (DD-CP) measurement is the difference of the two SD-CPs between two transmitters and two receivers.*     - *E.g., DL DD-CP of two UEs and two TRPs can be obtained from differencing the SD-CP between one UE and the two TRPs and the SD-CP between the other UE and same two TRPs.* |
| Samsung | The proposal defines SD-CP and DD-CP. We think that the wording can be improved for clarity as follows:  **For discussion purposes:**   * The single differential carrier phase (SD-CP) measurement is defined as one of:   + For a signal S1 transmitted from TX1 and received by RX1 and RX2; the carrier phase of S1 measured at RX1 minus the carrier phase of S1 measured at RX2   + For a signal S1 transmitted by TX1 and received by RX1 and a signal S2 transmitted by TX2 and received by RX1; the carrier phase of S1 measured at RX1 minus the carrier phase of S2 measured at RX1 * The double differential carrier phase (DD-CP) measurement is defined as one of:   + The difference between SD-CP1 measured at RX1 and RX2 of a signal transmitted from TX1, and SD-CP2 measured at RX1 and RX2 of a signal transmitted from TX2,   + The difference between SD-CP1 measured at RX1 of two signals transmitted from TX1 and TX2 and SD-CP2 measured at RX2 of two signals transmitted from TX1 and TX2. |
| Nokia/NSB | Again, we should not be “defining” things at this point. On top of Huawei’s suggestion, we suggest adding to the main bullet “for the purpose of the NR carrier phase study”. |
| Ericsson | We are not sure why this needs to be discussed now. This is too detailed given we are in early stage of the SI. We suggest to discuss this later. |
| CATT | We are fine with the modification suggested by Huawei and Nokia. |
| OPPO | We do not think we need to define that at the current stage. |
| Xiaomi | We are fine with the revision from Huawei |
| vivo 2 | CP measurement is unclear for us. So, the description about “*the single differential carrier phase (SD-CP) measurement is the difference of the CP measurements”*is too early for us, and we believe if CP measurement is clear, the single differential carrier phase is not big issue |
| LGE | For us, definition of “single differencing” and “double differencing” are already clear since they have been used in GNSS based carrier phase measurement. However, we are fine with the proposal if majority support to have it.  Anyway, we believe this proposal is only for make consensus on the definition for our study. Since the differencing technique is well known method to mitigate some errors in the carrier phase positioning, it would be worth studying. |
| Fraunhofer | Same as in P4.1 |
| Lenovo | If anything needs to be agreed at this time, we agree with Nokia's suggestion. |
| InterDigital | In our view, the definition of the single differential and double differential carrier phase at this stage is for discussion/study purpose only. Therefore, we support of revision version from Samsung. |
| Intel | Same view as Interdigital that this is only for discussion/study purposes. Consequently, we also think the version from Samsung is more appropriate. |
| Qualcomm | We are ok with Samsung’s suggested revision. In our understanding, this is equivalent to Huawei’s suggested revision together with Nokia’s suggestion of adding to the main bullet. Given it is only for discussion purposes, either of these approaches could be acceptable, but Samsung’s version appears somewhat more explicit/clearer. |
| **FL** | Due to the very diverged vies, the FL suggest delaying the discussion after we have a conclusion on Proposal 4-1, or to the next meeting. |

### Proposal 4-3

* *The difference between the carrier phases obtained by measuring the reference signal(s)* *from the same Tx antenna with two or more Rx antennas is defined as the Rx phase-deference (PD-mRx).*
  + *Note: Rx-PD measured by a TRP may be used for estimating UL-AOA*
* *The difference between the carrier phases obtained by measuring the reference signal(s) transmitted from two or more Tx antennas with the same Rx antenna is defined as the Tx phase-deference (PD-mTx).*
  + *Note: Tx PD measured by a UE may be used for estimating DL-AOD*

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| **Company** | **comments** |
| MTK | Suggest to finish discussion of proposal 4-1 first |
| ZTE | Based on SID, only carrier phase is described. This proposal actually is not carrier phase but angle phase. We doubt if it is in the scope of this SI. |
| Huawei, HiSilicon | Unclear about the motivation of defining the phase different measurement between antenna elements (or ARPs).  Take PD-mRx for example, different Rx antennas may have different carrier phase measurement, but this may be converted to a UL-AoA measurement, which can be further used to combine the multiple carrier phase measurements into a single one equivalent to a specific ARP location. |
| Samsung | We think that the two or more Rx antennas should be in the device (i.e. have the same sync source). Similarly, the two or more Tx antennas should be in the same device (i.e. have the same sync source). We can thus update the proposal as follows:   * *The difference between the carrier phases obtained by measuring the reference signal(s)* *from the same Tx antenna with two or more Rx antennas in the same device is defined as the Rx phase-~~deference~~ difference (PD-mRx).*   + *Note: Rx-PD measured by a TRP may be used for estimating UL-AOA. Rx-PD measured by a UE may be used for estimating DL-AOA.* * *The difference between the carrier phases obtained by measuring the reference signal(s) transmitted from two or more Tx antennas in the same device with the same Rx antenna is defined as the Tx phase- ~~deference~~ difference (PD-mTx).*   + *Note: Tx PD measured by a UE may be used for estimating DL-AOD. Tx PD measured by a TRP may be used for estimating UL-AOD.* |
| Nokia/NSB | First, we need to progress on 4-1 and 4-2. We are not sure this proposal brings much value. It may be better to say something much more general like:  studying the use of phase difference between antennas for the purpose of angle measurements can be included in the study. |
| Ericsson | We have similar views as ZTE. We think that AOA/AOD methods using carrier phase should not be considered in this study. |
| CATT | It can be low priority. |
| OPPO | That can be discussed after we discuss and progress on particular carrier phase measurement methods. |
| Apple | Same view as ZTE and Ericsson |
| Xiaomi | We are not sure it is in the scope of this SI. |
| LGE | As far as I’m concerned, accuracy of the carrier phase measurement for propagation time would be higher than DL-AoD estimation. Since the main objective of this item is improving accuracy, we would like to focus on the NR carrier phase measurement and deprioritize the phase-difference measurement for estimating DL-AoD and UL-AoA. |
| Fraunhofer | Same as in P4.1 |
| Lenovo | Same view as Nokia. |
| InterDigital | As commented in Proposal 4-1 and 4-2, we support the definition for study/discussion purpose. We are fine with the definition from the FL. We suggest removing the Note in each definition since we may need to discuss whether to study a combined carrier phase and angle-based positioning. |
| Locaila | We support samsung’s proposal. |
| Intel | OK with the version from Samsung, or wait to stabilize Proposals 4-1 and 4-2 first. |
| Qualcomm | We support Nokia’s suggested alternative: “studying the use of phase difference between antennas for the purpose of angle measurements can be included in the study”. We think AoD/AoA cannot be ruled out, as we elaborate more in our response to proposal 6-1 below. |
| **FL** | Due to the very diverged vies, the FL suggest delaying the discussion after we have a conclusion on Proposal 4-1, or to the next meeting. |

### Proposal 4-4

* *The difference between the carrier phases of difference subcarriers by measuring the same DL or UL positioning reference signal(s) is defined as the phase-deference of the subcarriers (PD-SC)*
  + *Note: PD-SC may be used for estimating TOA*

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| **Company** | **comments** |
| ZTE | The wording should be refined as follows. The note is unclear to us, prefer to delete it.   * *The difference between the carrier phases of ~~difference~~ subcarriers by measuring the same DL or UL positioning reference signal(s) is defined as the phase-deference of the subcarriers (PD-SC)* |
| Huawei, HiSilicon | Do not support this.  Subcarrier level phase difference is the same as ToA, because the carrier frequency information (RF frequency) not relevant, which has already been considered in super-resolution algorithm in Rel-16 and Rel-17. |
| Samsung | Definition is fine with some editorial updates   * *The difference between the carrier phases of ~~difference~~ different subcarriers by measuring the same DL or UL positioning reference signal(s) is defined as the phase- ~~deference~~ difference of the subcarriers (PD-SC)*   + *Note: PD-SC may be used for estimating TOA* |
| Nokia/NSB | Similar comment as to proposal 4-3. |
| Ericsson | We don’t see any need to introduce this definition at this stage. By the Fourier transform, the TOA is proportional to the phase-difference between carriers. |
| CATT | Using phases difference of subcarriers for TOA is already supported in Rel16. |
| Xiaomi | We are not sure it is in the scope of this SI. |
| LGE | We are generally fine with the Samsung’s revision.  However, intention of the “same DL or UL positioning reference signal(s)” is not clear for us. For example, does that mean PRS subcarriers within same PRS resource are used for PD-SC? |
| Fraunhofer | Same as in P4.1 |
| InterDigital | We are supportive of Samsung’s version for the definition of PD-SC. |
| Locaila | What’s the meaning of ‘different subcarriers’ ? Does it mean different subcarrier numbers or subcarriers from different txs?  Why should it be ‘.. the same DL or UL reference signals’ ? It makes confusion.  Phase difference is equivalent to time difference, therefore TDoA is more appropriate than ToA.  we suggest following wording.   * *The phase difference ~~between the carrier phases~~ of ~~difference~~ subcarriers by measuring the ~~same DL or UL positioning~~ reference signal(s) is defined as the phase-difference of the subcarriers (PD-SC)*   *Note: PD-SC may be used for estimating TDOA* |
| Intel | OK with the version from Samsung. |
| Qualcomm | We think this proposal is too specific and don’t see value at this stage. As pointed out by Huawei, Ericsson, and Localia, phase difference across subcarriers has an equivalence to TOA.  Note that there could be value in reporting phase separately for different subcarriers or groups of subcarriers, but this is captured in latest FL version of proposal 2-1 in the 3rd sub-bullet as “*NR carrier phase positioning with the carrier phase measurements of one carrier frequency or multiple frequencies*”. However, specifically reporting the difference between phases looks unnecessary. |
| **FL** | Due to the very diverged vies, the FL suggest delaying the discussion after we have a conclusion on Proposal 4-1, or to the next meeting. |

# PRU

## 5.1 Background

It is well known that for cm-level carrier phase positioning, the time/frequency synchronization errors have to be eliminated. In GNSS carrier phase positioning, differential carrier phase techniques are commonly used for such purpose. 3GPP has introduce the concept of the positioning reference unit (PRU), which are located at known position, for improving the positioning accuracy. PRU may play a key role in NR carrier phase positioning, similar to GNSS reference station in GNSS carrier phase positioning.

***Submitted Proposals:***

* ***(Huawei,*** [***R1-2203166***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203166.zip)***[1]) Proposal 2:*** *To evaluate positioning using carrier phase measurement, the following impairment should be considered*
  + *Carrier phase synchronization between TRPs*
  + *Carrier frequency error between TRP and UE*
  + *gNB ARP error*
* ***(Nokia,*** [***R1-2203178***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203178.zip)***[2]) Proposal 7:*** *RAN1 to study the CP positioning performance impact by introducing reference UE (PRU) for UE-assisted positioning, and identify the necessary physical layer procedure including aligning measurements by PRU and target UE.*
* ***(Nokia,*** [***R1-2203178***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203178.zip)***[2]) Proposal 8:*** *RAN1 to study/identify the CP positioning performance impact by introducing reference UE (PRU) for UE-based positioning, and identify the necessary physical layer procedure.*
* ***(CATT,*** [***R1-2203469***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203469.zip)***[4])Proposal 8****: Double differential technique with PRU can be used for solution for timing offset between TRPs.*
* ***(vivo, R1-2203568[5]) Proposal 2:*** *The phase measurement performance should be evaluated with errors(e.g., multi-path, frequency error, clock offset).*
* ***(Xiaomi,*** [***R1-2203824***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203824.zip)***[11]) Proposal 2:*** *Study PRU assisted carrier phase measurement for timing error and phase error mitigation.*
* ***(Samsung,*** [***R1-2203913***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203913.zip) ***[12]) Proposal 3:*** *Study the impact and mitigation of challenges when using the carrier-phase method for RAT-based positioning, including:*
  + *Impact of NLOS conditions and multi-path reflections.*
  + *Impact of phase ambiguity (integer ambiguity).*
  + *Impact of UE mobility*
  + *Synchronization errors*
* ***(InterDigital, R1-2204134[14]) Proposal 3:*** *Study a framework that allows the UE or network to mitigate unknown phase offset in phase measurements, e.g., phase error group.*
* ***(CMCC,*** [***R1-2204312***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204312.zip)***[15]) Observation 2:*** *The following challenges needs to be studied and overcame:*
  + *The phase synchronization error degrades the accuracy performance;*
  + *Negative impact of complicated propagation environment (e.g., NLOS, multipath) on the phase error.*
  + *Fast search of the integer ambiguity*
* ***(LGE, R1- 2204524[17]) Proposal 3:*** *Methods to deal with the conventional problems of the carrier phase measurement positioning in NR positioning system should be studied (e.g. integer ambiguity, transmitter/receiver clock error, and multipath).*
* ***(Lenovo,*** [***R1-2204561***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204561.zip)***[18])Proposal 4:*** *Support the use of Positioning Reference Units (PRUs) to mitigate clock errors for carrier phase measurements.*
* ***(Intel,*** [***R1-2204807***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204807.zip)***[20])Proposal #3:*** *Study initial phase calibration of the TX generators for the reference and target TRPs by using the RSTD measurements obtained with the Positioning Reference Unit (PRU) with known coordinate.*
* ***(Intel,*** [***R1-2204807***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204807.zip)***[20])Proposal #9:*** *Study initial phase calibration of the RX generators for the reference and target TRPs by using the measurements obtained with the Positioning Reference Unit (PRU) with known coordinate.*
* ***(Qualcomm,*** [***R1-2205040***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2205040.zip)***[23]) Proposal 2:*** *Study carrier-phase schemes that assume availability of PRUs*

## 5.1 Discussion

Based on the submitted proposals, it seems the use of the PRUs is essential for supporting NR carrier phase positioning in order to eliminating the TRP time/frequency synchronization errors.

