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| Technical Report | |
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# B.4 Evaluation results for NR carrier phase positioning

## B.4.1 Results from source [81]

### B.4.1.1 Description of evaluation scenarios

Evaluation scenarios, key technologies, and assumptions for performance analysis of NR carrier phase positioning in perfect scenarios are provided in Table B.4.1.1-1.

Evaluation scenarios, key technologies, and assumptions for performance analysis of NR carrier phase positioning with the TRP ARP error are provided in Table B.4.1.1-2.

Evaluation scenarios, key technologies, and assumptions for performance analysis of NR carrier phase positioning with the CFO and Oscillator-drift are provided in Table B.4.1.1-3.

Evaluation scenarios, key technologies, and assumptions for performance analysis of NR carrier phase positioning with the PCO are provided in Table B.4.1.1-4.

Evaluation scenarios, key technologies, and assumptions for performance analysis of NR carrier phase positioning with the initial phase offset are provided in Table B.4.1.1-5.

Evaluation scenarios, key technologies, and assumptions for performance analysis of NR carrier phase positioning with the TRP ARP error, frequency error, PCO, and initial phase offset are provided in Table B.4.1.1-6.

Figure B.4.1.1 presents the PRU setting in all double differential evaluation cases in Section B.4.1 (Note: For the positioning of a target UE, only a single PRU with LOS to TRPs was selected for double differential operation). The value of D, W and L in InF-SH and InF-DH scenarios are given by TR 38.901.



Figure B.4.1.1: PRU setting for double differential operation

Table B.4.1.1-1: NR carrier phase positioning enhancements - evaluation scenarios and parameters in perfect scenarios from [81]

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Parameter | [Case 1], [InF-SH] | [Case 2], [InF-SH] | [Case 3], [InF-SH] | [Case 4], [InF-SH] | [Case 5], [InF-SH] | [Case 6], [InF-DH] | [Case 7], [InF-DH] | [Case 8], [InF-DH] | [Case 9], [InF-DH] |
| Scenario  [TR 38.855, TR 38.857] | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 |
| Single carrier frequency, or multiple carrier frequencies, GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  2.6 GHz | Multiple, 3.45/3.55 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Multiple, 3.45/3.55 GHz |
| Bandwidth, MHz | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Subcarrier spacing, kHz | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | PRS  Comb-6 | PRS  Comb-6 | PRS  Comb-6 | PRS  Comb-6 | PRS  Comb-6 | PRS  Comb-6 | PRS  Comb-6 | PRS  Comb-6 | PRS  Comb-6 |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | None | DL-CPP | DL-CPP | DL-CPP | DL-CPP | DL-CPP | DL-CPP | DL-CPP | DL-CPP |
| R16/R17 positioning method  (if it is used together with CPP) | DL-TDOA | DL-TDOA | DL-TDOA | DL-TDOA | DL-TDOA | DL-TDOA | DL-TDOA | DL-TDOA | DL-TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | None | freq-domain | freq-domain | freq-domain | freq-domain | freq-domain | freq-domain | freq-domain | freq-domain |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | double differential | None | double differential | double differential | double differential | double differential | None | double differential | double differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | None | Integer least squares and cost functions | Integer least squares and cost functions | virtual Integer ambiguity | virtual Integer ambiguity | None | Integer least squares and cost functions | Integer least squares and cost functions | virtual Integer ambiguity |
| Multipath mitigation techniques  (e.g., first path detection, ...) | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement | Single-measurement | Single-measurement | Single-measurement | Single-measurement | Single-measurement | Single-measurement | Single-measurement | Single-measurement |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Chan and Least squares | Chan and Least squares | Chan and Least squares | Chan and Least squares | Chan and Least squares | Chan and Least squares | Chan and Least squares | Chan and Least squares | Chan and Least squares |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns |
| UE/TRP Initial phase offset | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CFO/Doppler | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Oscillator-drifts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ARP errors | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Phase Center Offsets | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Phase noise (FR2) | None | None | None | None | None | None | None | None | None |
| PRU assumptions and additional notes, if any | Four PRUs with LOS channel | None | Four PRUs with LOS channel | Four PRUs with LOS channel | Four PRUs with LOS channel | Four PRUs with LOS channel | None | Four PRUs with LOS channel | Four PRUs with LOS channel |

Table B.4.1.1-2: NR carrier phase positioning enhancements - evaluation scenarios and parameters with the TRP ARP error from [81]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Parameter | [Case 10], [InF-SH] | [Case 11], [InF-SH] | [Case 12], [InF-SH] | [Case 13], [InF-SH] | [Case 14], [InF-SH] | [Case 15], [InF-SH] | [Case 16], [InF-DH] | [Case 17], [InF-DH] |
| Scenario  [TS 38.855, TS 38.857] | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 |
| Single carrier frequency, or multiple carrier frequencies, GHz | Single  3.5 GHz | Single  3.5 GHz | Single  2.6 GHz | Multiple, 3.45/3.55 GHz | Single  3.5 GHz | Multiple, 3.45/3.55 GHz | Single  3.5 GHz | Multiple, 3.45/3.55 GHz |
| Bandwidth, MHz | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Subcarrier spacing, kHz | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | PRS  Comb-6 | PRS  Comb-6 | PRS  Comb-6 | PRS  Comb-6 | PRS  Comb-6 | PRS  Comb-6 | PRS  Comb-6 | PRS  Comb-6 |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | None | DL-CPP | DL-CPP | DL-CPP | None | DL-CPP | None | DL-CPP |
| R16/R17 positioning method  (if it is used together with CPP) | DL-TDOA | DL-TDOA | DL-TDOA | DL-TDOA | DL-TDOA | DL-TDOA | DL-TDOA | DL-TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | None | freq-domain | freq-domain | freq-domain | None | freq-domain | None | freq-domain |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | double differential | double differential | double differential | double differential | double differential | double differential | double differential | double differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | None | Integer least squares and cost functions | virtual Integer ambiguity | virtual Integer ambiguity | None | virtual Integer ambiguity | None | virtual Integer ambiguity |
| Multipath mitigation techniques  (e.g., first path detection, ...) | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement | Single-measurement | Single-measurement | Single-measurement | Single-measurement | Single-measurement | Single-measurement | Single-measurement |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Chan and Least squares | Chan and Least squares | Chan and Least squares | Chan and Least squares | Chan and Least squares | Chan and Least squares | Chan and Least squares | Chan and Least squares |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns |
| UE/TRP Initial phase offset | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CFO/Doppler | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Oscillator-drifts* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ARP errors | 1cm | 1cm | 1cm | 1cm | 5cm | 5cm | 1cm | 1cm |
| Phase Center Offsets | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Phase noise (FR2) | None | None | None | None | None | None | None | None |
| Additional notes, if any | Four PRUs with LOS channel | Four PRUs with LOS channel | Four PRUs with LOS channel | Four PRUs with LOS channel | Four PRUs with LOS channel | Four PRUs with LOS channel | Four PRUs with LOS channel | Four PRUs with LOS channel |

Table B.4.1.1-3: NR carrier phase positioning enhancements - evaluation scenarios and parameters with the CFO and Oscillator-drift from [81]

|  |  |  |
| --- | --- | --- |
| **Parameter** | **[Case 18], [InF-SH]** | **[Case 19], [InF-DH]** |
| Scenario  [TS 38.855, TS 38.857] | 38.857 | 38.857 |
| Single carrier frequency, or multiple carrier frequencies, GHz | Single  3.5 GHz | Single  3.5 GHz |
| Bandwidth, MHz | 100 | 100 |
| Subcarrier spacing, kHz | 30 | 30 |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | PRS  Comb-6 | PRS  Comb-6 |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | DL-CPP | DL-CPP |
| R16/R17 positioning method  (if it is used together with CPP) | DL-TDOA | DL-TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | freq-domain | freq-domain |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | double differential | double differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | Integer least squares and cost functions | Integer least squares and cost functions |
| Multipath mitigation techniques  (e.g., first path detection, ...) | first path detection | first path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement | Single-measurement |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Chan and Least squares | Chan and Least squares |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0ns | 0ns |
| UE/TRP Initial phase offset | 0 | 0 |
| CFO/Doppler | [-100, +100] Hz for UE;  [-10, +10] Hz for TRP | [-100, +100] Hz for UE;  [-10, +10] Hz for TRP |
| *Oscillator-drifts* | [-0.1, 0.1] ppm for UE, [-0.02, +0.02] ppm for TRP | [-0.1, 0.1] ppm for UE, [-0.02, +0.02] ppm for TRP |
| ARP errors | 0 | 0 |
| Phase Center Offsets | 0 | 0 |
| Phase noise (FR2) | None | None |
| Additional notes, if any | Four PRUs with LOS channel | Four PRUs with LOS channel |

Table B.4.1.1-4: NR carrier phase positioning enhancements - evaluation scenarios and parameters with the PCO from [81]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **[Case 20], [InF-SH]** | **[Case 21], [InF-SH]** | **[Case 22], [InF-DH]** | **[Case 23], [InF-DH]** |
| Scenario  [TS 38.855, TS 38.857] | 38.857 | 38.857 | 38.857 | 38.857 |
| Single carrier frequency, or multiple carrier frequencies, GHz | Multiple, 3.45/3.55 GHz | Multiple, 3.45/3.55 GHz | Multiple, 3.45/3.55 GHz | Multiple, 3.45/3.55 GHz |
| Bandwidth, MHz | 100 | 100 | 100 | 100 |
| Subcarrier spacing, kHz | 30 | 30 | 30 | 30 |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | PRS  Comb-6 | PRS  Comb-6 | PRS  Comb-6 | PRS  Comb-6 |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | DL-CPP | DL-CPP | DL-CPP | DL-CPP |
| R16/R17 positioning method  (if it is used together with CPP) | DL-TDOA | DL-TDOA | DL-TDOA | DL-TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | freq-domain | freq-domain | freq-domain | freq-domain |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | double differential | double differential | double differential | double differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | virtual Integer ambiguity | virtual Integer ambiguity | virtual Integer ambiguity | virtual Integer ambiguity |
| Multipath mitigation techniques  (e.g., first path detection, ...) | first path detection | first path detection | first path detection | first path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement | Single-measurement | Single-measurement | Single-measurement |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Chan and Least squares | Chan and Least squares | Chan and Least squares | Chan and Least squares |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0ns | 0ns | 0ns | 0ns |
| UE/TRP Initial phase offset | 0 | 0 | 0 | 0 |
| CFO/Doppler | 0 | 0 | 0 | 0 |
| *Oscillator-drifts* | 0 | 0 | 0 | 0 |
| ARP errors | 0 | 0 | 0 | 0 |
| Phase Center Offsets | dPhi in example 1  a=3, w=[-5deg, 5deg] | dPhi in example 1  a=3, w=[-10deg, 10deg] | dPhi in example 1  a=3, w=[-5deg, 5deg] | dPhi in example 1  a=3, w=[-10deg, 10deg] |
| Phase noise (FR2) | None | None | None | None |
| Additional notes, if any | Four PRUs with LOS channel | Four PRUs with LOS channel | Four PRUs with LOS channel | Four PRUs with LOS channel |

Table B.4.1.1-5: NR carrier phase positioning enhancements - evaluation scenarios and parameters with the initial phase offset from [81]

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **[Case 24], [InF-SH]** | **[Case 25], [InF-SH]** | **[Case 26], [InF-DH]** |
| Scenario  [TS 38.855, TS 38.857] | 38.857 | 38.857 | 38.857 |
| Single carrier frequency, or multiple carrier frequencies, GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz |
| Bandwidth, MHz | 100 | 100 | 100 |
| Subcarrier spacing, kHz | 30 | 30 | 30 |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | PRS  Comb-6 | PRS  Comb-6 | PRS  Comb-6 |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | DL-CPP | DL-CPP | DL-CPP |
| R16/R17 positioning method  (if it is used together with CPP) | DL-TDOA | DL-TDOA | DL-TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | freq-domain | freq-domain | freq-domain |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | single differential | double differential | double differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions |
| Multipath mitigation techniques  (e.g., first path detection, ...) | first path detection | first path detection | first path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement | Single-measurement | Single-measurement |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Chan and Least squares | Chan and Least squares | Chan and Least squares |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0ns | 0ns | 0ns |
| UE/TRP Initial phase offset | UE and TRP Initial phase offset | UE and TRP Initial phase offset | UE and TRP Initial phase offset |
| CFO/Doppler | 0 | 0 | 0 |
| *Oscillator-drifts* | 0 | 0 | 0 |
| ARP errors | 0 | 0 | 0 |
| Phase Center Offsets | 0 | 0 | 0 |
| Phase noise (FR2) | None | None | None |
| Additional notes, if any | Four PRUs with LOS channel | Four PRUs with LOS channel | Four PRUs with LOS channel |

