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 for improved accuracy based on NR carrier phase measurement**

**Agenda item: 9.5.2.2**

**Document for: Discussion and Decision**

***Joint reporting of POA and TOA for smoothing***

# 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.*

## (1st round) 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** |
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# 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 signaling 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.*

## (1st round) 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** |
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# 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.*
* ***(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.*

## (1st round) 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** |
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### 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** |
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### 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** |
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### 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** |
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# 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 (1st round) 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.*

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### 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.*

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# 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*

## (1st round) 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.*

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# 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.*
* ***(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*

## (1st round) 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.*

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# 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.*

## (1st round) 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.*

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# 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 (1st round) 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.*

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# 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 (1st round) 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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# 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 (1st round) 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** |
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# 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 (1st round) 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** |
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# Evaluation Assumptions for Carrier Phase Positioning

## 13.1 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 (1st round) 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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### 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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### 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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# Evaluation Results for Carrier Phase Positioning

## 14.1 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 (1st round) 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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# Target Accuracy for Carrier Phase Positioning

## 15.1 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 (1st round) 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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# 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 |
|  |  |  |
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# References

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