Proposal 5-1

* *The study of NR carrier phase positioning is based on the assumption of availability of PRUs.*

|  |  |
| --- | --- |
| **Company** | **comments** |
| ZTE | In some cases, the carrier phase based positioning can work well without PRU. Hence, we are not sure whether the PRU is required. We prefer to change the wording as  **Study the benefit of PRUs to facilitate NR carrier phase positioning.** |
| Huawei, HiSilicon | OK in general.  Suggest to add the following subbullet.   * *The study of NR carrier phase positioning is based on the assumption of availability of PRUs.* * *FFS: the accuracy of the known ARP location of the PRU* |
| Samsung | Proposal is not very clear. Maybe it is better to reword as: Study the use of PRUs to assist with carrier phase positioning. |
| Nokia/NSB | We would prefer something closer to:   * The study of NR carrier phase positioning includes the study of PRU availability. |
| Ericsson | We do not support FL’s proposal. For a fair comparison with existing NR positioning methods, any carrier phase-based positioning solution should be evaluated with the assistance data that can be provided by the Release 17 architecture.  FL: During the evaluation of Rel-16,Rel-17, where the impact of TRP time synchronization is not included in the baseline parameters. Although the investigation of the carrier phase positioning can also be done without considering TRP timing errors, it may not be practical due to TRP time is unlikely to be synchronized to support cm-level positioning. |
| CATT | Support. |
| OPPO | Do not support the proposal. The study of carrier phase positioning should make assumption on PRU. Like studying other positioning method, we shall first study the position method itself. The PRU is only use to assist the whole positioning system. Furthermore, the PRU specified in Rel-17 does not support the function related with carrier phase positioning.  FL: Similar to the response to Ericsson’s comment, how to eliminate TRP timing error can be much more important for carrier phase positioning due to it targets to cm-level accuracy. |
| Apple | This proposal is coming to a conclusion that has not been evaluated or discussed. Can use ZTE or Samsung’s wording to make sure that the use of PRUs is studied. |
| Xiaomi | We are fine with the modification from ZTE or Samsung. |
| vivo | We are fine with the modification from ZTE |
| NTT DOCOMO | We are supportive to NR carrier phase measurement based on PRUs, however, fair evaluation comparison with the existing methods as mentioned by Ericsson should be considered. |
| LGE | For timing/phase error mitigation, support the use of PRU seems to be required. In that sense, we are generally fine with studying support of the PRU for the NR carrier phase positioning. However, it is also required that studying whether the carrier phase positioning can be supported and guarantee reasonable performance even when PRU is not available. |
| Fraunhofer | “NR carrier phase positioning” sounds like a method enabled by PRU. More likely the intention is to make use of the PRU phase measurements for calibration or clock corrections. |
| Lenovo | We suggest to modify as follows:  • The study of NR carrier phase positioning includes the use of PRUs e.g. to mitigate clock errors |
| InterDigital | We don’t think that the availability of PRU is necessary for carrier phase positioning. In another word, carrier phase positioning can be used without PRU. However, we see the benefit of having PRU and are supportive to study PRU for carrier phase positioning. We are ok with the revision from ZTE. |
| **FL** | Based on the comments, it seems we may have the following Proposal 5-1  * *The use of PRUs to facilitate NR carrier phase positioning will be studied in the SI.* |
| Intel | Support the updated version from the FL. |
| Qualcomm | We agree with the latest FL proposal (immediately above). In addition to the FL replies to Ericsson and Oppo, we would like to add that to use difference between received carrier phases from two TRPs (analogous to difference between receive TOAs in TDOAs), we would need the two TRPs to be *phase-synced* (analogous to time-synced for TDOA), which could be even more challenging than time-sync and should not be assumed. Thus we think the PRUs are unavoidable here. |

(Round 2) Proposal 5-1

* *The use of PRUs to facilitate NR carrier phase positioning will be studied in the SI.*

|  |  |
| --- | --- |
| **Company** | **comments** |
| Huawei, HiSilicon | OK |
| Samsung | OK |
| Xiaomi | Ok |
| NTT DOCOMO | OK |
| ZTE | We are fine with FL's proposal. |
| LGE | Support |
| Vivo | We are fine with the motivation and prefer to revise as follows   * *The use of PRUs to improve accuracy based on NR carrier phase measurement ~~facilitate NR carrier phase positioning~~ will be studied in the SI.*   *FL: In Proposal 2-1, we have listed the NR carrier phase positioning based on NR carrier phase measurements. For this proposal, my suggestion is to use the term “NR carrier phase positioning” instead of “improve accuracy based on NR carrier phase measurement”. My consideration is that “carrier phase positioning” is the commom term used in industry and using a reference station or a refernce network for supporting is carrier phase positionin is also well known approach.* |
| Nokia/NSB | Support the FL proposal. |
| InterDigital | Support |
| Intel | Support |
| Qualcomm | Support |
| CATT | Support |
| **FL** | Based on the comments, suggest keeping the word of (Round 2) Proposal 5-1 to see if we can reach the consensus in the 3rd round discussion. |

### (Closed)(Round 3) Proposal 5-1

* *The use of PRUs to facilitate NR carrier phase positioning will be studied in the SI.*

|  |  |
| --- | --- |
| **Company** | **comments** |
| ZTE | We are fine with FL's proposal. |
| Huawei, HiSilicon | OK |
| Xiaomi | Ok |
| LGE | ok |
| CATT | Support |
| Nokia/NSB | Support. |
| Samsung | OK |
| Ericsson | Not support.  This proposal sounds like an expansion of the SID scope. In Rel-17 discussions, it was concluded that PRUs don’t have any RAN1 impact and the specification impact is mainly in other working groups. By this proposal, we seem to be adding PRUs to rel-18 scope (note that potential specification of PRUs is not currently in scope of the current SID). Given most spec impact of PRUs will be in other working groups and the already bloated number of items to study in the Rel-18 SID, we suggest to bring this proposal to the RAN plenary. We have concern with agreeing this in RAN1 now.  FL: The proposal is to evaluate the use of PRU during the SI. In FL’s understanding, the evaluation during the SI can be and should be done in RAN1. The impact on other WGs may be more during the WI stage, which can be evaluated during the SI. Also, using ground reference station at known location to support GNSS carrier phase positioning (e.g. RTK) is well-known and is essential. SID does not specifically specify which techniques should use or not use for supporting NR carrier phase positioning. Thus, it should be upto each WG to decide which techniques, including PRU, to be studied during the SI. |
| Intel | Support |
| InterDigital | Support |
| **FL** | Not sure if further revision will help to reach a consensus. We may consider to resolve the issue online in GTW session. |
| Lenovo | We feel that the proposal is worded too strongly, esp. "facilitate" gives the impression that carrier phase positioning may not be feasible at all without PRUs. The study of PRUs should rather be embedded in the overall context, like we suggested in the first round: "The study of NR carrier phase positioning includes the use of PRUs e.g. to mitigate clock errors."  FL: It is unclear to me why Lenovo consider “facilitate” is a too strong word. Looking it online, Definition of facilitate is simply: “to make easier : help bring about”. |
| Qualcomm | Support. In response to Lenovo, we think that there are indeed flavors of carrier phase that should be studied and that will not be feasible without PRUs. We do not aim to preclude studying other flavors of carrier phase that could be feasible without PRUs, and the current proposal wording does not preclude this either |
| Fraunhofer | Ok |
| MTK | The wording by FL is quite neutral and proper. Support the further analysis |
| Lenovo | Response to Qualcomm/FL: Agree that depending on the detailed carrier phase solution, a PRU may or may not be required, which is what we feel the study should clarify. If that is common understanding with the current wording, we don't have a problem with it. |

### Proposal 5-2

* *The necessary physical layer procedure and measurements of NR carrier phase positioning with the use of PRUs will be studied, which includes at least how to eliminate or calibrate the UE/TRP timing/frequency/phase errors based on differential carrier phase measurement techniques.*

|  |  |
| --- | --- |
| **Company** | **comments** |
| ZTE | This proposal should be the subbullet of proposal 5-1. |
| Huawei, HiSilicon | We would suggest to make the proposal clearer   * *The necessary physical layer procedure and measurements of NR carrier phase positioning with the use of PRUs will be studied, which includes at least how to eliminate or calibrate the timing/frequency/phase errors between UE and TRP and between TRPs based on differential carrier phase measurement.* |
| Samsung | This proposal is not needed at this time. We can just have proposal 5-1 to study how the PRU can assist with carrier phase positioning. |
| Nokia/NSB | We suggest the following revision:   * *The necessary physical layer procedure and measurements of NR carrier phase positioning with the use of PRUs will be studied, ~~which includes at least how to eliminate or calibrate the UE/TRP timing/frequency/phase errors based on differential carrier phase measurement techniques.~~* |
| Ericsson | We do not support the proposal. This is not needed at this stage of the SI. Plus, see our view on Proposal 5-1. |
| CATT | Support |
| Apple | Do not support. Need to evaluate and justify the need for the PRU first. If it is justified, we can have an agreement to have procedures and measurements for carrier phase positioning with PRUs. |
| Xiaomi | Can be considered after Proposal 5-1. |
| LGE | In general, the proposal seems to require to study potential impacts on physical layer procedure and measurement when PRU is supported. |
| Fraunhofer | Better capture the proposal within 5-1 as mentioned by ZTE |
| Lenovo | This proposal is not necessary if our suggested update to Proposal 5-1 is adopted. |
| InterDigital | This proposal is the next step of Proposal 5-1. We suggest discussing proposal 5-1 first. Once we have progress on Proposal 5-1, we can further discuss this proposal. |
| Intel | Support the version from Huawei, but also fine to wait further to stabilize Proposal 5-1 first. |
| Qualcomm | We support this. We are ok with Huawei’s suggestions. |
| Locaila | Suggest to add following.  *Note : Solutions without relying on PRU are not precluded.* |

# Phase-Difference for DL-AOD

## Background

UL-AOA is commonly estimated based on the phase-difference from different TRP antennas (*PD-mRx*). In Rel-16/17, DL-AOD is estimated based on the RSRP measurements from different DL beams from the same TRP. DL-AOD could be estimated if UE could provide the phase-difference obtained by receiving the signals from different TRP antennas (*PD-mTx*).

***Submitted Proposals:***

* ***(Locaila,*** [***R1-2203634***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203634.zip)***[7]) Proposal 3:*** *Study phase based DL-AoD measurement method and necessary impact on 5G NR system*
* ***(MediaTek,*** [***R1-2203753***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203753.zip)***[10]) Proposal 3-1:*** *The phase difference based AOD needs to be justified to be better than the RSRP based AOD. Otherwise there is no need to define another solution for the angle based measurement*
* ***(MediaTek,*** [***R1-2203753***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203753.zip)***[10]) Proposal 3-2:*** *Move the discussion of the phase difference based AOD to AI 9.5.2.2 for carrier phase measurement*
* ***(Samsung,*** [***R1-2203913***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203913.zip) ***[12]) Proposal 1:*** *Study and evaluate the performance of carrier-phase method for estimating the angle of arrival.*
* ***(OPPO,*** [***R1-2203966***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203966.zip)***[13])Proposal 9:*** *Study measuring and reporting the relative phase of different Tx antenna ports of TRP for positioning.*
* ***(OPPO,*** [***R1-2203966***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203966.zip)***[13])Proposal 10:*** *Study the PRS enhancement for supporting measuring relative phase of Tx antenna ports of TRP*
* ***(InterDigital, R1- 2204134[14]) Proposal 1****: Study transmission and reception modes (e.g., 2 TX 1RX, 1Tx 2 RX) for phase-difference based positioning*
* ***(Intel,*** [***R1-2204807***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204807.zip)***[20])Proposal #6:*** *Study phase-based azimuth and zenith angles of departure measurement for the multi element transmit antenna array for the DL-AOD positioning method.*
* ***(Qualcomm,*** [***R1-2205040***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2205040.zip)***[23])*** *Proposal 10: Support enhancing the UE-A/UE-B DL-AoD method with UE measurements that provide phase-difference and Angle of Departure information related to the first arrival path:* 
  + *Assistance Data Enhancement:*
  + *gNBs' antenna Configuration, PMI Codebook configuration & their association to the transmitted PRS resources, PMI to DL-AoD Mapping Table (for UE-B).*
  + *UE Measurement Enhancement:*
  + *Support a UE measuring multiple single-port PRS resources, sweeping a PMI codebook across the measured ports and determining the PMI index that maximizes the power associated with the earliest arriving path*

## Discussion

Once NR carrier phase measurements are supported in Rel-18, the UE could have the capability to provide the phase-difference obtained by receiving the signals from different TRP antennas (*PD-mTx*). Thus, it seems worthy to study the potential benefits and performance of using *PD-mTx* for DL-AOD.

### Proposal 6-1

* *The benefits and performance of using the phase-difference measurements for DL-AoD, which is obtained by measuring the DL reference signals from multiple TRP Tx antennas, will be investigated in Rel-18 SI.*

|  |  |
| --- | --- |
| **Company** | **comments** |
| MTK | We suggest to slightly change the wording as   * *The benefits and performance of using the phase-difference measurements for DL-AoD, which is obtained by measuring the DL reference signals from multiple TRP Tx antennas, will be investigated in Rel-18 SI, and the comparison with Rel-17 RSRP based DL-AoD is encouraged in order to justify the need to define a new type of DL-AoD method*   FL: I assume the comparison with Rel-17 RSRP based DL-AoD could be the details to be considred if we agree to study *using the phase-difference measurements for DL-AoD.* |
| ZTE | Based on SID, only carrier phase is described. This proposal actually is not carrier phase but antenna phase or angel phase. We doubt if it is in the scope of this SI.  The carrier phase based positioning is targeting at a high accuracy (similar to GNSS). But the accuracy of AoA/AoD is much lower than that of the carrier phase based positioning. Hence, the phase-difference measurements for AoA/AoD should be a low priority (if it was deemed to be included in this SI).  Hence, we prefer focusing section 4 and 7 first. |
| vivo | We would like to confirm whether the issue can be included in the carrier phase measurement? For us, it is more like the AoD enhancement. |
| Huawei, HiSilicon | The use of phase difference based DL-AoD can be the by-product of carrier phase measurement, but we consider this lower priority for the evaluation. |
| Samsung | We should study the performance of using phase-difference for DL/UL-AoD as well as DL/UL-AoA. Therefore, we suggest the following update:  *~~The benefits and performance of~~ Study using the phase-difference measurements for DL-AoD, DL-AoA, UL-AoD and UL-AoA. ~~which is obtained by measuring the DL reference signals from multiple TRP Tx antennas, will be investigated in Rel-18 SI~~*  FL: The scope could be too large to cover DL-AoD, DL-AoA, UL-AoD and UL-AoA. Also, in my view using phase-difference for UL-AOA may be implemented in Rel-16 w/o the need of additional support from the specs. |
| Nokia/NSB | Agree with Huawei. |
| Ericsson | Do not support the proposal. DL-AoD should not be considered in this study. We don’t think it is in the scope of the SID as mentioned by some other companies. Note that there were discussions in Rel. 17 and no agreements were possible in this direction at that time. The assistance data required for a UE-based DL-AoD was also discussed in Rel. 17, it is not possible to provide that detailed assistance data on exact location of each antenna element, for instance. |
| CATT | Low priority in our view |
| OPPO | We are ok to study that. |
| Apple | Should be low priority |
| Xiaomi | Prefer to confirm first it is in the scope of R18 carrier phase positioning or not. |
| NTT DOCOMO | We are open to discuss phase difference DL-AoD, however, it may be low priority in NR carrier phase measurement SI. |
| LGE | From our understanding, accuracy of the carrier phase measurement for propagation time would be higher than that of DL-AoD estimation. Since the main objective of this item is improving accuracy, we would like to focus on the NR carrier phase measurement and deprioritize the phase-difference measurement for angle based positioning methods. |
| Fraunhofer | Ok,  Looking at P2-1 from FL, the combination of the NR-phase measurements with any of the NR positioning methods can be studied. |
| InterDigital | We are supportive of the proposal. |
| Intel | Support. |
| Qualcomm | We support the proposal. We agree with the comments that this method is an enhancement to angle-based positioning rather than ‘true carrier phase’ (i.e., the schemes that build on Proposal 4-2). At the same time, we would like to repeat the observations that (1) it can easily reuse measurement definitions that will eventually be necessary for the ‘true’ carrier phase, and (2) accurate angle estimation may likely be needed as a pre-requisite for the ‘true’ carrier phase techniques, due to sensitivity of measured phase to the AoA/AoD, as we also observe in our response to proposal 8-1 below. In this light, we propose to support the proposal. |
| **FL** | Based on the feedbacks, for “the study of using the phase-difference measurements for DL-AoD”, 7 companies (e..g. MTK, Samsung, OPPO, Fraunhofer, IDC, Intel, and QC support it, 6 companies (ZTE, Huawei, Nokia, CATT, Apple, DCM) consider it as low priority, and 4 companies (Ericsson, vivo, Xiaomi, LGE) questions whether it is in the scope of the SI.  Given that SID does not explicitly mention the DL-AOD, we may need to first have the consensus on whether the use of phase-difference measurements for DL-AOD is in the SI scope. If we could not reach the consensus in RAN1 meeting, we may need to resolve the issue in RAN meeting. |