Table B.4.1.1-6: NR carrier phase positioning enhancements - evaluation scenarios and parameters with TRP ARP error, frequency error, PCO, and initial phase offset from [81]

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **[Case 27], [InF-SH]** | **[Case 28], [InF-SH]** | **[Case 29], [InF-DH]** |
| Scenario  [TS 38.855, TS 38.857] | 38.857 | 38.857 | 38.857 |
| Single carrier frequency, or multiple carrier frequencies, GHz | Single, 2.6 GHz | Multiple, 3.45/3.55 GHz | Multiple, 3.45/3.55 GHz |
| Bandwidth, MHz | 100 | 100 | 100 |
| Subcarrier spacing, kHz | 30 | 30 | 30 |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | PRS  Comb-6 | PRS  Comb-6 | PRS  Comb-6 |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | DL-CPP | DL-CPP | DL-CPP |
| R16/R17 positioning method  (if it is used together with CPP) | DL-TDOA | DL-TDOA | DL-TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | freq-domain | freq-domain | freq-domain |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | double differential | double differential | double differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | virtual Integer ambiguity | virtual Integer ambiguity | virtual Integer ambiguity |
| Multipath mitigation techniques  (e.g., first path detection, ...) | first path detection | first path detection | first path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement | Single-measurement | Single-measurement |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Chan and Least squares | Chan and Least squares | Chan and Least squares |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0ns | 0ns | 0ns |
| UE/TRP Initial phase offset | UE and TRP Initial phase offset | UE and TRP Initial phase offset | UE and TRP Initial phase offset |
| CFO/Doppler | [-100, +100] Hz for UE;  [-10, +10] Hz for TRP | [-100, +100] Hz for UE;  [-10, +10] Hz for TRP | [-100, +100] Hz for UE;  [-10, +10] Hz for TRP |
| *Oscillator-drifts* | [-0.1, 0.1] ppm for UE, [-0.02, +0.02] ppm for TRP | [-0.1, 0.1] ppm for UE, [-0.02, +0.02] ppm for TRP | [-0.1, 0.1] ppm for UE, [-0.02, +0.02] ppm for TRP |
| ARP errors | 1cm | 1cm | 1cm |
| Phase Center Offsets | dPhi in example 1  a=3, w=[-5deg, 5deg] | dPhi in example 1  a=3, w=[-5deg, 5deg] | dPhi in example 1  a=3, w=[-5deg, 5deg] |
| Phase noise (FR2) | None | None | None |
| Additional notes, if any | Four PRUs with LOS channel | Four PRUs with LOS channel | Four PRUs with LOS channel |

### B.4.1.2 Positioning accuracy evaluation results for NR Carrier Phase Positioning

Table B.4.1.2-1 provides horizontal positioning accuracy results using NR carrier phase positioning in perfect scenarios.

Table B.4.1.2-2 provides horizontal positioning accuracy results using NR carrier phase positioning with the TRP ARP error.

Table B.4.1.2-3 provides horizontal positioning accuracy results using NR carrier phase positioning with the CFO and Oscillator-drift.

Table B.4.1.2-4 provides horizontal positioning accuracy results using NR carrier phase positioning with the PCO.

Table B.4.1.2-5 provides horizontal positioning accuracy results using NR carrier phase positioning with the initial phase offset.

Table B.4.1.2-6 provides horizontal positioning accuracy results using NR carrier phase positioning with the TRP ARP error, frequency error, PCO, and initial phase offset.

Table B.4.1.2-1: NR carrier phase positioning - horizontal accuracy in perfect scenarios from [81]

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **[Case ID], [Scenario] [additional descriptions]** | **50%** | **67%** | **80%** | **90%** | **Met 1cm accuracy @ 50%-ile or 80%-ile of the UEs?**  **(Yes/No)** | | **Additional comments** |
| **[X=1] cm**  **@50%** | **[Y=1] cm**  **@80%** |
| Case 1, InF-SH,  Single-carrier, 100MHz, DD DL-TDOA | 0.072 | 0.102 | 0.117 | 0.127 | No | No |  |
| Case 2, InF-SH,  Single-freq, 100MHz, DL-CPP | 0.002 | 0.003 | 0.004 | 0.012 | Yes | Yes |  |
| Case 3, InF-SH,  Single-freq, 100MHz, Double differential (DD) DL-CPP | 0.003 | 0.004 | 0.007 | 0.090 | Yes | Yes |  |
| Case 4, InF-SH,  Single-freq (carrier phases of 2 subcarriers within one PFL), 100MHz, DD DL-CPP | 0.004 | 0.005 | 0.008 | 0.012 | Yes | No |  |
| Case 5, InF-SH  Two-freq, 100MHz, DD DL-CPP. | 0.003 | 0.004 | 0.005 | 0.007 | Yes | Yes |  |
| Case 6, InF-DH,  Single-carrier, 100MHz, DD DL-TDOA | 0.083 | 0.113 | 0.123 | 0.192 | No | No |  |
| Case 7, InF-DH,  Single-freq, 100MHz, DL-CPP | 0.006 | 0.020 | 0.030 | 0.096 | Yes | No |  |
| Case 8, InF-DH,  Single-freq, 100MHz, DD DL-CPP | 0.046 | 0.095 | 0.148 | 0.217 | No | No |  |
| Case 9, InF-DH  Two-freq, 100MHz, DD DL-CPP | 0.010 | 0.019 | 0.027 | 0.034 | Yes | No |  |

Table B.4.1.2-2: NR carrier phase positioning - horizontal accuracy with the TRP ARP error from [81]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **[Case ID], [Scenario] [additional descriptions]** | **50%** | **67%** | **80%** | **90%** | **Met 1cm accuracy @ 50%-ile or 80%-ile of the UEs?**  **(Yes/No)** | | | **Additional comments** |
| **[X=1cm]**  **@50%** | **[Y=1cm]**  **@80%** | |
| Case 10, InF-SH  Single-carrier, 100MHz, ARP error 1cm, DD DL-TDOA | 0.085 | 0.105 | 0.121 | 0.154 | No | | No |  |
| Case 11, InF-SH  Single-freq, 100MHz, ARP error 1cm, DD DL-CPP | 0.009 | 0.091 | 0.112 | 0.182 | Yes | | No |  |
| Case 12, InF-SH  Single-freq (carrier phases of 2 subcarriers within a single PFL), 100MHz, ARP error 1 cm, DD DL-CPP | 0.008 | 0.015 | 0.019 | 0.026 | Yes | | No |  |
| Case 13, InF-SH  Two-freq, 100MHz, ARP error 1 cm, DD DL-CPP | 0.007 | 0.010 | 0.013 | 0.018 | Yes | | No |  |
| Case 14, InF-SH  Single- carrier, 100MHz, ARP error 5 cm, DD DL-TDOA | 0.088 | 0.105 | 0.139 | 0.163 | No | | No |  |
| Case 15, InF-SH  Two-freq, 100MHz, ARP error 5 cm, DD DL-CPP | 0.033 | 0.046 | 0.056 | 0.069 | No | | No |  |
| Case 16, InF-DH  Single- carrier, 100MHz, ARP error 1cm, DD DL-TDOA | 0.091 | 0.116 | 0.143 | 0.189 | No | | No |  |
| Case 17, InF-DH  Two-freq, 100MHz, ARP error 1 cm, DD DL-CPP | 0.015 | 0.022 | 0.033 | 0.053 | No | | No |  |

Table B.4.1.2-3: NR carrier phase positioning - horizontal accuracy with the CFO and Oscillator-drift from [81]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **[Case ID], [Scenario] [additional descriptions]** | **50%** | **67%** | **80%** | **90%** | **Met 1cm accuracy @ 50%-ile or 80%-ile of the UEs?**  **(Yes/No)** | | | **Additional comments** |
| **[X=1cm]**  **@50%** | **[Y=1cm]**  **@80%** | |
| Case 18, InF-SH  Single-freq, 100MHz, DD DL-CPP;  CFO TRP10Hz and UE100Hz, Oscillator-drift TRP 0.02ppm, UE 0.1ppm, 6 OFDM symbol of a DL-PRS resource | 0.003 | 0.004 | 0.007 | 0.090 | Yes | | Yes |  |
| Case 19, InF-DH,  Single-freq, 100MHz, DD DL-CPP;  CFO TRP10Hz and UE100Hz, Oscillator-drift TRP 0.02ppm, UE 0.1ppm, 6 OFDM symbol of a DL-PRS resource | 0.046 | 0.095 | 0.148 | 0.217 | No | | No |  |

Table B.4.1.2-4: NR carrier phase positioning - horizontal accuracy with the PCO from [81]

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **[Case ID], [Scenario] [additional descriptions]** | **50%** | **67%** | **80%** | **90%** | **Met 1cm accuracy @ 50%-ile or 80%-ile of the UEs?**  **(Yes/No)** | | **Additional comments** |
| **[X=1cm]**  **@50%** | **[Y=1cm]**  **@80%** |
| Case 20, InF-SH,  Two-freq, 100MHz, DD DL-CPP; PCO, dPhi in Example 1; a=3, w=[-5deg, 5deg] | 0.004 | 0.005 | 0.006 | 0.009 | Yes | Yes |  |
| Case 21, InF-SH,  Two-freq, 100MHz, DD DL-CPP; PCO, dPhi in Example 1; a=3, w=[-10deg, 10deg] | 0.004 | 0.005 | 0.007 | 0.010 | Yes | Yes |  |
| Case 22, InF-DH,  Two-freq, 100MHz, DD DL-CPP; PCO, dPhi in Example 1; a=3, w=[-5deg, 5deg] | 0.010 | 0.020 | 0.027 | 0.035 | Yes | No |  |
| Case 23, InF-DH,  Two-freq, 100MHz, DD DL-CPP; PCO, dPhi in Example 1; a=3, w=[-10deg, 10deg] | 0.013 | 0.020 | 0.028 | 0.044 | No | No |  |

Table B.4.1.2-5: NR carrier phase positioning - horizontal accuracy with the initial phase offset from [81]

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **[Case ID], [Scenario] [additional descriptions]** | **50%** | **67%** | **80%** | **90%** | **Met 1cm accuracy @ 50%-ile or 80%-ile of the UEs?**  **(Yes/No)** | | **Additional comments** |
| **[X=1cm]**  **@50%** | **[Y=1]cm**  **@80%** |
| Case 24, InF-SH  Single-freq, 100MHz, SD DL-CPP | 0.068 | 0.100 | 0.128 | 0.151 | No | No |  |
| Case 25, InF-SH  Single-freq, 100MHz, DD DL-CPP | 0.002 | 0.003 | 0.004 | 0.012 | Yes | Yes |  |
| Case 26, InF-DH  Single-freq, 100MHz, DD DL-CPP | 0.046 | 0.095 | 0.148 | 0.217 | No | No |  |

Table B.4.1.2-6: NR carrier phase positioning - horizontal accuracy with the TRP ARP error, frequency error, PCO, and initial phase offset from [81]