### Question 6-1

* *Do you think the study of the phase-difference measurements for DL-AoD in in the scope of the SI?*

|  |  |  |  |
| --- | --- | --- | --- |
| **Company** | **YES** | **NO** | **comments** |
| MTK |  | X | 1, from our theoretical analysis, there are a lot similarity between phase difference AOD and RSRP AOD, because both method requires to know and use the antenna comfiguration. We have not conducted the simulation to check whether there is potential improvement by phase difference AOD. But we don't expect any significant improvement. Then we may treat phase difference AOD as low priority |
| Huawei, HiSilicon |  | X | At least from our side, this is low priority, because from evaluation perspective, it should be clear how phase difference AoD can work, if you take a look at the Rel-15 PMI design.  We are not against working that during the work item if the phase reporting is in general introduced, and fill-in the gap with respect to the signaling design. |
| Samsung | X |  | Phase difference measurement is within the scope of the work item. Phase difference measurement can be used for determining AoD or AoA. |
| ZTE |  | X | Based on the SID, we think it is out of the scope.  The carrier phase based positioning is targeting at a high accuracy (similar to GNSS). But the accuracy of AoA/AoD is much lower than that of the carrier phase based positioning. Hence, the phase-difference measurements for AoA/AoD is with a low priority (if it were deemed to be included in this SI). |
| Qualcomm | X |  | We think that due to the potential sensitivity of carrier phase measurement to the AoD, it may turn out to be very challenging to make carrier phase work without good AoD estimation, for which the phase-difference measurement can be very useful |
| Locaila | X |  | The phase based DL-AoD may potentially provide a solution for public safety such as E911. We have demonstrated less than 1m vertical positioning accuracy can be provided from 500m away using vertically spaced antennas. Since the impact on market can be significant, we need to investigate this solution further.  Note that phase based DL-AoD is not beamforming, nor in the kind of direction finding by MUSIC. The solution is more to do with the issue of angular ambiguity in hyperbola math. |
| Ericsson |  | X | In our view, this is out of scope. |

# Phase-Difference for TOA

## Background

The following proposals are related to use the phase-differences obtained from different subcarriers for positioning purpose (PD-SC).

***Submitted Proposals:***

* ***(OPPO,*** [***R1-2203966***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203966.zip)***[13])Proposal 7:*** *Study measuring and reporting the relative phase of different Res of PRS resource for positioning.*
* ***(OPPO,*** [***R1-2203966***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203966.zip)***[13])Proposal 8:*** *Study measuring and reporting relative phase of different Res of PRS resource for multiple different RE gaps to resolve the integer ambiguity issue.*
* ***(OPPO,*** [***R1-2203966***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203966.zip)***[13])Proposal 11:*** *Study measuring and reporting the relative phase between different Res of SRS resource for positioning.*
* ***(OPPO,*** [***R1-2203966***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203966.zip)***[13])Proposal 12:*** *Study measuring and reporting relative phase of different Res of SRS resource for multiple different RE gaps to resolve the integer ambiguity issue.*

## Discussion

In FL’s understanding, the TOA can be determined in frequency domain by using PD-SC in Rel-16. It is up to UE/TRP’s implementation on whether to use the approach for TOA estimation. However, Rel-16/Rel-17 does not support UE/TRP to report the PD-SC measurements. NR carrier phase positioning may also be developed based on the reporting of the carrier phase measurements together with the PD-SC, without the need to report other timing measurements, such as RSTD, RTOA, etc. Thus, it is worthy to discuss whether to introduce PD-SC in Rel-18.

### Proposal 7-1

* *The benefits of reporting phase-difference of subcarriers together with carrier phase measurements for NR carrier phase positioning can be investigated in Rel-18 SI.*

|  |  |
| --- | --- |
| **Company** | **comments** |
| ZTE | The proposal is not very clear why phase-difference of subcarriers should be reported together with carrier phase measurements. In our view, phase-difference of subcarriers is equivalent to carrier phase measurement somehow. Hence, the revision is suggested as   * *The benefits of reporting phase-difference of subcarriers ~~together with carrier phase measurements for NR carrier phase positioning~~ can be investigated in Rel-18 SI.* |
| Vivo | To be honest, we are totally confused about what is carrier phase measurement and it is unclear to evaluate reporting phase-difference of subcarrier |
| Huawei, HiSilicon | Subcarrier-level phase difference reporting should not be considered, because it loses the carrier frequency information.  We also agree with FL that the slope of “phase-frequency response” is actually the super-resolution of ToA.  We want to emphasize that the RF frequency associated with the carrier phase measurement could be overlapped with a subcarrier, and it may even be possible that multiple such RF frequencies within a carrier associated with the carrier phase measurements are reported. |
| Samsung | OK to study and investigate, but we should be careful that the work load is not too high. |
| Nokia/NSB | We feel that more discussion may be needed before agreeing to something like this proposal. We consider it as lower priority/secondary topic for this meeting. |
| Ericsson | We are not supportive of the proposal. The relative phase difference of different carriers is what we use to compute the TOA (in frequency domain). In this SI we should not study enhancements of TOA estimation.  Regarding OPPO Proposal 8, note that this is like using TOA measurements to help resolve the integer ambiguity problem, where TOA is estimated from a subset of the resource elements. |
| CATT | Support to study. Maybe low priority. |
| OPPO | We support to study and the revision of ZTE looks ok to us. |
| Apple | Should be low priority |
| Xiaomi | We are confused on the reporting phase-difference of subcarriers. The motivation is to resolve the integer ambiguity issue? Compared to use multiple carrier frequencies, what is the benefit to use different subcarriers? |
| LGE | We are fine with studying reporting phase difference but it is not the only option that should be investigated. How to report the measurement shall be discussed together with other issues including the definition of the carrier phase measurement and method for resolving integer ambiguity. |
| InterDigital | Support to study. |
| **FL** | It seems more discussion is need on whether to study the use of the phase-difference of subcarriers for supporting carrier phase positioning. |
| Qualcomm | We agree with Huawei, and think this should not be considered. Phase-difference of subcarriers is a specific report whose value is unclear. We can consider reporting phase of subcarriers or subcarrier-groups, and then the phase-difference, even if needed, could then be an implementation option at the node that computes the position. |

# ARP Phase Centre Offsets

## Background

***Submitted Proposals:***

* ***(Huawei,*** [***R1-2203166***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203166.zip)***[1]) Proposal 2:*** *To evaluate positioning using carrier phase measurement, the following impairment should be considered*
  + *Carrier phase synchronization between TRPs*
  + *Carrier frequency error between TRP and UE*
  + *gNB ARP error*
* ***(Nokia,*** [***R1-2203178***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203178.zip)***[2]) Proposal 6****: RAN1 needs to study antenna phase center offset impact on the carrier phase positioning accuracy and identify potential solutions.*
* ***(InterDigital,*** [***R1-2204134***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204134.zip)***[14]) Proposal 3:*** *Study a framework that allows the UE or network to mitigate unknown phase offset in phase measurements, e.g., phase error group.*
* ***(Fraunhofer,*** [***R1-2204836***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204836.zip)***[21]) Proposal 6:*** *Study the impact and feasibility of carrier phase calibration for phase based high accuracy positioning*
* ***(Qualcomm,*** [***R1-2205040***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2205040.zip)***[23]) Proposal 3:*** *Study the impact of antenna phase center calibration on carrier phase performance.*

## Discussion

The performance of the carrier phase positioning is expected to be impacted by multiple factors. One of them is the ARP phase center offset, which may not be in the center of a physical antenna. In addition, the phase center offset may be different for antenna Rx/Tx beam directions. It is important to study the impact and identify potential solutions.

Proposal 8-1

* *RAN1 needs to study the impact of antenna phase center offset on the carrier phase positioning accuracy and identify potential solutions.*

|  |  |
| --- | --- |
| **Company** | **comments** |
| ZTE | This proposal overlaps with proposals in section 5 and proposal 4-2.  FL: Actually, it may not be the same, e.g., the use of PRU may not be able to remove the impact of the APR offset. |
| vivo | We think the impact of all related errors (e.g, clock offset, phase offset, multipath ) are needed to be studied first.  FL: Yes. We have separate proposals for each of these error sources. |
| Huawei, HiSilicon | We consider it high priority of the study. |
| Samsung | This proposal can of a lower priority given the work load. |
| Nokia/NSB | Support. This is an important impairment which impacts carrier phase positioning and RAN1 should study it. We are okay to also highlight that clock/phase offsets and multipath should also be studied but those error sources are better understood in our opinion. |
| Ericsson | Support to study. |
| CATT | Support to study. |
| OPPO | Support to study |
| Xiaomi | Support to study. But we share same view as ZTE, it overlaps with proposals in section 5. |
| LGE | We have similar view with vivo.  Beside, even in the case RAN1 studies the impact of ARP, it would be better to start studying on identifying potential solution only after we found necessity of it.  FL: The impact of APR offset was actually discussed in Rel-17 by some companies. It seems the impact is clearly there. |
| Fraunhofer | Support |
| InterDigital | Support to study. |
| Intel | Support. |
| Qualcomm | We think this is an important impairment that should be studied. Also in light of the FL comment above the proposal “the phase center offset may be different for antenna Rx/Tx beam directions” – we would like to clarify that there are two separate factors at play here – the beamforming weights used, and the AoA/AoD, and both can impact the phase-center offset. |
| **FL** | Based on the feedbacks, it seems most companies are supportive to the proposal. Hopefully, the concerns of some companies are addressed during the discussion. It seems no revision is need for the proposal for the 2nd round discussion. |

(Round 2) Proposal 8-1

* *The impact of antenna phase center offset on the carrier phase positioning accuracy and identify potential solutions will be studied during the SI.*

|  |  |
| --- | --- |
| **Company** | **comments** |
| Huawei, HiSilicon | Sorry for having misinterpreted the previous proposal.  Just want to clarify from our side, this PCO is additional offset on the ARP and may change due to the observation direction and beam direction, but the ARP itself may also have errors, which should be taken into account. In practice, PCO and ARP error are mixed together and thus may not be distinguished from each other, but from evaluation perspective, we think both are preferably added for study.  FL: Okay. We may consider more precise definition or wording during the SI for them. |
| Samsung | Too early to say “*identify potential solutions*”, suggest to only agree to study the impact first.  *The impact of antenna phase center offset on the carrier phase positioning accuracy ~~and identify potential solutions~~ will be studied during the SI* |
| Xiaomi | Ok |
| LGE | Regarding FL’s reply for our previous comment, I’m sorry that my previous comment was not enough to express my intention. Actually we are ok with studying the impact of ARP on the carrier phase measurement, and we also believe that ARP is the one of the error source that need to be considered in positioning item. My point was similar to Samsung’s recent comment above. We would like to study first the impact of ARP on the carrier phase measurement. After that we can discuss whether the potential solution need to be identified during the SI.  FL: Thanks for the clarification. |
| vivo | We think more than one error needs to be studied, and a potential solution is too early for us |
| Nokia/NSB | Support the FL proposal. For companies that don’t want to say “potential solutions” what is the technical concern to studying potential solutions? It seems straightforward that we will investigate this impairment and if it impacts the accuracy negatively then we will need to look at solutions. |
| InterDigital | Support |
| Intel | Support |
| Qualcomm | Support. A grammatical correction – ‘identify’ could be replaced by ‘identifying’. Also to address concerns about ‘potential solutions’, one option may be to say ‘identifying potential solutions if considered beneficial’.  FL: We may take the suggestion to see if it can address the concern of some companies. |
| CATT | For the progress, we are okay to first to agree the study the impact in this meeting, and add the study of the potential solution in the further meetings, although in our view the study of the potential solution is needed. |
| **FL** | For the progress, let us first to agree what we can agree, and leave the study of potential solutions in FFS.  * *The impact of antenna phase center offset on the carrier phase positioning accuracy will be studied during the SI.* * *FFS: The potential solutions for eliminating the impact of antenna phase center offset will be studied during the SI.* |

(H) (Round 3) Proposal 8-1

* *The impact of antenna phase center error (e.g., phase center offset) on the carrier phase positioning accuracy will be studied during the SI.*
* *FFS: Study the potential solutions for minimizing the impact of antenna phase center error (e.g., phase center offset) if needed.*

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| --- | --- |
| **Company** | **comments** |
| ZTE | We are fine with FL's proposal. |
| Huawei, HiSilicon | Suggest to add “error” after offset.   * *The impact of antenna phase center offset/error on the carrier phase positioning accuracy will be studied during the SI.* * *FFS: The potential solutions for eliminating the impact of antenna phase center offset/error will be studied during the SI.*   FL: If we assume “*phase center offset*” is a type of error, then a better description may be: “phase center error (e.g., offset)”. |
| Xiaomi | Fine with the proposal |
| LGE | Ok |
| CATT | Support. |
| Nokia/NSB | We support the updated proposal from Huawei. |
| Samsung | Fine with the main bullet. For FFS, remove “will be studied” as this is already for further study. Also suggest changing “eliminating” to “minimizing” as the error might not be completely eliminated. Also add “if needed” as this will depend on the study in the first bullet.   * *The impact of antenna phase center offset on the carrier phase positioning accuracy will be studied during the SI.*   *FFS: ~~The~~ potential solutions for ~~eliminating~~ minimizing the impact of antenna phase center offset ~~will be studied during the SI~~ if needed*  FL: The suggestions seem fine in general. Adding “*if needed” may not need since it is “FFS:”. If we want to add “if needed”, then “FFS” can be removed.* |
| **FL** | I made the following changes for further discussion with the consideaion of the comments:   * *The impact of antenna phase center error (e.g., phase center offset) on the carrier phase positioning accuracy will be studied during the SI.* * *FFS: Study the potential solutions for minimizing the impact of antenna phase center error (e.g., phase center offset) if needed.* |
| Ericsson | Ok to study |
| Intel | OK |
| InterDigital | Ok with the latest version from the FL |