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **[Case ID], [Scenario], [additional descriptions]** | **50%** | **67%** | **80%** | **90%** | **Met 1cm accuracy @ 50%-ile or 80%-ile of the UEs?**  **(Yes/No)** | | **Additional comments** |
| **[X=1cm]**  **@50%** | **[Y=1]cm**  **@80%** |
| Case 27, InF-SH, Single-freq (carrier phases of 2 subcarriers within a single PFL), 100MHz, DD DL-CPP,  ARP error 1cm; CFO TRP10Hz and UE100Hz, Oscillator-drift TRP 0.02ppm and UE 0.1ppm,6 OFDM symbol;  PCO, dPhi in example 1, a=3, w=[-5deg, 5deg];  Random initial phase | 0.009 | 0.019 | 0.020 | 0.029 | Yes | No |  |
| Case 28, InF-SH, Two-freq, 100MHz, DD DL-CPP,  ARP error 1cm; CFO TRP10Hz and UE100Hz, Oscillator-drift TRP 0.02ppm and UE 0.1ppm,6 OFDM symbol;  PCO, dPhi in example 1, a=3, w=[-5deg, 5deg];  Random initial phase | 0.008 | 0.012 | 0.017 | 0.023 | Yes | No |  |
| Case 29, InF-DH, Two-freq, 100MHz, DD DL-CPP,  ARP error 1cm; CFO TRP 10Hz and UE 100Hz, Oscillator-drift TRP 0.02ppm and UE 0.1ppm,6 OFDM symbol;  PCO, dPhi in example 1, a=3, w=[-5deg, 5deg];  Random initial phase | 0.016 | 0.024 | 0.035 | 0.058 | No | No |  |

## B.4.2 Results from source [80]

### B.4.2.1 Description of evaluation scenarios

Evaluation scenarios, key techniques, and assumptions for performance analysis of NR carrier phase measurement are provided in Table B.4.2.1-1

Evaluation scenarios, key techniques, and assumptions for performance analysis of NR carrier phase positioning without error modeling are provided in Table B.4.2.1-2

Evaluation scenarios, key techniques, and assumptions for performance analysis of NR carrier phase positioning with different error modeling are provided in Table B.4.2.1-3~ B.4.2.1-4

Evaluation scenarios, key techniques, and assumptions for performance analysis of NR carrier phase positioning with multiple carriers measurement are provided in Table B.4.2.1-5

Table B.4.2.1-1: NR carrier phase measurement - evaluation scenarios and parameters from [80]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **[Case 001], [InF-SH]** | **[Case 002], [InF-DH]** | **[Case 003], [InF-SH]** | **[Case 004], [InF-DH]** | **[Case 005], [InF-SH]** | **[Case 006], [InF-DH]** |
| Channel model  [TS 38.855, TS 38.857] | TS 38.857 | TS 38.857 | TS 38.857 | TS 38.857 | TS 38.857 | TS 38.857 |
| Carrier frequency, or Multiple carrier frequencies, GHz | 3.5G | 3.5G | 3.5G | 3.5G | 3.5G | 3.5G |
| Bandwidth, MHz | 100M | 100M | 100M | 100M | 100M | 100M |
| Subcarrier spacing, kHz | 30KHZ | 30KHZ | 30KHZ | 30KHZ | 30KHZ | 30KHZ |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | PRS  1 Sample  (comb-6 frequency structure, 6 symbols within a slot | PRS  1 Sample  (comb-6 frequency structure, 6 symbols within a slot | PRS  1 Sample  (comb-6 frequency structure, 6 symbols within a slot | PRS  1 Sample  (comb-6 frequency structure, 6 symbols within a slot | PRS  1 Sample  (comb-6 frequency structure, 6 symbols within a slot | PRS  1 Sample  (comb-6 frequency structure, 6 symbols within a slot |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | DL | DL | DL | DL | DL | DL |
| R16/R17 positioning method  (if it is used together with CPP) | DL-TDOA | DL-TDOA | DL-TDOA | DL-TDOA | DL-TDOA | DL-TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | freq-domain | freq-domain | time-domain | time -domain | freq-domain | freq-domain |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | single differential | single differential | single differential | single differential | single differential | single differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions,…) | / | / | / | / | / | / |
| Multipath mitigation techniques  (e.g., first path detection, ...) | / | / | first path detection | first path detection | first path detection | first path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement instance | Single-measurement instance | Single-measurement instance | Single-measurement instance | Single-measurement instance | Single-measurement instance |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | / | / | / | / | / | / |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns |
| UE/TRP Initial phase offset | / | / | / | / | / | / |
| CFO/Doppler | / | / | / | / | / | / |
| Oscillator-drifts | / | / | / | / | / | / |
| ARP errors | / | / | / | / | / | / |
| Phase Center Offsets | / | / | / | / | / | / |
| Phase noise (FR2) | / | / | / | / | / | / |
| Additional notes, if any | / | / | / | / | / | / |

Table B.4.2.1-2: NR carrier phase positioning enhancements without error modeling- evaluation scenarios and parameters from [80]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **[Case 101], [InF-SH]** | **[Case 102], [InF-SH]** | **[Case 201], [InF-DH]** | **[Case 202], [InF-DH]** |
| Channel model  [TS 38.855, TS 38.857] | TS 38.857 | TS 38.857 | TS 38.857 | TS 38.857 |
| Carrier frequency, or Multiple carrier frequencies, GHz | 3.5G | 3.5G | 3.5G | 3.5G |
| Bandwidth, MHz | 100M | 100M | 100M | 100M |
| Subcarrier spacing, kHz | 30KHZ | 30KHZ | 30KHZ | 30KHZ |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | PRS  1 Sample  (comb-6 frequency structure, 6 symbols within a slot | PRS  1 Sample  (comb-6 frequency structure, 6 symbols within a slot | PRS  1 Sample  (comb-6 frequency structure, 6 symbols within a slot | PRS  1 Sample  (comb-6 frequency structure, 6 symbols within a slot |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | DL | DL | DL | DL |
| R16/R17 positioning method  (if it is used together with CPP) | DL-TDOA | DL-TDOA | DL-TDOA | DL-TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | freq-domain | freq-domain | freq-domain | freq-domain |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | single differential | single differential | single differential | single differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions,…) | Ideal integer cycle | cost functions | Ideal integer cycle | cost functions |
| Multipath mitigation techniques  (e.g., first path detection, ...) | first path detection | first path detection | first path detection | first path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement instance | Single-measurement instance | Single-measurement instance | Single-measurement instance |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Taylor series | Taylor series | Taylor series | Taylor series |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0ns | 0ns | 0ns | 0ns |
| UE/TRP Initial phase offset | / | / | / | / |
| CFO/Doppler | / | / | / | / |
| Oscillator-drifts | / | / | / | / |
| ARP errors | / | / | / | / |
| Phase Center Offsets | / | / | / | / |
| Phase noise (FR2) | / | / | / | / |
| Additional notes, if any | / | / | / | / |

Table B.4.2.1-3: NR carrier phase positioning enhancements with error modeling - evaluation scenarios and parameters from [80]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **[Case 301], [InF-SH]** | **[Case 302], [InF-SH]** | **[Case 401], [InF-SH]** | **[Case 402], [InF-SH]** |
| Channel model  [TS 38.855, TS 38.857] | TS 38.857 | TS 38.857 | TS 38.857 | TS 38.857 |
| Carrier frequency, or Multiple carrier frequencies, GHz | 3.5G | 3.5G | 3.5G | 3.5G |
| Bandwidth, MHz | 100M | 100M | 100M | 100M |
| Subcarrier spacing, kHz | 30KHZ | 30KHZ | 30KHZ | 30KHZ |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | PRS  1 Sample  (comb-6 frequency structure, 6 symbols within a slot | PRS  1 Sample  (comb-6 frequency structure, 6 symbols within a slot | PRS  1 Sample  (comb-6 frequency structure, 6 symbols within a slot | PRS  1 Sample  (comb-6 frequency structure, 6 symbols within a slot |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | DL | DL | DL | DL |
| R16/R17 positioning method  (if it is used together with CPP) | DL-TDOA | DL-TDOA | DL-TDOA | DL-TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | freq-domain | freq-domain | freq-domain | freq-domain |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | single differential | single differential | single differential | single differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions,…) | cost functions | cost functions | cost functions | cost functions |
| Multipath mitigation techniques  (e.g., first path detection, ...) | first path detection | first path detection | first path detection | first path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement instance | Single-measurement instance | Single-measurement instance | Single-measurement instance |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Taylor series | Taylor series | Taylor series | Taylor series |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0ns | 0ns | 0ns | 0ns |
| UE/TRP Initial phase offset | / | / | / | [0，2pi] |
| CFO/Doppler | UE residual CFO 30 HZ  TRP residual CFO 10 HZ | UE residual CFO 100 HZ  TRP residual CFO 10 HZ | / | / |
| Oscillator-drifts | / | / | / | / |
| ARP errors | / | / | T1=1cm | T1=5cm |
| Phase Center Offsets | / | / | / | / |
| Phase noise (FR2) | / | / | / | / |
| Additional notes, if any | / | / | / | / |

Table B.4.2.1-4: NR carrier phase positioning enhancements with error modeling - evaluation scenarios and parameters from [80]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **[Case 501], [InF-SH]** | **[Case 502], [InF-SH]** | **[Case 503], [InF-SH]** | **[Case 601], [InF-SH]** |
| Channel model  [TS 38.855, TS 38.857] | TS 38.857 | TS 38.857 | TS 38.857 | TS 38.857 |
| Carrier frequency, or Multiple carrier frequencies, GHz | 3.5G | 3.5G | 3.5G | 3.5G |
| Bandwidth, MHz | 100M | 100M | 100M | 100M |
| Subcarrier spacing, kHz | 30KHZ | 30KHZ | 30KHZ | 30KHZ |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | PRS  1 Sample  (comb-6 frequency structure, 6 symbols within a slot | PRS  1 Sample  (comb-6 frequency structure, 6 symbols within a slot | PRS  1 Sample  (comb-6 frequency structure, 6 symbols within a slot | PRS  1 Sample  (comb-6 frequency structure, 6 symbols within a slot |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | DL | DL | DL | DL |
| R16/R17 positioning method  (if it is used together with CPP) | DL-TDOA | DL-TDOA | DL-TDOA | DL-TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | freq-domain | freq-domain | freq-domain | freq-domain |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | single differential | single differential | single differential | single differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions,…) | cost functions | cost functions | cost functions | cost functions |
| Multipath mitigation techniques  (e.g., first path detection, ...) | first path detection | first path detection | first path detection | first path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement instance | Single-measurement instance | Single-measurement instance | Single-measurement instance |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Taylor series | Taylor series | Taylor series | Taylor series |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0ns | 0ns | 0ns | 0ns |
| UE/TRP Initial phase offset | / | / | / | / |
| CFO/Doppler | / | / | / |  |
| Oscillator-drifts | / | / | / | / |
| ARP errors | / | / | / | / |
| Phase Center Offsets | a=1  w=[-2, +2]  dPhi= [0, 5] | a=3  w=[-5, +5]  dPhi= [0, 5] | a=3  w=[-5, +5]  dPhi= [0, 20] | / |
| Phase noise (FR2) | / | / | / | [0,2pi] |
| Additional notes, if any | / | / | / | / |

Table B.4.2.1.5: NR carrier phase positioning enhancements with multiple carriers phase measurement- evaluation scenarios and parameters from [80]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **[Case 702], [InF-SH]** | **[Case 703], [InF-SH]** | **[Case 704], [InF-SH]** | **[Case 705], [InF-SH]** |
| Channel model  [TS 38.855, TS 38.857] | TS 38.857 | TS 38.857 | TS 38.857 | TS 38.857 |
| Carrier frequency, or Multiple carrier frequencies, GHz | 3.5G and 4G | 3.5G and 4G | 3.5G and 4G | 3.5G and 4G |
| Bandwidth, MHz | 100M+100M | 100M+100M | 100M+100M | 100M+100M |
| Subcarrier spacing, kHz | 30KHZ | 30KHZ | 30KHZ | 30KHZ |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | PRS  1 Sample  (comb-6 frequency structure, 6 symbols within a slot | PRS  1 Sample  (comb-6 frequency structure, 6 symbols within a slot | PRS  1 Sample  (comb-6 frequency structure, 6 symbols within a slot | PRS  1 Sample  (comb-6 frequency structure, 6 symbols within a slot |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | DL | DL | DL | DL |
| R16/R17 positioning method  (if it is used together with CPP) | DL-TDOA | DL-TDOA | DL-TDOA | DL-TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | freq-domain | freq-domain | freq-domain | freq-domain |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | single differential | single differential | single differential | single differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions,…) | cost functions | cost functions | cost functions | cost functions |
| Multipath mitigation techniques  (e.g., first path detection, ...) | first path detection | first path detection | first path detection | first path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement instance | Single-measurement instance | Single-measurement instance | Single-measurement instance |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Taylor series | Taylor series | Taylor series | Taylor series |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0ns | 0ns | 0ns | 0ns |
| UE/TRP Initial phase offset | / | / | / | / |
| CFO/Doppler | / | / | / | a=3  w=[-5, +5]  dPhi= [0, 5] |
| Oscillator-drifts | / | / | / | / |
| ARP errors | / | T1=1cm | / | / |
| Phase Center Offsets | / | / | / | / |
| Phase noise (FR2) | / | / | [0,2pi] | / |
| Additional notes, if any | / | / | / | / |

### B.4.2.2 Positioning accuracy evaluation results for NR Carrier Phase Positioning

Table B.4.2.2-1 provides carrier phase measurement accuracy results for InF-SH and InF-DH.

Table B.4.2.2-2 provides horizontal positioning accuracy results using NR carrier phase positioning without error modeling for InF-SH and InF-DH.

Table B.4.2.2-3 provides horizontal positioning accuracy results using NR carrier phase positioning with different errors for InF-SH.

Table B.4.2.2-4 provides horizontal positioning accuracy results using NR carrier phase positioning with multiple carriers for InF-SH.

Table B.4.2.2-1: NR carrier phase measurement accuracy (radian) for InF-SH and InF-DH from[80]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Assumptions | 50% | 67% | 80% | 90% |
| [Case 001], [carrier phase measurement], [SH]  [Option B (frequency domain) in 2.1.2]  (radian) | 0.16 | 0.24 | 0.31 | 0.43 |
| [Case 002], [carrier phase measurement], [DH]  [Option B (frequency domain) in 2.1.2]  (radian) | 0.19 | 0.29 | 0.44 | 1.36 |
| [Case 003], [carrier phase measurement], [SH]  [Option C (time domain) in 2.1.1] | 0.026 | 0.03 | 0.13 | 1.47 |
| [Case 004], [carrier phase measurement], [DH]  [Option C (time domain) in 2.1.1] | 1.83 | 2.59 | 3.36 | 4.41 |
| [Case 005], [carrier phase measurement], [SH]  [Option D (frequency domain with multipath mitigation) in 2.1.2] | 0.14 | 0.17 | 0.20 | 0.23 |
| [Case 006], [ carrier phase measurement], [DH]  [Option D (frequency domain with multipath mitigation) in 2.1.2] | 0.15 | 0.18 | 0.25 | 0.64 |

Table B.4.2.2-2: NR carrier phase positioning - horizontal accuracy without error modeling for InF-SH and InF-DH from [80]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Assumptions | 50% | 67% | 80% | 90% |
| [case 000] [SH] [TDOA only] | 0.039 | 0.049 | 0.072 | 0.099 |
| [case 101] [SH] [ideal integer cycle] | 0.0012 | 0.0017 | 0.0033 | 0.019 |
| [case 102] [SH] [cost function] | 0.0014 | 0.002 | 0.0044 | 0.09 |
| [case 200] [DH] [TDOA only] | 0.056 | 0.075 | 0.11 | 0.17 |
| [case 201] [DH] [ideal integer cycle] | 0.003 | 0.005 | 0.01 | 0.023 |
| [case 202] [DH] [cost function] | 0.007 | 0.14 | 0.33 | 0.82 |

Table B.4.2.2-3: NR carrier phase positioning - horizontal accuracy with different error modeling for InF-SH from [80]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Assumptions | 50% | 67% | 80% | 90% |
| [case 301] [SH] [cost function] [UE residual CFO 30 Hz] [TRP residual CFO 10 Hz] [single differential] | 0.0017 | 0.01 | 0.20 | 0.38 |
| [case 302] [SH] [cost function] [UE residual CFO 100 Hz] [TRP residual CFO 10 Hz] [single differential] | 0.0024 | 0.13 | 0.27 | 0.42 |
| [case 401] [SH] [cost function] [ ARP error with T1 =1cm] | 0.09 | 0.14 | 0.20 | 0.28 |
| [case 402] [SH] [cost function] [ ARP error with T1 =5cm] | 0.18 | 0.22 | 0.28 | 0.41 |
| [case 501] [SH] [cost function] [ PCO 1 ] | 0.0014 | 0.002 | 0.006 | 0.16 |
| [case 501] [SH] [cost function] [ PCO 2 ] | 0.0023 | 0.0036 | 0.006 | 0.15 |
| [case 503] [SH] [cost function] [ PCO 3] | 0.046 | 0.11 | 0.19 | 0.31 |
| [case 601] [SH] [cost function] [initial phase error [0,2𝜋]] [single differential] | 0.17 | 0.22 | 0.27 | 0.38 |

Table B.4.2.2-4: NR carrier phase positioning - horizontal accuracy with multiple carriers for InF-SH from [80]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Assumptions | 50% | 67% | 80% | 90% |
| [case 102] [SH] [cost function] | 0.0014 | 0.002 | 0.0044 | 0.09 |
| [Case 702] [SH] [cost carrier] [multiple carriers] | 0.0014 | 0.0016 | 0.003 | 0.10 |
| [Case 703] [SH] [cost carrier] [multiple carriers] [ARP error=0.01 m] | 0.089 | 0.14 | 0.18 | 0.27 |
| [case 704] [SH] [cost function] [multiple carriers] [initial phase error ] | 0.18 | 0.25 | 0.34 | 0.52 |
| [Case 705] [SH] [cost carrier] [multiple carriers]  [ PCO 3 NOTE2] | 0.01 | 0.05 | 0.13 | 0.26 |

## B.4.3 Results from source [79]

### B.4.3.1 Description of evaluation scenarios

Evaluation scenarios, key techniques, and assumptions for performance analysis of NR carrier phase positioning in perfect scenarios are provided in Table B.4.3.1-1.

Evaluation scenarios, key techniques, and assumptions for performance analysis of NR carrier phase positioning with the CFO are provided in Table B.4.3.1-2.

Evaluation scenarios, key techniques, and assumptions for performance analysis of NR carrier phase positioning with the random initial phase are provided in Table B.4.3.1-3.

Evaluation scenarios, key techniques, and assumptions for performance analysis of NR carrier phase positioning with the gNB ARP error are provided in Table B.4.3.1-4.

Evaluation scenarios, key techniques, and assumptions for performance analysis of NR carrier phase positioning with the gNB PCO are provided in Table B.4.3.1-5.

Evaluation scenarios, key techniques, and assumptions for performance analysis of NR carrier phase positioning with both the random initial phase and the gNB ARP error are provided in Table B.4.3.1-6.

Table B.4.3.1-1: NR carrier phase positioning enhancements - evaluation scenarios and parameters in perfect scenarios from [79]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Case 1, InF-SH** | **Case 2, InF-DH** | **Case 3, InF-SH** | **Case 4, InF-DH** | **Case 5, InF-SH** | **Case 6, InF-DH** |
| Scenario  [TS 38.855, TS 38.857] | 38.855 | 38.855 | 38.855 | 38.855 | 38.855 | 38.855 |
| Single carrier frequency, or multiple carrier frequencies, GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz |
| Bandwidth, MHz | 100 | 100 | 20 | 20 | 100 | 100 |
| Subcarrier spacing, kHz | 30 | 30 | 30 | 30 | 30 | 30 |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | UL | UL | UL | UL | UL | UL |
| R16/R17 positioning method  (if it is used together with CPP) | UL-TDOA | UL-TDOA | UL-TDOA | UL-TDOA | UL-TDOA | UL-TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | time-domain | time-domain | time-domain | time-domain | time-domain | time-domain |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | None | None | None | None | single differential | single differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions |
| Multipath mitigation techniques  (e.g., first path detection, ...) | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement | Single-measurement | Single-measurement | Single-measurement | Single-measurement | Single-measurement |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns |
| UE/TRP Initial phase offset | 0 | 0 | 0 | 0 | 0 | 0 |
| CFO/Doppler | 0 | 0 | 0 | 0 | 0 | 0 |
| Oscillator-drifts | 0 | 0 | 0 | 0 | 0 | 0 |
| ARP errors | 0 | 0 | 0 | 0 | 0 | 0 |
| Phase Center Offsets | 0 | 0 | 0 | 0 | 0 | 0 |
| Phase noise (FR2) | None | None | None | None | None | None |
| Additional notes, if any |  |  |  |  |  |  |
| PRU assumptions (Note 1) |  |  |  |  |  |  |
| Note 1: PRU deployment assumptions may include the assumptions on the number of PRUs, PRU locations, location errors, etc. | | | | | | |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Case 7, InF-SH** | **Case 8, InF-DH** | **Case 9, InF-SH** | **Case 10, InF-DH** | **Case 11, InF-SH** | **Case 12, InF-DH** |
| Scenario  [TS 38.855, TS 38.857] | 38.855 | 38.855 | 38.855 | 38.855 | 38.855 | 38.855 |
| Single carrier frequency, or multiple carrier frequencies, GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz |
| Bandwidth, MHz | 20 | 20 | 100 | 100 | 20 | 20 |
| Subcarrier spacing, kHz | 30 | 30 | 30 | 30 | 30 | 30 |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | UL | UL | UL | UL | UL | UL |
| R16/R17 positioning method  (if it is used together with CPP) | UL-TDOA | UL-TDOA | UL-TDOA | UL-TDOA | UL-TDOA | UL-TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | time-domain | time-domain | time-domain | time-domain | time-domain | time-domain |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | single differential | single differential | double differential | double differential | double differential | double differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions |
| Multipath mitigation techniques  (e.g., first path detection, ...) | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement | Single-measurement | Single-measurement | Single-measurement | Single-measurement | Single-measurement |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns |
| UE/TRP Initial phase offset | 0 | 0 | 0 | 0 | 0 | 0 |
| CFO/Doppler | 0 | 0 | 0 | 0 | 0 | 0 |
| Oscillator-drifts | 0 | 0 | 0 | 0 | 0 | 0 |
| ARP errors | 0 | 0 | 0 | 0 | 0 | 0 |
| Phase Center Offsets | 0 | 0 | 0 | 0 | 0 | 0 |
| Phase noise (FR2) | None | None | None | None | None | None |
| Additional notes, if any |  |  |  |  |  |  |
| PRU assumptions (Note 1) |  |  | PRU is 5m away from UE | PRU is 5m away from UE | PRU is 5m away from UE | PRU is 5m away from UE |
| Note 1: PRU deployment assumptions may include the assumptions on the number of PRUs, PRU locations, location errors, etc. | | | | | | |

Table B.4.3.1-2: NR carrier phase positioning enhancements - evaluation scenarios and parameters with the CFO from [79]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **Case 13, InF-SH** | **Case 14, InF-DH** | **Case 15, InF-SH** | **Case 16, InF-DH** |
| Scenario  [TS 38.855, TS 38.857] | 38.855 | 38.855 | 38.855 | 38.855 |
| Single carrier frequency, or multiple carrier frequencies, GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz |
| Bandwidth, MHz | 100 | 100 | 100 | 100 |
| Subcarrier spacing, kHz | 30 | 30 | 30 | 30 |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | UL | UL | UL | UL |
| R16/R17 positioning method  (if it is used together with CPP) | UL-TDOA | UL-TDOA | UL-TDOA | UL-TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | time-domain | time-domain | time-domain | time-domain |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | None | None | None | None |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions |
| Multipath mitigation techniques  (e.g., first path detection, ...) | first path detection | first path detection | first path detection | first path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement | Single-measurement | Single-measurement | Single-measurement |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0ns | 0ns | 0ns | 0ns |
| UE/TRP Initial phase offset | 0 | 0 | 0 | 0 |
| CFO/Doppler | [-30, +30] Hz | [-30, +30] Hz | [-100, +100] Hz | [-100, +100] Hz |
| Oscillator-drifts | 0 | 0 | 0 | 0 |
| ARP errors | 0 | 0 | 0 | 0 |
| Phase Center Offsets | 0 | 0 | 0 | 0 |
| Phase noise (FR2) | 0 | 0 | 0 | 0 |
| Additional notes, if any |  |  |  |  |
| PRU assumptions (Note 1) |  |  |  |  |
| Note 1: PRU deployment assumptions may include the assumptions on the number of PRUs, PRU locations, location errors, etc. | | | | |