(H) (Round 4) Proposal 8-1

* *The impact of antenna phase center error (e.g., phase center offset) on the carrier phase positioning accuracy will be studied during the SI.*
* *Study the potential solutions for minimizing the impact of antenna phase center error (e.g., phase center offset) if needed.*

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| --- | --- |
| **Company** | **comments** |
| vivo | Based on the proposal, it seems that supporting the second bullet or not depends on the evaluation in the first bullet. In this meeting, the related evaluation is limited, and the impact is unclear, so we prefer to put the second bullet as FFS and remove “if needed” and make an agreement after more evaluations have been provided |
| Huawei, HiSilicon | OK. It is anyway a study bullet. |
| LGE | We generally fine with the proposal but prefer to keep FFS in the 2nd bullet. |
| Samsung | We want to keep FFS in the second bullet. It is fine to keep the “if need” at the end, these solution would be further studied if there is a neeed based on the outcome of the first bullet. |
| CATT | Support |
| Intel | OK. |
| **FL** | To vivo/LGE/Samsung: I am wondering if the following change will address the comments:   * *The potential solutions for minimizing the impact of antenna phase center error (e.g., phase center offset) will be studied, if it is considered to be necessary after the evaluation of the impact.* |
| **Xiaomi** | Support |
| Ericsson | we are ok with latest FL proposal. |
| vivo | Thanks for the update, but we think the core part is evaluating at the first meeting, so we prefer to reuse the format in agenda 9   * *The impact of antenna phase center error (e.g., phase center offset) can ~~will~~ be evaluated during the SI* * *The methods for minimizing the impact of antenna phase center error (e.g., phase center offset) can ~~will~~ be studied during the SI, if it is considered to be necessary after the evaluation.*   FL: Okay. We may try to change “will” to “can” to see if it can be accepted in both sides. |
| **FL** | Based on the comments, we may consider the following changes for the next round discussion: (H) (Round 4) Proposal 8-1  * *The impact of antenna phase center error (e.g., phase center offset) on the carrier phase positioning accuracy can be studied during the SI.* * *The potential solutions for minimizing the impact of antenna phase center error (e.g., phase center offset) can be studied, if it is considered to be necessary after the evaluation.* |

### (Closed)( (Round 5) Proposal 8-1

* *The impact of antenna phase center error (e.g., phase center offset) on the carrier phase positioning accuracy can be studied during the SI.*
* *The potential solutions for minimizing the impact of antenna phase center error (e.g., phase center offset) can be studied, if it is considered to be necessary after the evaluation.*

|  |  |
| --- | --- |
| **Company** | **comments** |
| Fraunhofer | Okay |
| Samsung | OK |
| MTK | Okay, and any guideline/example for the modelling? |
| LGE | Ok |

# Multipath for Carrier Phase Positioning

## 9.1 Background

The performance of the carrier phase positioning is expected to be impacted by multiple factors as other positioning methods. The following proposals were submitted related to the study of the impact of the multipath on NR carrier phase positioning and identify potential solutions.

***Submitted Proposals:***

* ***(vivo,*** [***R1-2203568***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203568.zip)***[5]) Proposal 2:*** *The phase measurement performance should be evaluated with errors(e.g., multi-path, frequency error, clock offset).*
* ***(Samsung,*** [***R1-2203913***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203913.zip) ***[12]) Proposal 3:*** *Study the impact and mitigation of challenges when using the carrier-phase method for RAT-based positioning, including:*
  + *Impact of NLOS conditions and multi-path reflections.*
  + *Impact of phase ambiguity (integer ambiguity).*
  + *Impact of UE mobility*
  + *Synchronization errors*
* ***(LGE, R1- 2204524[17]) Proposal 3:*** *Methods to deal with the conventional problems of the carrier phase measurement positioning in NR positioning system should be studied (e.g. integer ambiguity, transmitter/receiver clock error, and multipath).*
* ***(InterDigital,*** [***R1-2204134***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204134.zip)***[14]) Proposal 4:*** *Study multi-path mitigation techniques for phase-based positioning*
* ***(CMCC,*** [***R1-2204312***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204312.zip)***[15]) Observation 2:*** *The following challenges needs to be studied and overcame:*
  + *The phase synchronization error degrades the accuracy performance;*
  + *Negative impact of complicated propagation environment (e.g., NLOS, multipath) on the phase error.*
  + *Fast search of the integer ambiguity*
* ***(Sharp,*** [***R1-2204669***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204669.zip)***[19]) Proposal:*** *The benefit of using NR carrier phase measurement for terrestrial network in multi-path environment and in LOS environment should be estimated for the introduction.*
* ***(Intel,*** [***R1-2204807***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204807.zip)***[20]))Proposal #1:*** *Study LOS/NLOS links classification for the carrier phase measurements to improve the accuracy of the carrier phase positioning methods.*
* ***(Fraunhofer,*** [***R1-2204836***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204836.zip)***[21]) Proposal 2:*** *Support reporting the phase measurements from the delay domain for the first and additional paths.*
* ***(Fraunhofer,*** [***R1-2204836***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204836.zip)***[21]) Proposal 3:*** *Consider one or more of the following options for the delay domain phase measurement:* 
  + *Option 1: The first path and N-path reporting is extended by a phase value for each reported path*
  + *Option 2: A magnitude the complex valued correlation value associated to the path is reported.*
  + *Option 3: The full complex valued CIR for a given length is reported.*
  + *Option 4: Relevant parts of the complex valued CIR are reported.*
* ***(Ericsson, R1- 2204952[22]) Proposal 5:*** *Study methods to measure the carrier phase of the first path.*
* ***(Ericsson, R1- 2204952[22]) Proposal 6:*** *Study methods to measure the carrier phase of additional paths.*

## 9.2 Discussion

The evaluation of the impact of multipath on NR carrier phase positioning may be further discussed in Section 13. For the methods of multipath mitigation,we may want to study how to reliably and accurately measure the carrier phase of the first path. For additional path, the impact of multipath on TOA and carrier phase measurement can be significantly different [25]. Thus, we may need to first investigate the feasibility to measure the carrier phase of the additional paths before discussing the potential benefits. Also, we may consider the reporting of other channel parameters for the multipathmitigation of the carrier phase positioning.

Proposal 9-1

* *RAN1 needs to study the methods of multipath mitigation for the carrier phase positioning, which may include, but not limited to the following:* 
  + *the methods to measure the carrier phase of the first path*
  + *the feasibility and benefits to measure the carrier phase of the additional paths*
  + *the benefits of the reporting other parameters channel parameters, such as CIR, CFR, SNR.*

|  |  |
| --- | --- |
| **Company** | **comments** |
| ZTE | We are generally fine with FL's proposal. |
| vivo | The performance impaction can be evaluated first, and then we can evaluate the potential solution in future meeting? |
| Huawei, HiSilicon | We do not support studying reporting CIR/CFR for carrier phase positioning, which is way beyond the scope of this objective. |
| Samsung | High level proposal is fine. We suggest to only agree on the main bullet and remove the sub-bullets. No need to discuss these details in the first meeting.   * *RAN1 needs to study the methods of handling multipath ~~mitigation~~ for the carrier phase positioning, ~~which may include, but not limited to the following:~~*    + *~~the methods to measure the carrier phase of the first path~~*   + *~~the feasibility and benefits to measure the carrier phase of the additional paths~~*   + *~~the benefits of the reporting other parameters channel parameters, such as CIR, CFR, SNR.~~*   FL: “*multipath mitigation”* may be more commonly used word instead of “*handling multipath”.* |
| Nokia/NSB | We think this proposal may be too detailed for this stage of the study. We are okay to investigate the impact of multipath on carrier phase positioning. |
| Ericsson | We are fine with FL’s proposal. |
| CATT | Suggest focus on the 1st sub bullet |
| OPPO | The sub-bullets are too much details. We are only ok to conclude something like the main bullet and we can investigate the impact of multi-path/NLOS. |
| Apple | Fine with the high level proposal. |
| Xiaomi | Prefer the modification by Samsung. |
| NTT DOCOMO | We are fine with the proposal. |
| LGE | In general, we agree that it is required to evaluate the performance impact by the NLOS paths first. However, whether and how to mitigate potential degradation due to the multipath should be discussed with proper evaluation results with consensus. |
| Fraunhofer | High priority.  Agree with Samsung revision since the multipath mitigation with carrier phase positioning is not the scope of the study. |
| Lenovo | Similar view with Nokia. We suggest the following high-level single line, i.e. no subbullets:  *Study the impact of multipath on carrier phase positioning, and mitigation methods if necessary.* |
| InterDigital | We are fine with the proposal. |
| **FL** | Based on the feedbacks, it seems we should focus on the main bullet in this meeting. |
| Intel | Fine with the proposal, but would suggest to also add a sub-bullet as follows:   * + *LOS/NLOS links classification for the carrier phase measurements*   Otherwise, we should perhaps just go with the version from Samsung – the main bullet only. |
| Qualcomm | We are ok with the latest FL suggestion, which is captured in the proposal from Samsung |

(Round 2) Proposal 9-1

* *The methods of mitigating multipath for the carrier phase positioning will be studied during the SI.*

|  |  |
| --- | --- |
| **Company** | **comments** |
| Huawei, HiSilicon | OK |
| Samsung | *“mitigating multipath*” means ran1 will discuss how to release the effect of multi-path, while we suggested “hanlding multipath” includes the make some restrcitions on using carrier phase due to multipath instead of dealing with multi-path itself. Suggested change:   * *The methods of ~~mitigating~~ handling multipath impact for the carrier phase positioning will be studied during the SI.*   FL: My understanding “mitigating multipath” can be any methods for reducing the impact of the multipath. The proposed “some restrcitions on using carrier phase” may also be considered one of them*.* |
| Xiaomi | Ok |
| NTT DOCOMO | OK |
| ZTE | We are fine with FL's proposal. |
| LGE | OK, and also fine with Samsung’s revision. |
| vivo | We think the impact needs to evaluate first and suggest revising it as follows.   * *The impact ~~methods~~ of ~~mitigating~~ multipath for the positioning based on carrier phase measurement ~~positioning~~ will be studied during the SI.*   FL: Okay. We may consider some wording changes, such as “and multipath mitigation can be studied if necessary”. |
| Nokia/NSB | We are okay with the proposal. |
| InterDigital | Support the FL’s proposal |
| Intel | OK |
| Qualcomm | OK |
| CATT | OK |
| **FL** | Based on the feedback, it seems we can use 2nd round proposal w/o change for 3rd discussion. |

(H) (Round 3) Proposal 9-1

* *The impact of multipath for the carrier phase positioning will be evaluated during the SI*
* *The methods of mitigating the impact of multipath for the carrier phase positioning will be studied during the SI, if it isconsidred to be necessary after the evaluation.*

|  |  |
| --- | --- |
| **Company** | **comments** |
| vivo | Sorry, we cannot agree the proposal directly in the first meeting without InF-DH scenario simulation and without consensus on multipath impaction for carrier phase positioning for OFDM signal.  FL: We could add that the impact of mitigating multipath for the carrier phase positioning will be evaluated as the precondition. |
| ZTE | We are fine with FL's proposal. |
| Huawei, HiSilicon | Support. We think that at least the carrier phase positioning should be evaluated under multi-path channel. |
| Xiaomi | Fine with the proposal |
| LGE | Fine with the proposal.  In our understanding, the proposal intend to studty possible methods/approaches which would be useful for mitigating multipath impact, and potential solutions for a specific scenario (e.g. for NLOS heavy) can be discussed if necessary. As commented by HW/HiSi, study on the carrier phase measurement should be conducted under multipath scenario, and it is worth studying effective methods for measureing carrier phase in multipath environment. |
| CATT | Support |
| Samsung | We think that the purpose of this proposal is to discuss how to handle and mitigate the effect (impact) of multipath. Therefore, we suggest the following update   * *The methods of handling and mitigating the impact of multipath for the carrier phase positioning will be studied during the SI.*   FL: Yes. When we say mitigating multipath, it really means mitigating the impact of the multipath. |
| **FL** | I made the following changes with the consideration of vivo’s comments: (H) (Round 3) Proposal 9-1  * *The impact of multipath for the carrier phase positioning will be evaluated during the SI.* * *The methods of mitigating the impact of multipath for the carrier phase positioning will be studied during the SI if it is considered to be necessary after the evaluation.* |
| Ericsson | Ok |
| Intel | OK |
| InterDigital | Ok with the latest version from the FL |
| FL | It seems we can use the latest changed in Round 3 for further checking in Round 4. |

### (Closed) (Round 4) Proposal 9-1

* *The impact of multipath for the carrier phase positioning will be evaluated during the SI*
* *The methods of mitigating the impact of multipath for the carrier phase positioning will be studied during the SI, if it is considered to be necessary after the evaluation.*

|  |  |
| --- | --- |
| **Company** | **comments** |
| Huawei, HiSilicon | OK |
| LGE | Fine with the proposal |
| Samsung | OK |
| Lenovo | Fine with the proposal, we just fixed small typos in the 2nd bullet. |
| CATT | Support |
| Intel | Support. |
| Xiaomi | Support |
| NTT DOCOMO | Support |
| Qualcomm | Support |
| MTK | ok |
| Ericsson | ok |
| Fraunhofer | Support |
| **FL** | It seems the proposal is stable. I will mark it as “stable” and request email endorsement. |

# Integer Ambiguity

## 10.1 Background

One of the key issues for carrier phase positioning is how to quickly and reliably resolve the integer ambiguity in the carrier phase measurements. The following proposals are submitted from interested companies for this issue.