Table B.4.3.1-3: NR carrier phase positioning enhancements - evaluation scenarios and parameters with the random initial phase from [79]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Case 17, InF-SH** | **Case 18, InF-DH** | **Case 19, InF-SH** | **Case 20, InF-DH** | **Case 21, InF-SH** | **Case 22, InF-DH** |
| Scenario  [TS 38.855, TS 38.857] | 38.855 | 38.855 | 38.855 | 38.855 | 38.855 | 38.855 |
| Single carrier frequency, or multiple carrier frequencies, GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz |
| Bandwidth, MHz | 100 | 100 | 100 | 100 | 100 | 100 |
| Subcarrier spacing, kHz | 30 | 30 | 30 | 30 | 30 | 30 |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | UL | UL | UL | UL | UL | UL |
| R16/R17 positioning method  (if it is used together with CPP) | UL-TDOA | UL-TDOA | UL-TDOA | UL-TDOA | UL-TDOA | UL-TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | time-domain | time-domain | time-domain | time-domain | time-domain | time-domain |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | single differential | single differential | single differential | single differential | double differential | double differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions |
| Multipath mitigation techniques  (e.g., first path detection, ...) | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement | Single-measurement | Single-measurement | Single-measurement | Single-measurement | Single-measurement |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns |
| UE/TRP Initial phase offset | UE Initial phase offset | UE Initial phase offset | UE and TRP Initial phase offset | UE and TRP Initial phase offset | UE and TRP Initial phase offset | UE and TRP Initial phase offset |
| CFO/Doppler | 0 | 0 | 0 | 0 | 0 | 0 |
| Oscillator-drifts | 0 | 0 | 0 | 0 | 0 | 0 |
| ARP errors | 0 | 0 | 0 | 0 | 0 | 0 |
| Phase Center Offsets | 0 | 0 | 0 | 0 | 0 | 0 |
| Phase noise (FR2) | None | None | None | None | None | None |
| Additional notes, if any |  |  |  |  |  |  |
| PRU assumptions (Note 1) |  |  |  |  | PRU is 5m away from UE | PRU is 5m away from UE |
| Note 1: PRU deployment assumptions may include the assumptions on the number of PRUs, PRU locations, location errors, etc. | | | | | | |

Table B.4.3.1-4: NR carrier phase positioning enhancements - evaluation scenarios and parameters with the gNB ARP error from [79]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Case 23, InF-SH** | **Case 24, InF-DH** | **Case 25, InF-SH** | **Case 26, InF-DH** | **Case 27, InF-SH** | **Case 28, InF-DH** |
| Scenario  [TS 38.855, TS 38.857] | 38.855 | 38.855 | 38.855 | 38.855 | 38.855 | 38.855 |
| Single carrier frequency, or multiple carrier frequencies, GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz |
| Bandwidth, MHz | 100 | 100 | 100 | 100 | 100 | 100 |
| Subcarrier spacing, kHz | 30 | 30 | 30 | 30 | 30 | 30 |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | UL | UL | UL | UL | UL | UL |
| R16/R17 positioning method  (if it is used together with CPP) | UL-TDOA | UL-TDOA | UL-TDOA | UL-TDOA | UL-TDOA | UL-TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | time-domain | time-domain | time-domain | time-domain | time-domain | time-domain |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | none | none | none | none | double differential | double differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions |
| Multipath mitigation techniques  (e.g., first path detection, ...) | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement | Single-measurement | Single-measurement | Single-measurement | Single-measurement | Single-measurement |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0 | 0 | 0 | 0 | 0 | 0 |
| UE/TRP Initial phase offset | 0 | 0 | 0 | 0 | 0 | 0 |
| CFO/Doppler | 0 | 0 | 0 | 0 | 0 | 0 |
| Oscillator-drifts | 0 | 0 | 0 | 0 | 0 | 0 |
| ARP errors | 1cm | 1cm | 5cm | 5cm | 1cm | 1cm |
| Phase Center Offsets | 0 | 0 | 0 | 0 | 0 | 0 |
| Phase noise (FR2) | 0 | 0 | 0 | 0 | 0 | 0 |
| Additional notes, if any |  |  |  |  |  |  |
| PRU assumptions (Note 1) |  |  |  |  | PRU is 5m away from UE | PRU is 5m away from UE |
| Note 1: PRU deployment assumptions may include the assumptions on the number of PRUs, PRU locations, location errors, etc | | | | | | |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Case 29, InF-SH** | **Case 30, InF-DH** | **Case 31, InF-SH** | **Case 32, InF-DH** | **Case33, InF-SH** | **Case 34, InF-DH** |
| Scenario  [TS 38.855, TS 38.857] | 38.855 | 38.855 | 38.855 | 38.855 | 38.855 | 38.855 |
| Single carrier frequency, or multiple carrier frequencies, GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz |
| Bandwidth, MHz | 100 | 20 | 100 | 20 | 100 | 20 |
| Subcarrier spacing, kHz | 30 | 30 | 30 | 30 | 30 | 30 |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | UL | UL | UL | UL | UL | UL |
| R16/R17 positioning method  (if it is used together with CPP) | UL-TDOA | UL-TDOA | UL-TDOA | UL-TDOA | UL-TDOA | UL-TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | time-domain | time-domain | time-domain | time-domain | time-domain | time-domain |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | double differential | double differential | double differential | double differential | double differential | double differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions |
| Multipath mitigation techniques  (e.g., first path detection, ...) | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement | Single-measurement | Single-measurement | Single-measurement | Single-measurement | Single-measurement |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0 | 0 | 0 | 0 | 0 | 0 |
| UE/TRP Initial phase offset | 0 | 0 | 0 | 0 | 0 | 0 |
| CFO/Doppler | 0 | 0 | 0 | 0 | 0 | 0 |
| Oscillator-drifts | 0 | 0 | 0 | 0 | 0 | 0 |
| ARP errors | 5cm | 5cm | 1cm | 1cm | 5cm | 5cm |
| Phase Center Offsets | 0 | 0 | 0 | 0 | 0 | 0 |
| Phase noise (FR2) | 0 | 0 | 0 | 0 | 0 | 0 |
| Additional notes, if any |  |  |  |  |  |  |
| PRU assumptions (Note 1) | PRU is 5m away from UE | PRU is 5m away from UE | PRU is 2m away from UE | PRU is 2m away from UE | PRU is 2m away from UE | PRU is 2m away from UE |
| Note 1: PRU deployment assumptions may include the assumptions on the number of PRUs, PRU locations, location errors, etc. | | | | | | |

Table B.4.3.1-5: NR carrier phase positioning enhancements - evaluation scenarios and parameters with the gNB PCO from [79]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Case 35, InF-SH** | **Case 36, InF-DH** | **Case 37, InF-SH** | **Case 38, InF-DH** | **Case 39, InF-SH** | **Case 40, InF-DH** | **Case 41, InF-SH** | **Case 42, InF-DH** |
| Scenario  [TS 38.855, TS 38.857] | 38.855 | 38.855 | 38.855 | 38.855 | 38.855 | 38.855 | 38.855 | 38.855 |
| Single carrier frequency, or multiple carrier frequencies, GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz |
| Bandwidth, MHz | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Subcarrier spacing, kHz | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | UL | UL | UL | UL | UL | UL | UL | UL |
| R16/R17 positioning method  (if it is used together with CPP) | UL-TDOA | UL-TDOA | UL-TDOA | UL-TDOA | UL-TDOA | UL-TDOA | UL-TDOA | UL-TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | time-domain | time-domain | time-domain | time-domain | time-domain | time-domain | time-domain | time-domain |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | single differential | single differential | single differential | single differential | double differential | double differential | double differential | double differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions |
| Multipath mitigation techniques  (e.g., first path detection, ...) | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement | Single-measurement | Single-measurement | Single-measurement | Single-measurement | Single-measurement | Single-measurement | Single-measurement |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| UE/TRP Initial phase offset | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CFO/Doppler | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Oscillator-drifts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ARP errors | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Phase Center Offsets | a=1  w=0 | a=1  w=0 | a=3  w=0 | a=3  w=0 | a=1  w=0 | a=1  w=0 | a=3  w=0 | a=3  w=0 |
| Phase noise (FR2) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Additional notes, if any |  |  |  |  |  |  |  |  |
| PRU assumptions (Note 1) |  |  |  |  | PRU is 5m away from UE | PRU is 5m away from UE | PRU is 5m away from UE | PRU is 5m away from UE |
| Note 1: PRU deployment assumptions may include the assumptions on the number of PRUs, PRU locations, location errors, etc. | | | | | | | | |

Table B.4.3.1-6: NR carrier phase positioning enhancements - evaluation scenarios and parameters with both the random initial phase and the gNB ARP error from [79]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Case 43, InF-SH** | **Case 44, InF-DH** | **Case 45, InF-SH** | **Case 46, InF-DH** | **Case 47, InF-SH** | **Case 48, InF-SH** |
| Scenario  [TS 38.855, TS 38.857] | 38.855 | 38.855 | 38.855 | 38.855 | 38.855 | 38.855 |
| Single carrier frequency, or multiple carrier frequencies, GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  2.6 GHz | Single  2.6 GHz |
| Bandwidth, MHz | 100 | 100 | 100 | 100 | 160 | 160 |
| Subcarrier spacing, kHz | 30 | 30 | 30 | 30 | 30 | 30 |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 | posSRS  Comb-4 |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | UL | UL | UL | UL | UL | UL |
| R16/R17 positioning method  (if it is used together with CPP) | UL-TDOA | UL-TDOA | UL-TDOA | UL-TDOA | UL-TDOA | UL-TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | time-domain | time-domain | time-domain | time-domain | time-domain | time-domain |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | double differential | double differential | double differential | double differential | double differential | double differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions | Integer least squares and cost functions | virtual Integer ambiguity | virtual Integer ambiguity |
| Multipath mitigation techniques  (e.g., first path detection, ...) | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement | Single-measurement | Single-measurement | Single-measurement | Single-measurement | Single-measurement |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares | Taylor series and Least squares |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0 | 0 | 0 | 0 | 0 | 0 |
| UE/TRP Initial phase offset | UE and TRP Initial phase offset | UE and TRP Initial phase offset | UE and TRP Initial phase offset | UE and TRP Initial phase offset | UE and TRP Initial phase offset | UE and TRP Initial phase offset |
| CFO/Doppler | 0 | 0 | 0 | 0 | 0 | 0 |
| Oscillator-drifts | 0 | 0 | 0 | 0 | 0 | 0 |
| ARP errors | 1cm | 1cm | 5cm | 5cm | 1cm | 5cm |
| Phase Center Offsets | 0 | 0 | 0 | 0 | 0 | 0 |
| Phase noise (FR2) | 0 | 0 | 0 | 0 | 0 | 0 |
| Additional notes, if any |  |  |  |  |  |  |
| PRU assumptions (Note 1) | PRU is 5m away from UE | PRU is 5m away from UE | PRU is 5m away from UE | PRU is 5m away from UE | PRU is 5m away from UE | PRU is 5m away from UE |
| Note 1: PRU deployment assumptions may include the assumptions on the number of PRUs, PRU locations, location errors, etc. | | | | | | |

### B.4.3.2 Positioning accuracy evaluation results for NR Carrier Phase Positioning

Table B.4.3.2-1 provides horizontal positioning accuracy results using NR carrier phase positioning in perfect scenarios.

Table B.4.3.2-2 provides horizontal positioning accuracy results using NR carrier phase positioning with the CFO.

Table B.4.3.2-3 provides horizontal positioning accuracy results using NR carrier phase positioning with the random initial phase.

Table B.4.3.2-4 provides horizontal positioning accuracy results using NR carrier phase positioning with the gNB ARP error.

Table B.4.3.2-5 provides horizontal positioning accuracy results using NR carrier phase positioning with the gNB PCO.

Table B.4.3.2-6 provides horizontal positioning accuracy results using NR carrier phase positioning with both the random initial phase and the gNB ARP error.

Table B.4.3.2-1: NR carrier phase positioning - horizontal accuracy in perfect scenarios from [79]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **[Case ID], [Scenario], [additional descriptions]** | **50%** | **67%** | **80%** | **90%** | **Met 1cm accuracy @ 50%-ile of the UEs?**  **(Yes/No)** | **Additional comments** |
| Case 1, InF-SH, 100M, UL-POA | 0.00018 | 0.00036 | 0.00074 | 0.00184 | Y |  |
| Case 2, InF-DH, 100M, UL-POA | 0.00024 | 0.00058 | 0.00234 | 1.0541 | Y |  |
| Case 3, InF-SH, 20M, UL-POA | 0.00086 | 0.00208 | 0.15945 | 2.3373 | Y |  |
| Case 4, InF-DH, 20M, UL-POA | 0.54928 | 1.8733 | 3.3055 | 7.4243 | N |  |
| Case 5, InF-SH, 100M, single differential UL-POA | 0.00023 | 0.00054 | 0.00122 | 0.00434 | Y |  |
| Case 6, InF-DH, 100M, single differential UL-POA | 0.00111 | 0.57064 | 0.97391 | 1.3698 | Y |  |
| Case 7, InF-SH, 20M, single differential UL-POA | 0.00124 | 0.00350 | 0.84404 | 1.7309 | Y |  |
| Case 8, InF-DH, 20M, single differential UL-POA | 0.91584 | 1.4492 | 2.101 | 3.5818 | N |  |
| Case 9, InF-SH, 100M, double differential UL-POA (PRU 5m) | 0.00058 | 0.00125 | 0.00255 | 0.01901 | Y |  |
| Case 10, InF-DH, 100M, double differential UL-POA (PRU 5m) | 0.00278 | 0.62379 | 1.0138 | 1.3716 | Y |  |
| Case 11, InF-SH, 20M, double differential UL-POA (PRU 5m) | 0.00237 | 0.00961 | 1.0986 | 2.005 | Y |  |
| Case 12, InF-DH, 20M, double differential UL-POA (PRU 5m) | 0.96012 | 1.483 | 2.1519 | 4.0226 | N |  |

Table B.4.3.2-2: NR carrier phase positioning - horizontal accuracy with the CFO from [79]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **[Case ID], [Scenario], [additional descriptions]** | **50%** | **67%** | **80%** | **90%** | **Met 1cm accuracy @ 50%-ile of the UEs?**  **(Yes/No)** | **Additional comments** |
| Case 13, InF-SH, CFO TRP10Hz and UE30Hz | 0.00013 | 0.00028 | 0.00059 | 0.00135 | Y |  |
| Case 14, InF-DH, CFO TRP10Hz and UE30Hz | 0.00031 | 0.00086 | 0.1895 | 1.3262 | Y |  |
| Case 15, InF-SH, CFO TRP10Hz and UE100Hz | 0.00016 | 0.00035 | 0.00065 | 0.0016 | Y |  |
| Case 16, InF-DH, CFO TRP10Hz and UE100Hz | 0.00031 | 0.00092 | 0.2615 | 1.2725 | Y |  |

Table B.4.3.2-3: NR carrier phase positioning - horizontal accuracy with the random initial phase from [79]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **[Case ID], [Scenario], [additional descriptions]** | **50%** | **67%** | **80%** | **90%** | **Met 1cm accuracy @ 50%-ile of the UEs?**  **(Yes/No)** | **Additional comments** |
| Case 17, InF-SH, random initial phase (trans), single differential UL-POA | 0.00025 | 0.00051 | 0.00101 | 0.00316 | Y |  |
| Case 18, InF-DH, random initial phase (trans), single differential UL-POA | 0.00120 | 0.60019 | 1.0193 | 1.387 | Y |  |
| Case 19, InF-SH, random initial phase (rec/trans), single differential UL-POA | 1.0251 | 1.2896 | 1.5892 | 2.0754 | N |  |
| Case 20, InF-DH, random initial phase (rec/trans), single differential UL-POA | 0.95185 | 1.1896 | 1.4667 | 1.8026 | N |  |
| Case 21, InF-SH, random initial phase (rec/trans), double differential UL-POA (PRU 5m) | 0.00050 | 0.00103 | 0.00241 | 0.01369 | Y |  |
| Case 22, InF-DH, random initial phase (rec/trans), double differential UL-POA (PRU 5m) | 0.00236 | 0.64968 | 1.0402 | 1.3857 | Y |  |

Table B.4.3.2-4: NR carrier phase positioning - horizontal accuracy with the gNB ARP error from [79]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **[Case ID], [Scenario], [additional descriptions]** | **50%** | **67%** | **80%** | **90%** | **Met 1cm accuracy @ 50%-ile of the UEs?**  **(Yes/No)** | **Additional comments** |
| Case 23, InF-SH, ARP error 1cm, UL-POA | 1.3368 | 1.746 | 2.121 | 2.5781 | N |  |
| Case 24, InF-DH, ARP error 1cm, UL-POA | 1.2329 | 1.579 | 1.9317 | 2.4507 | N |  |
| Case 25, InF-SH, ARP error 5cm, UL-POA | 1.4595 | 1.8272 | 2.2436 | 2.6966 | N |  |
| Case 26, InF-DH, ARP error 5cm, UL-POA | 1.2318 | 1.5742 | 1.9392 | 2.387 | N |  |
| Case 27, InF-SH, ARP error 1cm, double differential UL-POA (PRU 5m) | 0.00283 | 0.00701 | 0.57269 | 1.2051 | Y |  |
| Case 28, InF-DH, ARP error 1cm, double differential UL-POA (PRU 5m) | 0.75118 | 1.0593 | 1.3217 | 1.6719 | N |  |
| Case 29, InF-SH, ARP error 5cm, double differential UL-POA (PRU 5m) | 0.74247 | 1.0553 | 1.3606 | 1.8066 | N |  |
| Case 30, InF-DH, ARP error 5cm, double differential UL-POA (PRU 5m) | 0.92375 | 1.1703 | 1.3996 | 1.7605 | N |  |
| Case 31, InF-SH, ARP error 1cm, double differential UL-POA (PRU 2m) | 0.00149 | 0.00298 | 0.00936 | 0.89098 | Y |  |
| Case 32, InF-DH, ARP error 1cm, double differential UL-POA (PRU 2m) | 0.56419 | 0.94121 | 1.1915 | 1.4847 | N |  |
| Case 33, InF-SH, ARP error 5cm, double differential UL-POA (PRU 2m) | 0.01052 | 0.65011 | 1.0335 | 1.5082 | N |  |
| Case 34, InF-DH, ARP error 5cm, double differential UL-POA (PRU 2m) | 0.85975 | 1.0953 | 1.361 | 1.7484 | N |  |

Table B.4.3.2-5: NR carrier phase positioning - horizontal accuracy with the gNB PCO from [79]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **[Case ID], [Scenario], [additional descriptions]** | **50%** | **67%** | **80%** | **90%** | **Met 1cm accuracy @ 50%-ile of the UEs?**  **(Yes/No)** | **Additional comments** |
| Case 35, InF-SH, PCO a=1, single differential UL-POA | 0.5936 | 0.9333 | 1.2081 | 1.5331 | N |  |
| Case 36, InF-DH, PCO a=1, single differential UL-POA | 0.8349 | 1.1274 | 1.3985 | 1.8244 | N |  |
| Case 37, InF-SH, PCO a=3, single differential UL-POA | 0.8469 | 1.1156 | 1.3922 | 1.7844 | N |  |
| Case 38, InF-DH, PCO a=3, single differential UL-POA | 0.9192 | 1.1661 | 1.4393 | 1.8515 | N |  |
| Case 39, InF-SH, PCO a=1, double differential UL-POA (PRU 5m) | 0.0006 | 0.0015 | 0.0041 | 0.6446 | Y |  |
| Case 40, InF-DH, PCO a=1, double differential UL-POA (PRU 5m) | 0.3676 | 0.8621 | 1.1561 | 1.6252 | N |  |
| Case 41, InF-SH, PCO a=3, double differential UL-POA (PRU 5m) | 0.0007 | 0.0017 | 0.0075 | 0.9076 | Y |  |
| Case 42, InF-DH, PCO a=3, double differential UL-POA (PRU 5m) | 0.4896 | 0.8937 | 1.2148 | 1.644 | N |  |

Table B.4.3.2-6: NR carrier phase positioning - horizontal accuracy with both the random initial phase and the gNB ARP error from [79]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **[Case ID], [Scenario], [additional descriptions]** | **50%** | **67%** | **80%** | **90%** | **Met 1cm accuracy @ 50%-ile of the UEs?**  **(Yes/No)** | **Additional comments** |
| Case 43, InF-SH, ARP error 1cm, double differential UL-POA (PRU 5m), random initial phase (rec/trans) | 0.00306 | 0.00848 | 0.65333 | 1.2305 | Y |  |
| Case 44, InF-DH, ARP error 1cm, double differential UL-POA (PRU 5m), random initial phase (rec/trans) | 0.71086 | 1.0234 | 1.2683 | 1.6288 | N |  |
| Case 45, InF-SH, ARP error 5cm, double differential UL-POA (PRU 5m), random initial phase (rec/trans) | 0.73594 | 1.0428 | 1.3812 | 1.779 | N |  |
| Case 46, InF-DH, ARP error 5cm, double differential UL-POA (PRU 5m), random initial phase (rec/trans) | 0.88533 | 1.1479 | 1.3841 | 1.7463 | N |  |
| Case 47, InF-SH, ARP error 1cm, double differential/multi-freq UL-POA (PRU 5m), random initial phase (rec/trans) | 0.01252 | 0.01766 | 0.02765 | 0.04860 | N |  |
| Case 48, InF-SH, ARP error 5cm, double differential/multi-freq UL-POA (PRU 5m), random initial phase (rec/trans) | 0.05986 | 0.08327 | 0.11879 | 0.19365 | N |  |

Figure B.4.3.2-1 provides horizontal positioning accuracy results using NR carrier phase positioning in perfect scenarios.

Figure B.4.3.2-2 provides horizontal positioning accuracy results using NR single differential carrier phase positioning in perfect scenarios.

Figure B.4.3.2-3 provides horizontal positioning accuracy results using NR double differential carrier phase positioning in perfect scenarios.

Figure B.4.3.2-4 provides horizontal positioning accuracy results using NR carrier phase positioning with the CFO.

Figure B.4.3.2-5 provides horizontal positioning accuracy results using NR carrier phase positioning with the random initial phase of the transmitter.

Figure B.4.3.2-6 provides horizontal positioning accuracy results using NR carrier phase positioning with the random initial phase of the transmitter and the receiver.

Figure B.4.3.2-7 provides horizontal positioning accuracy results using NR single differential carrier phase positioning with the gNB ARP error.

Figure B.4.3.2-8 provides horizontal positioning accuracy results using NR double differential carrier phase positioning with PRU 5m away from UE with the gNB ARP error.

Figure B.4.3.2-9 provides horizontal positioning accuracy results using NR double differential carrier phase positioning with PRU 5m away from UE with the gNB ARP error.

Figure B.4.3.2-10 provides horizontal positioning accuracy results using NR single differential carrier phase positioning with the gNB PCO.

Figure B.4.3.2-11 provides horizontal positioning accuracy results using NR double differential carrier phase positioning with the gNB PCO.

Figure B.4.3.2-12 provides horizontal positioning accuracy results using NR double differential carrier phase positioning with both the random initial phase and the gNB ARP error.

Figure B.4.3.2-13 provides horizontal positioning accuracy results using NR double differential and multi-frequency carrier phase positioning with both the random initial phase and the gNB ARP error.