***Submitted Proposals:***

* ***(Nokia,*** [***R1-2203178***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203178.zip)***[2]) Proposal 5****: RAN1 to study the impact of integer ambiguity on CP positioning and identify potential solutions with necessary physical layer procedures.*
* ***(CATT,*** [***R1-2203469***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203469.zip)***[4])Proposal 6:*** *Both continuous location tracking algorithm and one-shot location calculation algorithm can be studied for solution for UE location calculation with integer ambiguity.*
* ***(CATT,*** [***R1-2203469***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203469.zip)***[4])Proposal 7****: Carrier phases measurements from two or more carrier frequencies are helpful for fast resolution of the integer ambiguity.*
* ***(Locaila,*** [***R1-2203634***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203634.zip)***[7]) Proposal 2:*** *Investigate ambiguity resolution methods and necessary impact on the 5G NR system*
* ***(Xiaomi,*** [***R1-2203824***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203824.zip)***[11]) Proposal 1:*** *Study the potential solution for integer ambiguity and considering the impacts on UE RF with reusing of PRS/SRS and other specification impacts.*
* ***(Xiaomi,*** [***R1-2203824***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203824.zip)***[11]) Proposal 4****: Study the potential solution for cycle slips detection and repair and considering the impacts on UE RF and other specification impacts.*
* ***(OPPO,*** [***R1-2203966***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203966.zip)***[13])Proposal 5:*** *The issue of ambiguity of integer wavelengths in phase measurement results shall be studied.*
* ***(Intel,*** [***R1-2204807***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204807.zip)***[20])Proposal #4:*** *Study carrier phase ambiguity resolution using the subcarrier measurements within the DL PRS signal bandwidth.*
* ***(Qualcomm,*** [***R1-2205040***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2205040.zip)***[23]) Proposal 4:*** *Use brute-force integer ambiguity resolution as a baseline for comparison of simulation results.*

## 10.2 Discussion

Proposal 10-1

* *Study the impact of integer ambiguity on CP positioning and identify potential solutions with necessary physical layer procedures. The study may include, but not limited to, the following:*
  + *Resolution of integer ambiguity with the carrier phase and other existing measurements obtained in one time instance, or in a sequential time instances;*
  + *Resolution of integer ambiguity with the carrier phase and other existing measurements obtained from one carrier frequency, or multiple carrier frequencies;*
  + *Resolution of integer ambiguity with the carrier phase and other existing measurements obtained from the subcarrier frequencies within the DL/UL RS signal bandwidth*
  + *Integer cycle slips detection and repair;*
* *The impacts on potential solutions on UE/gNB implementation and specification may also be studied.*

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| **Company** | **comments** |
| ZTE | We think the main bullets are enough for study. The subbullet seems not clear, e.g. in the first subbullet, why other existing measurements should be restricted in one time instance? What is the time instance ? |
| Vivo | We propose to revise as follows Proposal 10-1 *Study the range of integer ambiguity based on NR carrier phase measurement and evaluate the impact of corresponding integer ambiguity on CP positioning* |
| Huawei, HiSilicon | Given the limit time, we prefer only to prioritize the second subbullet.  We do not support the third bullet, as explained before, which loses the carrier frequency information.  We consider the fourth bullet low priority, because it should be based on tracking of carrier phase measurement over time, including the modelling of hardware impairment, which expands the scope. |
| Samsung | High level proposal is fine. We suggest to only agree on the first main bullet and remove the sub-bullets and second bullet. No need to discuss these details in the first meeting.   * *Study the impact of integer ambiguity on CP positioning and identify potential solutions for mitigation ~~with necessary physical layer procedures. The study may include, but not limited to, the following:~~*   + *~~Resolution of integer ambiguity with the carrier phase and other existing measurements obtained in one time instance, or in a sequential time instances;~~*   + *~~Resolution of integer ambiguity with the carrier phase and other existing measurements obtained from one carrier frequency, or multiple carrier frequencies;~~*   + *~~Resolution of integer ambiguity with the carrier phase and other existing measurements obtained from the subcarrier frequencies within the DL/UL RS signal bandwidth~~*   + *~~Integer cycle slips detection and repair;~~*   + *~~The impacts on potential solutions on UE/gNB implementation and specification may also be studied~~* |
| Nokia/NSB | We are okay with the suggestion from ZTE to just agree to the main bullet for now. In our view the sub-bullets are all detailed solutions that we should discuss. The 2nd main bullet seems not needed in our opinion. |
| Ericsson | We are supportive of the main bullet: *Study the impact of integer ambiguity on CP positioning and identify potential solutions with necessary physical layer procedures.”*  The sub-bullets seem too detailed for now. Some specific comments below:  Positioning standardization in 3GPP has considered tracking as an application and nothing which can be assumed. We should stick to that in order to have a fair comparison between different positioning methods.  Regarding the sub-bullet: *“Resolution of integer ambiguity with the carrier phase and other existing measurements obtained from one carrier frequency,* ***or multiple carrier frequencies****”*: Is the multiple carrier frequency related to bandwidth aggregation? We are not supportive of multiple carrier frequency for carrier phase positioning in Rel-18. We should use the Rel. 17 positioning as baseline here and we don’t have support for bandwidth aggregation for carrier based positioning.  Regarding the sub-bullet: *“Resolution of integer ambiguity with the carrier phase and other existing measurements obtained from the subcarrier frequencies within the DL/UL RS signal bandwidth”*:We are fine with using multiple subcarrier frequencies.  Regarding the sub-bullet: “*Integer cycle slips detection and repair”:* We do not support to study this. Integer cycle slip detection is done by tracking and should consequently be considered an application. |
| CATT | Support. |
| OPPO | We also prefer to only agree the main bullet now. The details in the sub-bullet shall be next step after we have done the first stage study. |
| Apple | Agree to main bullet |
| Xiaomi | We support the main bullet.  And the first and the second sub-bullet can be considered with higher priority than the third and fourth sub-bullet. |
| NTT DOCOMO | Support |
| LGE | We are fine with main bullets and prefer to keep them for study. Meanwhile intention of some sub bullets seems to overlap with other proposals which may require further discussion for consensus. |
| Fraunhofer | Okay with the proposal, the second bullet is worth further investigations. |
| Lenovo | We think at least the subbullet *Integer cycle slips detection and repair* should be removed for now, as it may be rather hardware-specific. |
| InterDigital | We support the first main bullet. We are supportive of the modification from Sasmung, i.e., all the subbullets and the second main bullet can be removed since these are the aspects that can be studied further.. |
| **FL** | Based on the feedbacks, it seems we should focus on the main bullet in this meeting. |
| Locaila | We share the same view with Ericsson. |
| Intel | Support the main bullet at this point. We support the third sub-bullet and first and second sub-bullets in part. We have concerns like Ericsson on use of multiple carrier frequencies in second sub-bullet and regarding the assumptions on tracking - related to the first (sequential measurements) and fourth sub-bullets. |
| Qualcomm | We are fine with latest FL proposal to stick to the main bullet |

(Round 2) Proposal 10-1

* *The impact of integer ambiguity on NR carrier phase positioning and potential solutions of the integer ambiguity will be studied during the SI.*

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| **Company** | **comments** |
| MTK | Okay for without any subbullets |
| Huawei, HiSilicon | OK |
| Samsung | Wording change:   * *The impact of integer ambiguity on NR carrier phase positioning and potential solutions of resolving the integer ambiguity will be studied during the SI.* |
| Xiaomi | Ok |
| NTT DOCOMO | OK |
| ZTE | OK for study.  But we think it is an issue of implementation (e.g., an integer search with assistance from classical TOA/TDOA). |
| LGE | OK and also fine with the Samsung’s revision. |
| vivo | The same view as other proposals, and suggest to revise as follows   * *The impact of integer ambiguity on the positioning based on NR carrier phase measurement ~~positioning~~ and potential solutions of the integer ambiguity will be studied during the SI.*   FL: While vivo’s intention is clear, I would suggest keeping the term “*carrier phase positioning”, since the issue of integer ambiguity is well known to carrier phase positioning.* |
| Nokia/NSB | Ok with Samsung’s revision. We don’t agree with vivo’s revision as we think it is not technically correct. Integer ambiguity is about the positioning method but doesn’t necessarily imply that it is a standalone technique. |
| InterDigital | Support |
| Intel | Support Samsung’s version with minor edit as below:   * *The impact of integer ambiguity on NR carrier phase positioning and potential solutions ~~of~~ to resolve~~ing~~ the integer ambiguity will be studied during the SI.* |
| Qualcomm | Support Intel’s proposal |
| CATT | Intel’s suggestion is fine to us. |
| **FL** | Based on the comments, suggest using the verson in Intel’s comments for 3rd round discussion. |

### (Closed)(Round 3) Proposal 10-1

* *The impact of integer ambiguity on NR carrier phase positioning and potential solutions to resolve the integer ambiguity will be studied in the SI.*

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| **Company** | **comments** |
| ZTE | OK for study.  But we think it is an issue of implementation (e.g., an integer search with assistance from classical TOA/TDOA).  FL: The methods used for integer ambiguity may have the impact on the specs, e.g., signaling. |
| Huawei, HiSilicon | OK. |
| Locaila | We support |
| Xiaomi | Support the proposal |
| LGE | Ok |
| CATT | Ok |
| Nokia/NSB | Okay |
| Samsung | OK |
| Ericsson | Ok |
| Intel | OK |
| InterDigital | Support the FL’s prposal |
| **FL** | The proposal seems stable for email endorsement. |

# Phase-smoothed timing measurements

## 11.1 Background

Using carrier phase information for smoothing pseudorange measurements is supported for GNSS positioning (see TS 37.355). Due to the small measurement noise of carrier phase measurements, using carrier phase measurements to smother other timing measurements may improve the accuracy, which can be implemented without the need to resolve the integer ambiguity in carrier phase measurements.

***Submitted Proposals:***

* ***(CATT,*** [***R1-2203469***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203469.zip)***[4])Proposal 3****: Joint reporting of POA and TOA for smoothing TOA with POA can be studied to improve the traditional DL/UL-TDOA performance.*
* ***(Fraunhofer,*** [***R1-2204836***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204836.zip)***[21]) Proposal 4:*** *Support phase based smoothing for DL-TDoA and UL-TdoA methods in Rel-18.* 
  + *Consider the signaling of the coherency transmission status to the UE (UE based positioning) or to the LMF to notify on the applicability of phase based smoothing.*

## 11.2 Discussion

### Proposal 11-1

* *Using carrier phase information for smoothing exiting timing measurements for DL-TdoA, UL-TdoA and Multi-RTT can be studied in Rel-18 for UE-assisted and UE-based positioning.*

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| **Company** | **comments** |
| ZTE | What is the difference between this proposal and the last bullet of proposal 2-1? |
| Huawei, HiSilicon | Low priority. |
| Samsung | This proposal is not needed at this stage given proposal 1 and the following sub-bullet:  “*Combination of NR carrier phase positioning with any of the standardized Rel. 17 positioning methods*” |
| Nokia/NSB | Question to the proponents. What is the spec impact of such a smoothing technique? |
| Ericsson | open to study this |
| CATT | Support. |
| OPPO | This proposal is not needed since proposal 2-1 already covers the related issue. |
| LGE | In my understanding, the last bullet in the proposal 2-1 already covers the intention of this proposal. Could you elaborate differences between proposals? |
| Fraunhofer | This is a straightforward well-known approach for processing phase measurements, which under the defined constraints (known in GNSS) will provide high improvement for NR timing based methods. Clearly this a promising solution to evaluate in this SI.  To Nokia: we assume that the carrier phase measurements associated with RTOA or RSTD may be then reported and probably the RS update rate matching the UE mobility. |
| Lenovo | Agree with Oppo, proposal 2-1 already covers the related issue. |
| InterDigital | This may be an issue that is in the scope of other proposals, e.g.., Proposal 2-1. |
| **FL** | It seems there is a need to have more discussion on the method. A simple description of using carrier phase to smooth code phase is available in:  <https://gssc.esa.int/navipedia/index.php/Carrier-smoothing_of_code_pseudoranges>  The impact on specs may be some parameters related to the smoother, e.g., *smoothingInterval* defined in TS 37.355. |
| Locaila | Agreed.  This is exactly the reason why we need block type continuous PRS symbol arrangement. In order for accumulation of phase value and smoothing, the symbol information have to be arranged in contiguous and continuous REs. |
| Intel | At this point, prefer to leave it at the version in Proposal 2-1. |

# Time and Frequency Adjustments for carrier phase positioning

## 12.1 Background

The UE receiver may perform autonomous time adjustment (ATA) and autonomous frequency adjustment (AFA) during a carrier phase positioning, which could cause unexpected large positioning errors.

***Submitted Proposals:***

* ***(CATT,*** [***R1-2203469***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203469.zip)***[4])Proposal 4****: At least the following two methods to eliminate the impact of ATA/AFA can be studied.*
  + *Method 1: UE reports both the value and time stamp of ATA and/or AFA to the network side.*
  + *Method 2: Network controls the effective time window of ATA and AFA for UE.*

## 12.2 Discussion

### Proposal 12-1

* *The impact of UE autonomous time adjustment (ATA) and autonomous frequency adjustment (AFA) on NR carrier phase positioning and the potential solutions to the issue can be studied in Rel-18 SI.*

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| **Company** | **comments** |
| ZTE | It can be with a low priority from our view. |
| Vivo | The performance impaction can be evaluated first. |
| Huawei, HiSilicon | Low priority. |
| Samsung | It is not clear ATA and AFA should be in the scope. These seems up to UE implementation. |
| Ericsson | Ok to study |
| CATT | Support |
| OPPO | It id low priority |
| LGE | There are several error sources that can cause phase discontinuity when receiver measure the carrier phase It would be worth considering the impact of the carrier phase measurement error by not only the TAT/AFA but also the other error sources. After investigation, we can select error sources which degrade positioning accuracy significantly, and discuss potential solutions if it is needed. |
| InterDigital | Similar view as Samsung and it may be discussed further. |
| **FL** | It seems the issue can be considered as low priority in this meeting. |
| Locaila | We are supportive on this work, but the wording is somewhat misleading.  It needs more clarification, or defer discussion to next meeting. |

# Evaluation Assumptions for Carrier Phase Positioning

## Background

The following proposals were submitted related to the evaluation assumptions for Carrier Phase Positioning.

***Submitted Proposals:***

* ***(CATT,*** [***R1-2203469***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203469.zip)***[4])Proposal 9****: Reuse simulation assumption of InF-SH channel scenario in FR1 in Rel-17 for the simulation of CPP, where the key simulation parameters in Table 1 can be considered.*
* ***(ZTE,*** [***R1-2203626***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203626.zip)***[6]) Proposal 1****: InF-SH is used for evaluation of carrier phase based positioning.*
* ***(ZTE,*** [***R1-2203626***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203626.zip)***[6]) Proposal 2:*** *The bandwidth (e.g., 100MHz) used for evaluation of carrier phase based positioning should be aligned among companies.*
* ***(Samsung,*** [***R1-2203913***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203913.zip) ***[12]) Proposal 4:*** *Reuse evaluation scenarios and assumptions in TS38.885 and TS38.857 with proper modelling of the carrier phase measurements.*
* ***(Samsung,*** [***R1-2203913***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203913.zip) ***[12]) Proposal 5****: studying the possible direction to resolve the challenges, including:*
  + *Applicable conditions for using Carrier phase method*
  + *Phase detection based on different frequency ranges*
  + *UE mobility*
  + *Synchronization improvement*
* ***(OPPO,*** [***R1-2203966***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203966.zip)***[13])Proposal 2:*** *In the study of phase measurement, the impact of phase noise in NR system shall be considered.*
* ***(OPPO,*** [***R1-2203966***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203966.zip)***[13])Proposal 3:*** *The impact of Tx/Rx timing delay on phase measurement for positioning shall be considered.*
* ***(OPPO,*** [***R1-2203966***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203966.zip)***[13])Proposal 4:*** *The impact of CFO on phase measurement for positioning shall be considered.*
* ***(OPPO,*** [***R1-2203966***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203966.zip)***[13])Proposal 6:*** *The impact of multi-path and NLOS shall be considered in study of phase-based measurement for positioning.*
* ***(Lenovo,*** [***R1-2204561***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204561.zip)***[18])Proposal 2:*** *RAN1 to consider indoor scenarios, e.g., indoor office or indoor factories as a starting point for evaluating the performance of carrier phase positioning.*
* ***(NTT DOCOMO,*** [***R1-2204387***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204387.zip)***[16]) Observation 2:*** *Both outdoor location and indoor location can be considered as target scenario of NR carrier phase measurement.*
* ***(NTT DOCOMO,*** [***R1-2204387***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204387.zip)***[16]) Observation 4:*** *It may be better to discuss targeting frequency range (e.g. FR1 and/or FR2) and applicability of NR carrier phase measurement.*
* ***(NTT DOCOMO,*** [***R1-2204387***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204387.zip)***[16]) Observation 5:*** *RAN1 can evaluate the accuracy improvement gain of the carrier phase measurement mechanism e.g., carrier phase-based adjustment for timing-based measurements, and if sufficient gain is observed, RAN1 can also discuss necessary specification impacts to obtain/provide carrier phase information for positioning.*
* ***(Ericsson, R1- 2204952[22]) Proposal 2:*** *Evaluate carrier phase-based positioning solutions with the IOO and InF scenarios.*
* ***(Ericsson, R1- 2204952[22]) Proposal 3:*** *Performance evaluations must not assume that it is possible to track the carrier phase over time.*
* ***(Ericsson, R1- 2204952[22]) Proposal 4:*** *Study the implications of oscillator-drift and methods to handle the errors it introduces.*
* ***(Qualcomm, R1-2205040[23]) Proposal 4:*** *Use brute-force integer ambiguity resolution as a baseline for comparison of simulation results.*
* ***(Qualcomm,*** [***R1-2205040***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2205040.zip)***[23]) Proposal 5:*** *Study the need for phase coherence across time when evaluating carrier-phase based techniques. Simulation evaluations should clarify assumptions made on phase-coherence at both transmitter and receiver.*
* ***(Qualcomm,*** [***R1-2205040***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2205040.zip)***[23]) Proposal 6:*** *Reuse Simulation Assumptions of NR Rel-16/17 for InH, InF, Umi for FR1 and FR2, for carrier phase positioning.*
* ***(Qualcomm,*** [***R1-2205040***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2205040.zip)***[23]) Proposal 7:*** *For carrier phase positioning, consider any new scenarios that are introduced for other Rel-18 positioning techniques. Introduce an additional FDD scenario targeting scenarios with small number of antennas at the TRPs.*
* ***(Qualcomm,*** [***R1-2205040***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2205040.zip)***[23]) Proposal 8:*** *Study carefully the sources and impacts of carrier phase measurement errors.*

## 13.2 Discussion

Based on proposals from interested companies, it seems the major companies propose reusing the simulation assumptions of NR Rel-16/17 for carrier phase positioning. In addition, some companies also propose considering additional error sources, e.g., phase noise, CFO, and oscillator-drift, which are not included in the simulation assumptions of NR Rel-16/17.

Consider the limited time of the SI, it may not be practical to evaluate all Rel-16/17 scenarios. Considering the phase noise of FR2 can be much larger than FR1 and the wavelength of FR2 is much shorter than FR1, resolving the integer ambiguity for FR2 may be much more difficult than FR1, one way to reduce the evaluation effort is to focus on FR1. In addition, consider GNSS carrier phase positioning is popularly used outdoor scenarios, the study of NR carrier phase positioning may focus on indoor scenarios to reduce the evaluation effort.

For carrier phase positioning, it normally requires tracking the carrier phase for resolving the integer ambiguity. However, under some conditions (e.g., the CP measurements are available from multiple carrier frequencies), fast integer ambiguity resolution with single-shot measurements could also be possible. Thus, the suggest is to support the performance evaluation for both single-shot positioning (without tracking the carrier phase over time) and with tracking the carrier phase.

Proposal 13-1

* *Reuse the simulation assumptions of NR Rel-16/17 for carrier phase positioning*
  + *Note: Modification of the simulation assumptions defined in NR Rel-16/17 are allowed if needed.*
* *The evaluation scenarios:*
  + *Baseline: InF-SH*
  + *Optional: other InF scenarios, IOO, Umi*
* *Frequency range:* 
  + *Baseline: FR1*
  + *Optional: FR2*

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| **Company** | **comments** |
| ZTE | We are fine with FL’s proposal.  One general comment: More details for simulation should be investigated including how to get the phase measurement, e.g. in time domain or in frequency domain in the simulation, or perfect phase is used in the simulation.  FL: Similar to Rel-16/Rel-17 investigation, how to obtain the measurements is normally implementation dependent. Does ZTE propose a baseline algorithm/method to obtain the carrier phase measurements? |
| vivo | InF-DH can also be supported for the evaluation of the multipath scenario  FL: Yes. Maybe include in the Optional scenario. |
| Huawei, HiSilicon | We do not support evaluation for FR2, because of the phase noise.  FL: My understanding is also that carrier phase positioning may not be suitable for FR2. But, at least two companies have mentioned FR2 in their proposal. Maybe we can add FFS to see if any company still wants to FR2. |
| Samsung | For simulations, we should also include Umi/Uma and V2X highway scenarios   * *The evaluation scenarios:*   + *Baseline: InF-SH, Umi/Uma and V2X highway*   + *Optional: other InF scenarios, IOO, ~~Umi~~*   FL: The scope of the simulation evaluation may be too large, if *Umi/Uma* and *V2X highway* are include in baseline scenarios. Interested companies are welcome to present *Umi/Uma and V2X highway, if they consider carrier phase positioning is particularly useful for these scenarios.* |
| Nokia/NSB | Maybe the note could be an FFS point instead. We should not just open the door for companies to make whatever changes they want as this makes alignment more difficult. Otherwise we support the proposal.  FL: Add “only” if needed to address the concern. |
| Ericsson | We support the proposal in general. However, we don’t think that tracking should be part of the evaluations.  FL: Share the similar view that we can focus on single-shot. Suggest not to exclude tracking if some companies are willing to bring the simulation results.  We may well restrict to FR1 and InF-SH which is a scenario where carrier phase positioning likely works better than in most other scenarios. However, we should make sure to include all realistic error sources. |
| CATT | Support. We should limit the scope of the baseline scenarios. |
| Apple | We are fine with the proposal |
| Xiaomi | We are fine with the baseline scenario. |
| NTT DOCOMO | We are fine with the proposal. |
| LGE | We are generally fine with the proposal.  Regarding optional evaluation scenarios, we prefer to focus on the indoor positioning. |
| Lenovo | Support FL's proposal. |
| InterDigital | We support the proposal. |
| **FL** | With the consideration of the comments, weProposal 13-1  * *Reuse the simulation assumptions of NR Rel-16/17 for carrier phase positioning*   + *Note: Modification of the simulation assumptions defined in NR Rel-16/17 are allowed only if needed.* * *The evaluation scenarios:*   + *Baseline: InF-SH*   + *Optional: InF-DH, IOO, Umi, Uma* * *Frequency range:*    + *Baseline: FR1*   + *FFS: Optional: FR2* |
| Locaila | We support samsung’s proposal |
| Intel | Fine with the updated FL proposal. |
| Qualcomm | We propose both FR1 and FR2 as baselines. In response to Huawei’s comment, while we certainly agree phase noise is worse in FR2, we believe it may not be large enough to rule out FR2. We also point out the obvious advantages of FR2 – larger BW to help resolve the first path and extract its phase, and smaller wavelength which holds the promise of higher accuracy (as the accuracy is potentially of the order of the wavelength). FL: Okay. Maybe we keep FR2 as *Optional as the compromise.* |

(Round 2) Proposal 13-1

* *Reuse the simulation assumptions of NR Rel-16/17 for carrier phase positioning*
  + *Note: Modification of the simulation assumptions defined in NR Rel-16/17 are allowed if needed.*
* *The evaluation scenarios:*
  + *Baseline: InF-SH*
  + *Optional: other InF scenarios, IOO, Umi*
* *Frequency range:* 
  + *Baseline: FR1*
  + *Optional: FR2*

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| **Company** | **comments** |
| Huawei, HiSilicon | We think the baseline should be InF-SH and InF-DH as did in Rel-17.  FL: For the progress, suggest include “FFS: InF-DH” as baseline for now. If more companies are interested in “InF-DH”, we will consider removing “FFS”. |
| Spreadtrum | We don’t think FR2 is necessary, at least for Rel-18. Carrier phase positioning at FR1 can provide sub-centimeter accuracy already. Carrier phase positioning at FR2 will introduce phase noise as HW mentioned, and also high complexity.  FL: Assume it is fine to include as Optional for the purpose of evaluation. |
| Samsung | We can accept for progress with the following update   * *Reuse the simulation assumptions of NR Rel-16/17 for carrier phase positioning*   + *Note: Modification of the simulation assumptions defined in NR Rel-16/17 are allowed if needed.* * *The evaluation scenarios:*   + *Baseline: InF-SH*   + *Optional: ~~other~~ reported by companies e.g., InF scenarios, IOO, Umi, Highway* * *Frequency range:*    + *Baseline: FR1*   + *Optional: FR2*   FL: For the evaluation scenarios, it is understandable that each company may have some special scnearios in mind. However, it would be better for most companies to provide the evaluation results focusing on scnearios, even for the optional ones. Maybe we can add “other scnerios are not precluded to address Samsung’s concern. |
| Xiaomi | Ok for the baseline. |
| ZTE | We also think FR2 should not be included as Spreadtrum mentioned. |
| LGE | We are fine with the revised proposal from FL. |
| vivo | Same view as Huawei. |
| Nokia/NSB | The note is still confusing to us. We can like with it if we add that these changes are optional.  FL: Thanks for the understanding. |
| InterDigital | Support |
| Intel | OK |
| Qualcomm | OK with FL proposal. In response to companies commenting against FR2, we would like to repeat that FR2 has potential for more accuracy due to larger BW and smaller wavelength. We also believe that while phase noise is a potential concern and should be studied, it is likely that it will not be a showstopper. So it is too early to eliminate FR2. |
| CATT | Support |
| **FL** | *With ths consideration of the comments, suggest following modification for next round discussion.*   * *Reuse the simulation assumptions of NR Rel-16/17 for carrier phase positioning*   + *Note: Modification of the simulation assumptions defined in NR Rel-16/17 are allowed only if needed.* * *The evaluation scenarios:*   + *Baseline: InF-SH*     - *FFS: InF-DH*   + *Optional: other InF scenarios, IOO, Umi*     - *Note: Other evaluation scenarios are not precluded.* * *Frequency range:*    + *Baseline: FR1*   + *Optional: FR2* |

(H) (Round 3) Proposal 13-1

* *Reuse the simulation assumptions of NR Rel-16/17 for carrier phase positioning*
  + *Note: Optional modification of the simulation assumptions defined in NR Rel-16/17 are allowed only if needed.*
* *The evaluation scenarios:*
  + *Baseline: InF-SH*
    - *FFS: InF-DH*
  + *Optional: InF-DH, IOO, Umi, Highway*
    - *Note: Other evaluation scenarios are not precluded.*
* *Frequency range:* 
  + *Baseline: FR1*
  + *Optional: FR2*

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| --- | --- |
| **Company** | **comments** |
| vivo | The same view in proposals 9-1, and InF-DH needs to be supported to investigate the carrier phase positioning performance in different scenarios.  FL: How about we specifically list InF-DH as the optional one. |
| ZTE | OK |
| Huawei, HiSilicon | We also think that InF-DH should be evaluated. |
| Xiaomi | We are fine with the proposal |
| LGE | Fine with the proposal. |
| Nokia/NSB | We suggest to change the first note as follows:   * + *Note: Optional ~~M~~modification of the simulation assumptions defined in NR Rel-16/17 are allowed only if needed.*   Otherwise support. |
| Samsung | Optional scenarios, can be reported by companies, they don’t need to be all simulated. Therefore, we would like to include highway in that group. We understand that not all optional secnatios will be evalaued, this is why it is optional.   * *Reuse the simulation assumptions of NR Rel-16/17 for carrier phase positioning*   + *Note: Modification of the simulation assumptions defined in NR Rel-16/17 are allowed only if needed.* * *The evaluation scenarios:*   + *Baseline: InF-SH*     - *FFS: InF-DH*   + *Optional: other InF scenarios, IOO, Umi, Highway*     - *Note: Other evaluation scenarios are not precluded.* * *Frequency range:*    + *Baseline: FR1*   + *Optional: FR2*   FL: Okay. Will add *Highway to optional scenario.* |
| Nokia/NSB | We suggest to change the first note as follows:   * + *Note: Optional ~~M~~modification of the simulation assumptions defined in NR Rel-16/17 are allowed only if needed.*   Otherwise support. |
| **FL** | I mde the following modification with the consideration of received comments for further discussion:  * *Reuse the simulation assumptions of NR Rel-16/17 for carrier phase positioning*   + *Note: Optional modification of the simulation assumptions defined in NR Rel-16/17 are allowed only if needed.* * *The evaluation scenarios:*   + *Baseline: InF-SH*     - *FFS: InF-DH*   + *Optional: InF-DH, IOO, Umi, Highway*     - *Note: Other evaluation scenarios are not precluded.* * *Frequency range:*    + *Baseline: FR1*   + *Optional: FR2* |
| Ericsson | Ok |
| Intel | OK |
| InterDigital | Ok with the latest version from the FL |
| **FL** | It seems we can use the latest changed for the next round discussion. |

(H) (Round 4) Proposal 13-1

* *Reuse the simulation assumptions of NR Rel-16/17 for carrier phase positioning*
  + *Note: Optional modification of the simulation assumptions defined in NR Rel-16/17 are allowed only if needed.*
* *The evaluation scenarios:*
  + *Baseline: InF-SH*
    - *FFS: InF-DH*
  + *Optional: InF-DH, IOO, Umi, Highway*
    - *Note: Other evaluation scenarios are not precluded.*
* *Frequency range:* 
  + *Baseline: FR1*
  + *Optional: FR2*