A picture containing graphical user interface

Description automatically generated

Figure B.4.3.2-1: NR carrier phase positioning - horizontal accuracy in perfect scenarios from [79]

Chart

Description automatically generated

Figure B.4.3.2-2: NR single differential carrier phase positioning - horizontal accuracy in perfect scenarios from [79]

Chart, line chart

Description automatically generated

Figure B.4.3.2-3: NR double differential carrier phase positioning - horizontal accuracy in perfect scenarios from [79]

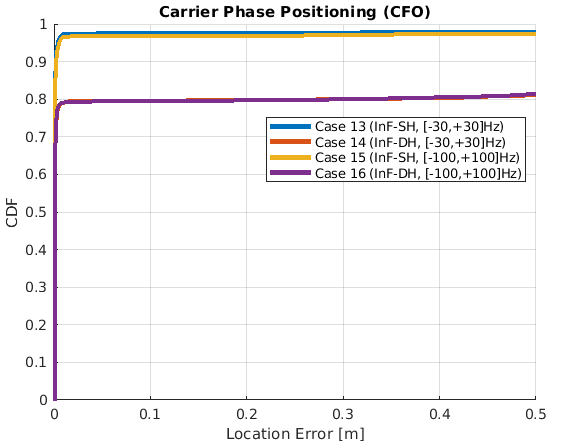


Figure B.4.3.2-4: NR carrier phase positioning - horizontal accuracy with the CFO from [79]

Chart

Description automatically generated with medium confidence

Figure B.4.3.2-5: NR carrier phase positioning - horizontal accuracy with the random initial phase of the transmitter from [79]

Chart

Description automatically generated

Figure B.4.3.2-6: NR carrier phase positioning - horizontal accuracy with the random initial phase of the transmitter and the receiver from [79]

Table

Description automatically generated

Figure B.4.3.2-7: NR single differential carrier phase positioning - horizontal accuracy with the gNB ARP error from [79]

Chart, line chart

Description automatically generated

Figure B.4.3.2-8: NR double differential carrier phase positioning with PRU 5m away from UE - horizontal accuracy with the gNB ARP error from [79]

Chart

Description automatically generated

Figure B.4.3.2-9: NR double differential carrier phase positioning with PRU 2m away from UE - horizontal accuracy with the gNB ARP error from [79]

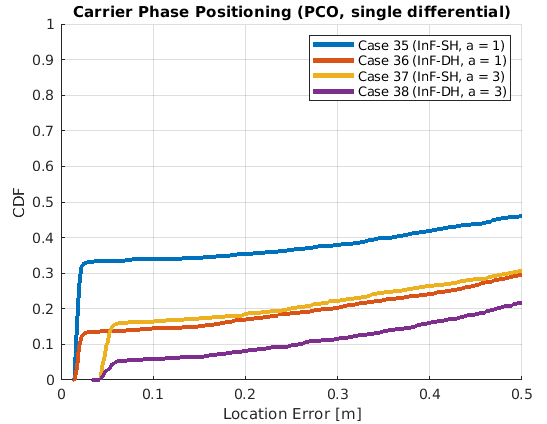


Figure B.4.3.2-10: NR single differential carrier phase positioning - horizontal accuracy with the gNB PCO from [79]

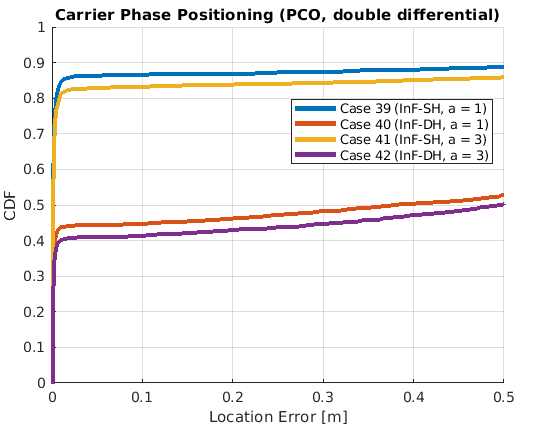


Figure B.4.3.2-11: NR double differential carrier phase positioning - horizontal accuracy with the gNB PCO from [79]

Chart

Description automatically generated

Figure B.4.3.2-12: NR double differential carrier phase positioning - horizontal accuracy with both the random initial phase and the gNB ARP error from [79]

Chart

Description automatically generated

Figure B.4.3.2-13: NR double differential and multi-frequency carrier phase positioning - horizontal accuracy with both the random initial phase and the gNB ARP error from [79]

## B.4.4 Results from source [82]

### B.4.4.1 Description of evaluation scenarios

Table B.4.4-1: NR positioning enhancements - evaluation scenarios and parameters [82]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Parameter** | **[Case 1],**  **[InF-SH]** | **[Case 2],**  **[InF-SH]** | **[Case 3],**  **[InF-SH]** | **[Case 4],**  **[InF-SH]** | **[Case 5],**  **[InF-SH]** |
| Scenario  [TS 38.855, TS 38.857] | 38.855 | 38.855 | 38.855 | 38.855 | 38.855 |
| Single carrier frequency, or multiple carrier frequencies, GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz |
| Bandwidth, MHz | 100 | 100 | 100 | 100 | 100 |
| Subcarrier spacing, kHz | 30 | 30 | 30 | 30 | 30 |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | DL PRS,  6 symbols with Comb-6 | DL PRS,  6 symbols with Comb-6 | DL PRS,  6 symbols with Comb-6 | DL PRS,  6 symbols with Comb-6 | DL PRS,  6 symbols with Comb-6 |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | DL | DL | DL | DL | DL |
| R16/R17 positioning method  (if it is used together with CPP) | n/a | n/a | n/a | n/a | n/a |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | Time-domain | Time-domain | Time-domain | Time-domain | Time-domain |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | None | None | None | Double differential | Double differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | Ideal IR resolution | Ideal IR resolution | Ideal IR resolution | Ideal IR resolution | Ideal IR resolution |
| Multipath mitigation techniques  (e.g., first path detection, ...) | First path detection | First path detection | First path detection | First path detection | First path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single measurement | Single measurement | Single measurement | Single measurement | Single measurement |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Least square based on Taylor seires | Least square based on Taylor seires | Least square based on Taylor seires | Least square based on Taylor seires | Least square based on Taylor seires |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0ns | 0ns | 0ns | 0ns | 0ns |
| UE/TRP Initial phase offset | none | UE initial phase offset | UE and TRP initial phase offset | none | UE and TRP initial phase offset |
| CFO/Doppler | none | none | none | none | none |
| *Oscillator-drifts* | none | none | none | none | none |
| ARP errors | none | none | none | none | none |
| Phase Center Offsets | none | none | none | none | none |
| Phase noise (FR2) | none | none | none | none | none |
| PRU Assumptions | 4 PRUs modeled in factory, closest in distance used for a given target UE | 4 PRUs modeled in factory, closest in distance used for a given target UE | 4 PRUs modeled in factory, closest in distance used for a given target UE | 4 PRUs modeled in factory, closest in distance used for a given target UE | 4 PRUs modeled in factory, closest in distance used for a given target UE |
| Additional notes, if any |  |  |  |  |  |

### B.4.4.2 Positioning accuracy evaluation results for NR carrier phase positioning

Table B.4.4-1: NR carrier phase positioning - horizontal accuracy [82]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| [Case ID], [Scenario]  [additional descriptions] | 50% | 67% | 80% | 90% | Additional comments |
| Case 1, DL-PoA, without initial phase offset | 0.000195 | 0.001438 | 0.003124 | 0.005876 |  |
| Case 2, DL-PoA with UE Rx initial phase offset | 0.1143 | 0.1187 | 0.2324 | 0.301 |  |
| Case 3, DL-PoA with initial phase offset for both TRP and UE | 0.4995 | 1.25 | 1.482 | 1.796 |  |
| Case 4, DL-CP double differencing without initial phase offset for both TRP and UE | 0.0001401 | 0.004913 | 0.007357 | 0.009230 |  |
| Case 5, DL-CP double differencing with initial phase offset for both TRP and UE | 0.0001401 | 0.005002 | 0.007372 | 0.009237 |  |

## B.4.5 Results from source [87]

### B.4.5.1 Description of evaluation scenarios

Evaluation scenarios, key techniques, and assumptions for performance analysis of NR carrier phase positioning are provided in Table B.4.5.1-1.

Evaluation scenarios, key techniques, and assumptions for performance analysis of NR carrier phase positioning are provided in Table B.4.5.1-2.

Evaluation scenarios, key techniques, and assumptions for performance analysis of NR carrier phase positioning are provided in Table B.4.5.1-3.

Table B.4.5.1-1: NR carrier phase positioning enhancements - evaluation scenarios and parameters from [87]

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **[Case 01], [InF-SH]** | **[Case 02], [InF-SH]** | **[Case 03], [InF-SCH]** |
| Scenario  [TS 38.855, TS 38.857] | TR 38.357 | TR 38.357 | TR 38.357 |
| Single carrier frequency, or multiple carrier frequencies, GHz | Single,  3 GHz | Single,  3 GHz | Single,  3 GHz |
| Bandwidth, MHz | 10 MHz | 10 MHz | 10 MHz |
| Subcarrier spacing, kHz | 30 kHz | 30 kHz | 30 kHz |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | DL PRS + Pos SRS  Comb = 1 | DL PRS + Pos SRS  Comb = 4  Same sub-carrier in symbols of slot | DL PRS + Pos SRS  Comb = 4  Sub-carrier offset between symbols of slot |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | DL + UL round-trip carrier phase + slope estimate  Ranging | DL + UL round-trip carrier phase + slope estimate  Ranging | DL + UL round-trip carrier phase  Ranging |
| R16/R17 positioning method  (if it is used together with CPP) | N/A | N/A | N/A |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | Frequency Domain | Frequency Domain | Frequency Domain |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | Round trip carrier phase | Round trip carrier phase | Round trip carrier phase |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | Slope of carrier phase | Round trip carrier phase | Round trip carrier phase |
| Multipath mitigation techniques  (e.g., first path detection, ...) | First path detection | First path detection | First path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single measurement in DL + Single measurement in UL | Single measurement in DL + Single measurement in UL | Single measurement in DL + Single measurement in UL |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Least squares for slope | Least squares for slope | Least squares for slope |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | N/A (single TRP) | N/A (single TRP) | N/A (single TRP) |
| UE/TRP Initial phase offset |  |  |  |
| CFO/Doppler | 0 | 0 | 0 |
| *Oscillator-drifts* | 0 | 0 | 0 |
| ARP errors | 0 | 0 | 0 |
| Phase Center Offsets | 0 | 0 | 0 |
| Phase noise (FR2) | N/A | N/A | N/A |
| Additional notes, if any |  |  |  |
| PRU assumptions (Note 1) | No PRUs | No PRUIs | No PRUs |
| Note 1: PRU deployment assumptions may include the assumptions on the number of PRUs, PRU locations, location errors, etc. | | | |

Table B.4.A.1-2: NR carrier phase positioning enhancements - evaluation scenarios and parameters from [87]

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **[Case 04], [InF-SH]** | **[Case 05], [InF-SH]** | **[Case 06], [InF-SH]** | **[Case 07], [InF-SH]** | **[Case 08], [InF-SH]** | **[Case 09], [InF-SH]** | **[Case 10], [InF-SH]** |
| Scenario  [TS 38.855, TS 38.857] | TR 38.857 | TR 38.857 | TR 38.857 | TR 38.857 | TR 38.857 | TR 38.857 | TR 38.857 |
| Single carrier frequency, or multiple carrier frequencies, GHz | Single,  3.5 GHz | Single,  3.5 GHz | Single,  3.5 GHz | Single,  3.5 GHz | Single,  3.5 GHz | Single,  3.5 GHz | Single,  3.5 GHz |
| Bandwidth, MHz | 100 MHz | 100 MHz | 100 MHz | 100 MHz | 100 MHz | 20 MHz | 20 MHz |
| Subcarrier spacing, kHz | 30 kHz | 30 kHz | 30 kHz | 30 kHz | 30 kHz | 30 kHz | 30 kHz |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | DL PRS  Comb = 4, Number of OFDM symbols=4 | DL PRS  Comb = 4, Number of OFDM symbols=4 | DL PRS  Comb = 4, Number of OFDM symbols=4 | DL PRS  Comb = 4, Number of OFDM symbols=4 | DL PRS  Comb = 4, Number of OFDM symbols=4 | DL PRS  Comb = 4, Number of OFDM symbols=4 | DL PRS  Comb = 4, Number of OFDM symbols=4 |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | DL | DL | DL | DL | DL | DL | DL |
| R16/R17 positioning method  (if it is used together with CPP) | DL-TDOA | DL-TDOA | DL-TDOA | DL-TDOA | DL-TDOA | DL-TDOA | DL-TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | ideal | time domain | Ideal+1%error | Ideal+10%error | time domain | ideal | time domain |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | NA | NA | NA | NA | NA | NA | NA |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | Cost functions | Cost functions | Cost functions | Cost functions | Cost functions | Cost functions | Cost functions |
| Multipath mitigation techniques  (e.g., first path detection, ...) | NA | NA | NA | NA | NA | NA | NA |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single measurement in DL | Single measurement in DL | Single measurement in DL | Single measurement in DL | Single measurement in DL | Single measurement in DL | Single measurement in DL |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Taylor series | Taylor series | Taylor series | Taylor series | Taylor series | Taylor series | Taylor series |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns |
| UE/TRP Initial phase offset |  |  |  |  |  |  |  |
| CFO/Doppler | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Oscillator-drifts* | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ARP errors | 0 | 0 | 0 | 0 | [-2,+2] | 0 | 0 |
| Phase Center Offsets | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Phase noise (FR2) | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Additional notes, if any |  |  |  |  |  |  |  |
| PRU assumptions (Note 1) | No PRUs | No PRUIs | No PRUs | No PRUs | No PRUs | No PRUs | No PRUs |
| Note 1: PRU deployment assumptions may include the assumptions on the number of PRUs, PRU locations, location errors, etc. | | | | | | | |