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| **Company** | **comments** |
| Vivo | We are not sure the Highway can be included in the proposal based on the scope of SID   * + Study solutions for accuracy improvement based on NR carrier phase measurements [RAN1, RAN4]     - Reference signals, physical layer measurements, physical layer procedures to enable positioning based on NR carrier phase measurements for both UE-based and UE-assisted positioning [RAN1]     - Focus on reuse of existing PRS and SRS, with new reference signals only considered if found necessary   FL: My understanding is highway scenario can still be based on existing PRS and SRS. |
| Huawei, HiSilicon | InF-DH appears at both FFS bullet and Optional bullet, but it does not help add up the importance of DH in the evaluation.  We still think DH should be one of the baselines.  FL: My understanding is that carrier phase positioning is general requires good LOS environment. It would difficult to simulate carrier phase positioning under strong multipath environment. |
| LGE | We have concern on Highway scenario. Since there is no consensus on studying/supporting the carrier phase measurement based positioning in SL scenario so far, we do not prefer including Highway scenario which is mainly used for SL evaluation.  Regarding InF-DH, it seems strange for us that InF-DH is captured as FFS for the baseline scenario while it is considered as an optional scenario. Although we don’t have strong view, but slightly prefer to consider InF-DH as optional feature rather than keep it FFS for a baseline.  FL: The intention is that *InF-DH is at least Optional. We may need further discussion to make it as baseline.* |
| Samsung | Fine with proposal  Regarding the highway scenario, the intention is to evaluate carrier phase method on the Uu (DL/UL) interface in a highway scenario. This is not for SL positioning. |
| CATT | Okay, although it seems too many optional scnearios. |
| Intel | OK |
| Xiaomi | We are fine with the baseline scenario. |
| NTT DOCOMO | Regarding Highway scenario, it is not clear to us what is target use case excluding SL positioning. However, we can accept the current proposal since the scenario is optional. |
| MTK | For InF-DH, similar view as Huawei to put it at baseline. Measurement by carrier phase may degrade the performance under some scenarios. The simulation may help us know the limitation.  FL: Understand the intention. |
| Ericsson | We share concern on the *Highway* scenario similar to vivo, LGE, Docomo.  But given Samsung clarified their intention, could we add the following note to the proposal?  note: for the highway scenario, carrier phase positioning on Uu (DL/UL) interface is to be evaluated.  FL: Item seems reasonable to add the note for clarity.. |
| **FL** | For InF-DH, it seems at least three companies (vivo, Huawei, MTK) request adding InF-DH as baseline scenario. Hopefully, it can be accepted by other companies.  For Highway scenario, since it is optional scenario, and it is up to the company on whether to evaluate it. It seems fine to incude it, as long as we are clear that it is based on existing DL/UL PRS signals (or Uu interface signals.  So, we may consider the following changes:   * *Reuse the simulation assumptions of NR Rel-16/17 for carrier phase positioning*   + *Note: Optional modification of the simulation assumptions defined in NR Rel-16/17 are allowed only if needed.* * *The evaluation scenarios:*   + *Baseline: InF-SH, InF-DH*   + *Optional: IOO, Umi, Highway*     - *Note 1: Other evaluation scenarios are not precluded.*     - *Note 1: Existing Rel-17 DL/UL reference signals in Uu interface is to be used for the Highway scenario.* * *Frequency range:*    + *Baseline: FR1*   + *Optional: FR2* |

### (Closed) (Round 5) Proposal 13-1

* *Reuse the simulation assumptions of NR Rel-16/17 for carrier phase positioning*
  + *Note: Optional modification of the simulation assumptions defined in NR Rel-16/17 are allowed only if needed.*
* *The evaluation scenarios:*
  + *Baseline: InF-SH, InF-DH*
  + *Optional: IOO, Umi, Highway*
    - *Note 1: Other evaluation scenarios are not precluded.*
    - *Note 2: Existing Rel-17 DL/UL reference signals in Uu interface is to be used for the Highway scenario.*
* *Frequency range:* 
  + *Baseline: FR1*
  + *Optional: FR2*

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| **Company** | **comments** |
| Fraunhofer | Companies should report how the phase measurements are estimated and processed.  On the note in the first sub-bullet, we believe companies should be allowed to evaluate UE tracks for the carrier phase measurements evaluation.  FL: We have the agreement “NR carrier phase positioning performance will be evaluated at least with the carrier phase measurements of a single measurement instance.” It does not exclude company to simulate the tracking mode. |
| Samsung | OK |
| InterDigital | Ok |
| LGE | Although we are not sure about target use case of Highway scenario in DL/UL positioning, we can accept the proposal with the added note since it seems like companies have common understanding on that.  Minor comment:  *Note ~~1~~2: Existing Rel-17 DL/UL reference signals in Uu interface is to be used for the Highway scenario.*  FL: corrected. |

Proposal 13-2

* *In addition to the assumptions of NR Rel-16/17, the following error sources may also be considered during the evaluation:*
  + *Phase noise*
  + *CFO*
  + *Oscillator-drift*
* *Note: Other error sources are not precluded*

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| **Company** | **comments** |
| ZTE | If those are considered, we suggest to discuss the detailed error model to align models among companies.  FL: We may need to agree which error source to be considered, and then work on more details on the error model. |
| vivo | Phase error between UE and TRP should also be considered.  FL: Maybe we can include the timing errors. |
| Huawei, HiSilicon | We do not support adding phase noise.  FL: Maybe we can add FFS: Phase Error (FR2). If we agree focusing on FR1, then I share the similar view that phase noise may not need to be there.  I think that the gNB ARP error and even the PRU ARP error should be considered in the evaluation.  The proposal can be revised below.   * *In addition to the assumptions of NR Rel-16/17, the following error sources may also be considered during the evaluation:*   + *CFO*   + *Oscillator-drift*   + *gNB antenna reference point location error*   + *PRU antenna reference point location error* * *Note: Other error sources are not precluded* |
| Samsung | Maybe it’s simpler to define one general phase error model instead of multiple ones.  FL: It is unclear to me on what “one general phase error model” is. |
| Nokia/NSB | PCO should also be considered as an optional error source. |
| Ericsson | We are supportive of FL’s proposal. |
| CATT | Support |
| Apple | Agree with Samsung |
| LGE | As commented by ZTE, details on these error sources shall be discussed together. |
| InterDigital | Ok with the proposal |
| Locaila | We are supportive on this work, but need more clarification.  What’s the criteria for measurement of the factors? Why is this in 3GPP scope? What can be potential solutions ? |
| Intel | Support |
| Qualcomm | We agree with the proposal and the suggestion to add ARP location errors. In response to ZTE’s comment, a possible solution is to assume a simple model, analogous to the truncated-gaussian modeling of the timing-errors used in Rel-16/17 for timing-based positioning. Regarding phase noise, it should be considered for FR2 |
| **FL** | Based on the comments, maybe we can include FR2 for phase noise and add APR offset. |

(H) (Round 2) Proposal 13-2

* *In addition to the assumptions of NR Rel-16/17, the following error sources may also be considered during the evaluation:*
  + *Phase noise (FR2)*
  + *CFO*
  + *Oscillator-drift*
  + *gNB antenna reference point location error*
  + *PRU antenna reference point location error*
  + *Initial phase error on the UE side and TRP side*
* *Note: Other error sources are not precluded*

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| --- | --- |
| **Company** | **comments** |
| Huawei, HiSilicon | OK |
| Samsung | Don’t support  In legacy rel16/17, there could be multiple casues for the sych errors, yet RAN1 just defined a truncated gaussion model for simulation. Here we can assume similar work, we prefer not to dive into every detail of the phase error causes, but to use a general simuation model to check the impact of it.  FL: Does Samsung has a suggestion on what “a general simuation model” is? In this proposal, it say “the following error sources may also be considered,” It does not mean they have to be considered. Different from R16/R17, the targeting accuracy of carrier phase positioning is much higher than R16/R17. Thus, sonce error sources that can be ignored in R16/R17 evaluation may need to be considered in here. |
| ZTE | We are generally fine with FL's proposal. More details for error models should be further discussed. |
| LGE | Generally fine with updated version. |
| vivo | Based on the reply to us of FL in the 1st round, phase error can be included in timing error, so which is timing error here?  FL: I might misunderstand “phase error” in vivo’s previous comments. In my understanding, many factor can cause “phase error”, such as those listed in Proposal 13-2. So, I assume the “phase error” in vivo’s previous comments is something that is not included in the list, e.g., the initial phase offset in the received phase measurements caused by timing errors. Maybe vivo can be explain more specifically what the ““phase error” is vivo’s comments. |
| Nokia/NSB | If proposal 10-1 is also agreed then we are okay with this proposal. |
| InterDigital | Support |
| Intel | OK |
| Qualcomm | OK |
| CATT | Support |
| **FL** | It seems we may need a further discussion to see if the FL’s comments have address the comments, and then decide whether there is a need to further modifiy the proposal for the next rounf discussion. |
| **vivo 2** | Our mean is the initial phase error on the UE side and TRP side.  FL: Okay. Let us specifically add “initial phase error” for further comments. |
| **FL** | With the consideration of vivo’s comment, “*Initial phase error on the UE side and TRP side”* is added to (H) (Round 2) Proposal 13-2 for further discussion. |
| Ericsson | We agree with the proposal except for:  “PRU antenna reference point location error” --> “UE antenna reference point location error”  FL: To be more general, maybe we can use a more general term “antenna reference point location error of the transmitter and the receiver”. |
| Intel | Support the latest version. |
| InterDigital2 | Support the latest version from the FL |

### (Closed) (Round 3) Proposal 13-2

* *In addition to the assumptions of NR Rel-16/17, the following error sources may also be considered during the evaluation:*
  + *Phase noise (FR2)*
  + *CFO*
  + *Oscillator-drift*
  + *Transmitter/receiver antenna reference point location errors*
  + *Transmitter/receiver initial phase error*
* *Note: Other error sources are not precluded*

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| --- | --- |
| **Company** | **comments** |
| vivo | Support |
| Huawei, HiSilicon | OK |
| LGE | Ok |
| Samsung | Our intention is just to avoid the complicated modeling of each error source then adding much more workload in evaluation. Then maybe adding another note saying:  *Note2: one or more error sources in above might be modeled jointly during the evaluation.*  FL: The proposal is only for which error sources to be considered. How to model them can be discussed separately.  We would also like to add an addition source of error:   * + *UE location drift due to Mobility of the UE*   FL: It is unclear to me what “UE location drift” means. UE may move very fast (e.g., freeway) or or very slow. But, the motion of UE may not be counted as the error sources. |
| CATT | Ok |
| Intel | OK |
| MTK | ok |
| Ericsson | In place of the ‘UE location drift due to Mobility of the UE’, could we add ‘Doppler’ instead?  FL: Similar to UE motion, it seems to me that “Doppler”, which is caused by UE motion belong to evaluation condition instead of error sources in my view. |
| **FL** | Seem no revision is needed. Hopefully, FL’s response have addressed the comments. |
| Fraunhofer | Okay |
| Samsung | During a positioning measurement interval, if the UE is moving it would change it position from the start of the measurement interval to the end of the measurement and hence this will impact the measurement accuracy. Therefore, we would like to add:   * + *UE location drift due to Mobility of the UE during the measurement interval*   FL: Again, in my view this belong to the evaluation assumptions of UE moving speed in my view. For example, for *highway* scenario, which Samsung is interested in, one may assume UE moves at speed of 60km/hr, while for InF scenarios, one may assume UE moves speed is 3 km/hr. Then, the impact of UE motion will be evaluated. |

Proposal 13-3

* *NR carrier phase positioning performance can be evaluated for both single-shot positioning (without tracking the carrier phase over time) and with tracking the carrier phase.*

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| **Company** | **comments** |
| ZTE | We suggest to discuss the details, e.g. how to get the phase measurement based on the single-shot positioning in the simulation. And how to get the tracking phase in the simulation. Otherwise, it is hard to align companies’ assumptions. |
| Vivo | In this stage, may be too early to consider tracking the carrier phase |
| Huawei, HiSilicon | We prefer to prioritize single shot. The tracking of carrier phase requires enormous change of evaluation assumption. |
| Samsung | Intention of this proposal is not clear. If intention is to cover mobility, we suggest to reword as follows:  NR carrier phase positioning performance can be evaluated with stationary UEs and with UEs that are moving. |
| Nokia/NSB | We also prefer to prioritize single shot for now. |
| Ericsson | We want to prioritize single shot in Rel-18. Tracking should be excluded from rel-18 positioning evaluations. |
| CATT | We are fine to prioritize single shot in Rel-18. |
| Apple | Prioritize single shot for Rel-18 |
| NTT DOCOMO | Given that we need to evaluate performance gain of NR carrier phase measurement from the existing methods, single shot should be prioritized. |
| LGE | We tend to agree with other companies that it seems too early to determine it in this stage. |
| InterDigital | We are fine to prioritize single-shot positioning. |
| **FL** | *It seems most companies suggest focusing on single-shot, let us focusing single-shot case for now.*   * *NR carrier phase positioning performance will be evaluated at least for single-shot positioning (without tracking the carrier phase over time).* |
| Locaila | Request for clarification.  What’s the meaning of ‘single-sot’? Is it sampling moment of a symbol or a group of symbols? What’s the length of ‘carrier phase tracking’ ?.  *FL: single-shot here refers to the carrier phase measurements reported by single time instance. The measurement can be multiple OFDM symbols, depending on the PRS/SRS configuration. For the tracking case, it will depend on the need of the positioning in my view, which can be further discussed.* |
| Intel | We also prefer to focus on single-shot positioning. |
| Qualcomm | Agree with latest FL update proposal |

### (Closed) (Round 2) Proposal 13-3

* *NR carrier phase positioning performance will be evaluated at least with the carrier phase measurements of a single measurement instance.*

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| --- | --- |
| **Company** | **comments** |
| Huawei, HiSilicon | OK |
| Samsung | OK |
| Xiaomi | Ok |
| NTT DOCOMO | OK |
| ZTE | OK |
| LGE | Although our preference is to study further, but we are fine with the majority view. |
| Nokia/NSB | OK |
| InterDigital | Support |
| Intel | Support. |
| Qualcomm | Support |
| CATT | Support |
| FL | It seems the responses so far are all supportive. We may consider recommending it for email endorsement for the first check point of May 16. |

# Evaluation Results for Carrier Phase Positioning

## Background

***Submitted Proposals:***

* ***(Nokia,*** [***R1-2203178***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203178.zip)***[2])******Proposal*** *2: Capture the above simulation results in the TR.*
* ***(Nokia,*** [***R1-2203178***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203178.zip)***[2]) Proposal*** *3: RAN1 to conclude that carrier phase positioning can significantly improve the accuracy of the NR positioning.*

## 14.2 (Closed) Discussion

In FL’s view, how to capture the simulation results in the TR may be further discussed once we have reach the consensus on the evaluation scenarios and assumptions. Interested companies are invited to provide their views on when/how capture the simulation results in the TR.

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| **Company** | **comments** |
| Huawei, HiSilicon | Agree with FL’s view. |
| Nokia/NSB | We are okay with waiting until more consensus is reached. |
| LGE | We tend to agree with FL’s comment that it would be better to consider how to capture the simulation results after we make consensus on essential parts for the investigation. |
| Locaila | Support.  We will bring further field test and simulation results. |
| Qualcomm | Agree with FL’s view |

# Target Accuracy for Carrier Phase Positioning

## Background

With the enhancements of the carrier phase measurements, it is expected the target positioning accuracy will be increased in Rel-18. The following proposals were submitted from interested companies for this issue.

***Submitted Proposals:***

* ***(Huawei,*** [***R1-2203166***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2203166.zip)***[1]) Proposal 1:*** *Rel-18 shall target the accuracy requirement of 1cm@50% for positioning using carrier phase measurement.*
* ***(Lenovo,*** [***R1-2204561***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204561.zip)***[18])Proposal 1:*** *RAN1 to study and define the performance requirements carrier phase positioning in terms of horizontal and vertical accuracy requirements.*
* ***(Qualcomm,*** [***R1-2205040***](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2205040.zip)***[23]) Proposal 9:*** *A desired accuracy target for carrier phase positioning should be of the order of the carrier wavelength [e.g., 1cm for 30GHz, or 7.5cm for 4GHz], in presence of realistic sources of error in the carrier phase measurements.*

## 15.2 (Closed) Discussion

It is expected that the positioning accuracy will be significantly increased with the carrier phase measurements. The suggestions in [1][23] to define the target positioning accuracy to the order of cm-level seems reasonable. However, we could also wait for more evaluation results before defining the target positioning accuracy. Interested companies are invited to provide their views on when (e.g., this meeting) and how to define the target accuracy requirement of carrier phase positioning.

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| **Company** | **comments** |
| Huawei, HiSilicon | We think that the requirement should be set prior to obtaining the results, similar to Rel-16 and Rel-17.  The target can be revisited once the evaluation is available.  It is weird that the requirement is placed at the very end of the discussion, which motivates the study in the first place. |
| Samsung | Agree to wait for positioning results before setting tighter accuracy requirements. |
| Nokia/NSB | We are okay to open the discussion on requirements. |
| Ericsson | We prefer to wait a bit before defining requirements. |
| CATT | We are fine to wait for the next meeting to define the target requirements. |
| LGE | Agree with FL’s comment |
| InterDigital | Agree with the FL. |
| Locaila | We suggest to coordinate with current ongoing discussion on sidelink positioning requirements. |
| Qualcomm | We are ok to wait for more results. Note that unlike Rel-16/17, this time there are no explicit new requirements from SA1 towards which carrier-phase needs to be targeted before the study. But the potential of sub-centimeter accuracy is a compelling motivation all by itself, without the need to set an explicit target right at the beginning  There is no ‘others’ section to add comments, so adding this comment here: Just below the header on the first page of this document there is a text “***Joint reporting of POA and TOA for smoothing***” which looks like a typo and should be deleted. |

# Contact Information

This is the first meeting of Rel-18. The delegates who will works this Rel-18 feature are invited to provide their contract information on the following table.

|  |  |  |
| --- | --- | --- |
| **Company** | **Name** | **email** |
| CATT | Ren Da | [renda@catt.cn](mailto:renda@catt.cn) |
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| MTK | Harrison Chuang | harrison.chuang@mediatek.com |

# (Closed)Proposals for GTW Session

### (H)(Round 5) Proposal 4-1

* *For the purposes of discussion, for NR downlink and/or uplink carrier phase positioning, the carrier phase (CP) at a RF frequency at a receiver is a phase that is a function of the signal propagation time from an Tx antenna reference point of a transmitter (e.g., a TRP or a UE) to a Rx antenna reference point of the receiver (e.g., a UE or a TRP).*
  + *The propogation time can be expressed in a fractional part of a cycle of the RF frequency and a number of integer cycles, but the CP may be independent of the number of integer cycles.*

### (H)(Round 3) Proposal 5-1

* *The use of PRUs to facilitate NR carrier phase positioning will be studied in the SI.*

### (H) (Round 5) Proposal 8-1

* *The impact of antenna phase center error (e.g., phase center offset) on the carrier phase positioning accuracy can be studied during the SI.*
* *The potential solutions for minimizing the impact of antenna phase center error (e.g., phase center offset) can be studied, if it is considered to be necessary after the evaluation.*

### (H) (Round 5) Proposal 13-1

* *Reuse the simulation assumptions of NR Rel-16/17 for carrier phase positioning*
  + *Note: Optional modification of the simulation assumptions defined in NR Rel-16/17 are allowed only if needed.*
* *The evaluation scenarios:*
  + *Baseline: InF-SH, InF-DH*
  + *Optional: IOO, Umi, Highway*
    - *Note 1: Other evaluation scenarios are not precluded.*
    - *Note 2: Existing Rel-17 DL/UL reference signals in Uu interface is to be used for the Highway scenario.*
* *Frequency range:* 
  + *Baseline: FR1*
  + *Optional: FR2*

### (H) (Round 3) Proposal 13-2

* *In addition to the assumptions of NR Rel-16/17, the following error sources may also be considered during the evaluation:*
  + *Phase noise (FR2)*
  + *CFO*
  + *Oscillator-drift*
  + *Transmitter/receiver antenna reference point location errors*
  + *Transmitter/receiver initial phase error*
* *Note: Other error sources are not precluded*

# Some considerations for the next meeting

In this section, we are discussing some suggestions for the next meeting:

1. ***Reference Signals for Carrier Phase Measurements:***

For the RS used for Carrier Phase Measurements, it is assumed the basedline reference signals are the existing Rel-16 PRS/SRS signals. For RS configurations, similar to the cases of Rel-16 and Rel-17 studies, we may assume we do not define the baseline configurations. However, given that carriper phase positioning performance, similar to other positioning methods, is highly related to the reference signals and configurations used in the simulation, it is highly suggested that the sources provide the deltail information on the reference signals and configurations that are used for the evaluation.

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| **Company** | **comments** |
| MTK | If we would like to have the “sibcarrier” signal having continuous phase across symbols, we may apply ECP with comb-4. If it is to evaluate the phase of “a carrier”, we would like to try the following  1, NCP Comb-6 6 symbols  2, NCP Comb-6 12 symbols |
| Huawei, HiSilicon | We are not against reusing existing multiple symbol RS, but the phase measurement may vary from symbol to symbol if we consider Doppler/CFO. |
| CATT | To MTK: In our understand, thee continuity of the carrier phase (or the phase of the absolute carrier frequency, including absolute frequencies of the subcarriers) are not impacted by cyclic prefix. Thus, it is unclear why there is a need to apply ECP with comb-4. |
|  |  |
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1. ***Errro Modelling:***

In this meeting, we agreed to study the impact of a list of the error sources. However, it may not be practical for most companies to evaluate the impact of all of the error sources that were agreed to be investigated. In addition, we also don’t define the details of the error modelling of these error sources. Different assumptions of the errors and modelling may lead to quict different performance evaluation results. Thus, it is highly suggested that the sources provide the deltail information what error sources they have considred, why they are considred, what are the error models used, when presenting the evaluation results in the next meeting. Based on the inputs from the companies, we may further discuss whether we need to have the common (baseline) error models for the further evaluation.

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| --- | --- |
| **Company** | **comments** |
| MTK | 1, The total effect of Doppler and CFO due to crystal could use a single frequency offset value. We may try 100Hz, 200Hz, 300Hz (similar value for RAN4 evaluation)  2, to evaluate under a signal measurement instance, probably the oscillator drift could be omitted. The oscillator drift may result in the the changing frequency offset, which will have obvious impact when the time span of evaluation is longer  3, the initial phase at TX and RX could be randomly generated but being constant throughout the simulation  4, multipath is to follow 38.901 setting |
| Huawei, HiSilicon | We think that Dopper shift/CFO, initial phase and multi-path can be easiliy implemented with the existing channel model.  We think ARP error should be additionally modelled, but what is more important is to investigate under which baseline length a certain ARP error does not significantly affect the positioning accuracy with double difference methods. The baseline length is widely adopted in GNSS RTK so as to give a guideline on the coverage of a RTK station. |
| CATT | In our view, for the errors, that have the same imact for all carrier phase measurement (including CFO/time offset, etc.) should be cancelled out whe double differencial is used. The antenna phase center may not be cancelled out due to it have different impact fro different beam directions. We assume that may be one of the reasons that many papers discuss the calibration of the GNSS antenna phase center errors. |
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1. ***Methods in obtaining the carrier phase measurements:***

How to obtain the carrier phase measurements is obviously a key to support carrier phase positioning. However, to FL’s knowledge, most existing literature for obtaining carrier phase measurements are related to GNSS systems, which is signal carrier system with CDM type signals. NR is multicarrier system with OFDM signals. Thus, it may be very helpful if RAN1 could have some baseline implementation of the receiver for carrier phase measurements, so that we can have a good consistency during the evaluation and compatison of the evaluation results.

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| **Company** | **comments** |
| MTK | 1, We will at least try Huawei’s solution, to IDFT to time domain, the phas(due to fractional cycle) e within the identified first path could be treated as the phase of the carrier, or the phase of carrier + a SCS. It seems to us that when doing the IDFT, the DC carrier or DC+ a subcarrier may need to allocated as the first element of a vector collecting CFR for IDFT. It is like to perform fftshift on the CFR having DC at the center  2, for each subcarrier, we will see the desired phase as frequency x propagation time. We also want to try under the observation of multi-subcarriers in frequency domain, whether the propagation time ( = fractional cycle + number of integer cycles) could be measured well. Or, the measurement accuracy is still not good enough so that it can only be treated as a value of approaching number of integer cycles |
| Huawei, HiSilicon | One key principle to convert the CFR to CIR with the first path phase is to ensure that the CFR are symmetric around the DC component, so that the phase will not be distorted by the asymmetry of spectrum. |
| CATT | We assume more evaluation is need to see if and how to mitigate the multipath. As discussed in our paper R1-2203472, the impact of multipath can be limited to 0.25 wavelenth. So, the impact on accuracy may be limited to 1-2 wavelength if we do not consider the potential large initial positioning error caused by multipath to existing positioning methods. There is a dependency of the integer ambiguity resolutions on the initial positioning accuracy determined by other positioning methods. |
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1. ***Methods for NR carrier phase positioning***

Once the carrier phase measurements are obtained, many existing GNSS carrier phase positioning methods may be used to support NR carrier phase positioning. However, there could be still some unique advantages for supporting NR carrier phase positioning, since NR is multi-carrier system and have much stronger signals the GNSS. Thus, companies are encouraged to detail their proposals on how to take the advantages for NR system for supporting NR carrier phase positioning.

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| **Company** | **comments** |
| MTK | 1, the direction of trying to leverage the multicarrier property to enhance the measurement of carrier phase seems to deserve more investigation. |
| Huawei, HiSilicon | We are open to study multiple frequencies, but we do not consider coherent multiple carrier is needed, since this is somehow related to CA positioning. It means that different frequencies are supposed to have its individual initial phase.  On incoherent multipe frequencies, we should pay attention that the modeling of ARP difference for different frequencies at both UE and gNB. |
| CATT | Share the similar view as MTK and Huawei. We also don’t think coherent multiple carrier is needed. |
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1. ***Antenna Center Offset Modelling***

In the diecussion of Proposal 8-1, there is a comment from MTK on the modelling of the antenna phase cener offset.

If we assume antenna phase cener error is a combination of: a) the offset between mean mean position of electrical antenna phase center (MPC) and antenna reference point (APR), and b) the antenna phase center variations (PCV). If so, the following options may be considered:

* OP1: Only consider PCO, e.g., model it as a zero-mean and Gusisan 3D distribution;
* OP2: Only consider PCV, assume PCO is known or can be calibrated. In this case, PCV may be modelled as a zero-mean and Gusisan 3D distribution;
* OP3: Conside both PCO and PCV. Then, we may need to also model both of them. The the phase error is PCO+PCV.

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| **Company** | **comments** |
| MTK | 1, thanks CATT for providing this. Otherwise when each company has its own assumption, the results may be diverse  2, we may pick up OP2. The variance is FFS |
| Huawei, HiSilicon | We want to understand better the difference between PCO and ARP error.  The ARP error is something that we considered as a fixed error. For example, one may say that TRP location is (x,y,z) by using equipment to calibrate the coordinates, but there could be anyway some remaining unknown fixed error that is fixed.  The PCO, according to the discussion in Rel-17, is something that can be varying from one beam to another beam, or from one observation direction to another observation direction, which is somehow difficult to model.  We haven’t full find a map on the concept that we have in mind to the PCO/PCV concept here. |
| CATT | After reading a number of papers related to the calibration of GNSS antenna phase ceneter, it seems the error pattern depends not only or the GNSS signals angle and different antenna types.  <https://geodesy.noaa.gov/ANTCAL/FAQ.xhtml> 8) What is PCO? The initial phase center offset (PCO) for a particular frequency, given in north-east-up components relative to the antenna reference point (ARP). PCO is considered the average point of signal reception if the satellite signal direction is not taken into account. 9) What is PCV? Phase center variations (PCV) capture the component of an antenna calibration which depends upon the direction of the incoming signal. PCV may be provided as a function of elevation angle in the antenna frame (1D), or elevation and azimuth angle in antenna frame (2D). Like the PCO, the PCV is dependent upon the GNSS signal frequency. 10) What is a relative calibration? In a relative calibration, all antenna offsets ([**PCO**](https://geodesy.noaa.gov/ANTCAL/FAQ.xhtml#faq8)) and phase center variations ([**PCV**](https://geodesy.noaa.gov/ANTCAL/FAQ.xhtml#faq9)) are computed with respect to a reference antenna which is normally assigned zero PCV values. For [**NGS relative calibrations**](http://geodesy.noaa.gov/CORS/Articles/MaderGPS-Sol-1999.pdf), the reference antenna is the Dorne Margolin choke ring antenna, type T (AOAD/M\_T NONE). A relative calibration is therefore biased by the phase advance/delay experienced by the reference antenna. A file with NGS relative calibrations conducted to date are available on request, please contact ngs.antcal @ noaa.gov. 11) What is an absolute calibration? To conduct an [**absolute calibration**](http://geodesy.noaa.gov/CORS/Articles/Bilich-and-Mader_ION2010.pdf), the antenna being tested is moved via a robot so that a particular satellite is received at different angles by the test and reference antennas. This angular separation enables cancellation of the reference antenna effects, leaving behind only the antenna offsets ([**PCO**](https://geodesy.noaa.gov/ANTCAL/FAQ.xhtml#faq8)) and phase center variations ([**PCV**](https://geodesy.noaa.gov/ANTCAL/FAQ.xhtml#faq9)) of the test antenna.    The above Figure is from:  https://www.researchgate.net/publication/251989374 Towards modeling phase center variations for multi-frequency and multi-GNSS |
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