Table B.4.A.1-3: NR carrier phase positioning enhancements - evaluation scenarios and parameters from [87]

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **[Case 11], [InF-SH]** | **[Case 22], [InF-SH]** | **[Case 23], [InF-SCH]** |
| Scenario  [TS 38.855, TS 38.857] | TR 38.357 | TR 38.357 | TR 38.357 |
| Single carrier frequency, or multiple carrier frequencies, GHz | Single,  3 GHz | Single,  3 GHz | Single,  3 GHz |
| Bandwidth, MHz | 10 MHz | 10 MHz | 10 MHz |
| Subcarrier spacing, kHz | 30 kHz | 30 kHz | 30 kHz |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | DL PRS + Pos SRS  Comb = 1 | DL PRS + Pos SRS  Comb = 4  Same sub-carrier in symbols of slot | DL PRS + Pos SRS  Comb = 4  Sub-carrier offset between symbols of slot |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | DL + UL round-trip carrier phase + slope estimate  Trilateration | DL + UL round-trip carrier phase + slope estimate  Trilateration | DL + UL round-trip carrier phase  Trilateration |
| R16/R17 positioning method  (if it is used together with CPP) | N/A | N/A | N/A |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | Frequency Domain | Frequency Domain | Frequency Domain |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | Round trip carrier phase | Round trip carrier phase | Round trip carrier phase |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | Slope of carrier phase | Round trip carrier phase | Round trip carrier phase |
| Multipath mitigation techniques  (e.g., first path detection, ...) | First path detection | First path detection | First path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single measurement in DL + Single measurement in UL | Single measurement in DL + Single measurement in UL | Single measurement in DL + Single measurement in UL |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Least squares for slope | Least squares for slope | Least squares for slope |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | N/A (single TRP) | N/A (single TRP) | N/A (single TRP) |
| UE/TRP Initial phase offset |  |  |  |
| CFO/Doppler | 0 | 0 | 0 |
| *Oscillator-drifts* | 0 | 0 | 0 |
| ARP errors | 0 | 0 | 0 |
| Phase Center Offsets | 0 | 0 | 0 |
| Phase noise (FR2) | N/A | N/A | N/A |
| Additional notes, if any |  |  |  |
| PRU assumptions (Note 1) | No PRUs | No PRUIs | No PRUs |
| Note 1: PRU deployment assumptions may include the assumptions on the number of PRUs, PRU locations, location errors, etc. | | | |

### B.4.5.2 Positioning accuracy evaluation results for NR Carrier Phase Positioning

Table B.4.5.2-1 provides horizontal positioning accuracy results using NR carrier phase positioning for scenarios described in Table B.4.A.1-1.

Table B.4.5.2-2 provides horizontal positioning accuracy results using NR carrier phase positioning for scenarios described in Table B.4.A.1-2.

Table B.4.5.2-3 provides horizontal positioning accuracy results using NR carrier phase positioning for scenarios described in Table B.4.A.1-3.

Table B.4.5.2-1: NR carrier phase positioning - horizontal accuracy from [87].

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **[Case ID], [Scenario]**  **[additional descriptions]** | **50%** | **67%** | **80%** | **90%** | **Met 1cm accuracy @ 80%-ile of UEs?**  **(Yes/No)** | **Additional comments** |
| [Case 01], [InF-SH], [Round-trip carrier phase with Comb-1] | 0.0010 @ 5m  0.0023 @ 20m  0.0044 @ 50m | 0.0017 @ 5m  0.0038 @ 20m  0.0065 @ 50m | 0.0023 @ 5m  0.0054 @ 20m  0.008 @ 50m | 0.003 @ 5m  0.008 @ 20m  0.012 @ 50m | Y @ 5m  Y @ 20m  Y @50m | 5m/20m/50m is distance between UE & TRP |
| [Case 02], [InF-SH], [Round-trip carrier phase with Comb-4 no offset hoping between symbols] | 0.0018 @ 5m  0.0052 @ 20m  0.0095 @ 50m | 0.0027 @ 5m  0.0086 @ 20m  0.0131 @ 50m | 0.0041 @ 5m  0.0111 @ 20m  0.0166 @ 50m | 0.006 @ 5m  0.014 @ 20m  0.025 @ 50m | Y @ 5m  N @ 20m  N @50m | 5m/20m/50m is distance between UE & TRP |
| [Case 03], [InF-SH], [Round-trip carrier phase with Comb-4 with offset hoping between symbols] | 0.0030 @ 5m  0.0095 @ 20m  0.013 @ 50m | 0.0047 @ 5m  0.0131@ 20m  0.020 @ 50m | 0.0063 @ 5m  0.016@ 20m  0.027 @ 50m | 0.012 @ 5m  0.025@ 20m  0.040 @ 50m | Y @ 5m  N @ 20m  N @50m | 5m/20m/50m is distance between UE & TRP |

Table B.4.5.2-2: NR carrier phase positioning - horizontal accuracy from [87].

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **[Case ID], [Scenario] [additional descriptions]** | **50%** | **67%** | **80%** | **90%** | **Met 1cm accuracy @ 50%-ile or 80%-ile of the UEs?**  **(Yes/No)** | | **Additional comments** |
| **[X=1] cm**  **@50%** | **[Y=1] cm**  **@80%** |
| Case 04, InF-SH,  100MHz, perfect phase | 0.001 | 0.002 | 0.003 | 0.7 | Yes | Yes |  |
| Case 05, InF-SH,  100MHz, time domain estimated phase | 0.001 | 0.35 | 1.06 | 1.68 | Yes | No |  |
| Case 06, InF-SH,  100MHz, perfect phase +1%error | 0.001 | 0.003 | 0.87 | 1.51 | Yes | No |  |
| Case 07, InF-SH,  100MHz, perfect phase +10%error | 0.98 | 1.21 | 1.47 | 1.92 | No | No |  |
| Case 08, InF-SH,  100MHz, time domain estimated phase, TRP error [-2, 2]cm | 1.06 | 1.28 | 1.54 | 2.02 | No | No |  |
| Case 09, InF-SH,  20MHz, perfect phase | 0.001 | 0.002 | 1.34 | 2.47 | Yes | No |  |
| Case 10, InF-SH,  20MHz, time domain estimated phase, no integer ambiguity | 0.03 | 0.04 | 0.05 | 0.06 | No | No | Assuming ideal integer number |

Table B.4.5.2-3: NR carrier phase positioning - horizontal accuracy from [87].

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **[Case ID], [Scenario]**  **[additional descriptions]** | **50%** | **67%** | **80%** | **90%** | **Met 1cm @ 80%?**  **(Yes/No)** | **Additional comments** |
| [Case 11], [InF-SH], [Round-trip carrier phase with Comb-1] | 0.2 | 0.34 | 0.5 | 0.7 | Yes |  |
| [Case 12], [InF-SH], [Round-trip carrier phase with Comb-4 no offset hoping between symbols] | 0.52 | 0.79 | 1.04 | 1.45 | Marginal |  |
| [Case 13], [InF-SH], [Round-trip carrier phase with Comb-4 with offset hoping between symbols] | 0.68 | 0,98 | 1.51 | 2.02 | No |  |

Figure B.4.5.2-1 provides horizontal positioning accuracy CDF using NR carrier phase positioning for scenarios described in Table B.4.5.1-3.

Chart

Description automatically generated

Figure B.4.5.2-1: NR carrier phase positioning - horizontal CDF from [87] for scenarios described in Table B.4.5.1-3.

## B.4.6 Results from source [85]

### B.4.6.1 Description of evaluation scenarios

Evaluation scenarios, key technologies, and assumptions for performance analysis of NR carrier phase positioning with the initial phase offset are provided in Table B.4.6.1-1.

Evaluation scenarios, key technologies, and assumptions for performance analysis of NR carrier phase positioning with the CFO and Oscillator-drift are provided in Table B.4.6.1-2.

Evaluation scenarios, key technologies, and assumptions for performance analysis of NR carrier phase positioning with the TRP ARP error are provided in Table B.4.6.1-3.

Evaluation scenarios, key technologies, and assumptions for performance analysis of NR carrier phase positioning in perfect scenarios are provided in Table B.4.6.1-4.

Table B.4.6.1-1: NR carrier phase positioning enhancements - evaluation scenarios and parameters with the initial phase offset from [85]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **[Case 1-1-1], [InF-SH]** | **[Case 1-1-2], [InF-SH]** | **[Case 1-1-3], [InF-SH]** | **[Case 1-1-4], [InF-SH]** | **[Case 1-1-5], [InF-SH]** | **[Case 1-1-6], [InF-SH]** | **[Case 1-1-7], [InF-SH]** | **[Case 1-1-8], [InF-SH]** |
| Scenario  [TR 38.855, TR 38.857] | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 |
| Single carrier frequency, or multiple carrier frequencies, GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz |
| Bandwidth, MHz | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Subcarrier spacing, kHz | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | DL | DL | DL | DL | DL | DL | DL | DL |
| R16/R17 positioning method  (if it is used together with CPP) | TDOA | TDOA | TDOA | TDOA | TDOA | TDOA | TDOA | TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | Single differential | Single differential | Single differential | Single differential | Single differential | Single differential | Single differential | Single differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error |
| Multipath mitigation techniques  (e.g., first path detection, ...) | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Least squares | Least squares | Least squares | Least squares | Least squares | Least squares | Least squares | Least squares |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns |
| UE/TRP Initial phase offset | [0,0.001]\* 2π | [0,0.005]\* 2π | [0,0.01]\* 2π | [0,0.02]\* 2π | [0,0.04]\* 2π | [0,0.06]\* 2π | [0,0.08]\* 2π | [0,0.1]\* 2π |
| CFO/Doppler | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Oscillator-drifts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ARP errors | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Phase Center Offsets | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Phase noise (FR2) | None | None | None | None | None | None | None | None |
| PRU assumptions and additional notes, if any | Without PRU | | | | | | | |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **[Case 1-1-9], [InF-SH]** | **[Case 1-1-10], [InF-SH]** | **[Case 1-1-11], [InF-SH]** | **[Case 1-2-1], [InF-DH]** | **[Case 1-2-2], [InF-SH]** | **[Case 1-2-3], [InF-SH]** | **[Case 1-2-4], [InF-SH]** | | **[Case 1-2-5], [InF-DH]** |
| Scenario  [TR 38.855, TR 38.857] | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 | | 38.857 |
| Single carrier frequency, or multiple carrier frequencies, GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | | Single  3.5 GHz |
| Bandwidth, MHz | 100 | 100 | 100 | 100 | 100 | 100 | 100 | | 100 |
| Subcarrier spacing, kHz | 30 | 30 | 30 | 30 | 30 | 30 | 30 | | 30 |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | | PRS (2 symbols,  Comb-2) |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | DL | DL | DL | DL | DL | DL | DL | | DL |
| R16/R17 positioning method  (if it is used together with CPP) | TDOA | TDOA | TDOA | TDOA | TDOA | TDOA | TDOA | | TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging | | Freq-domain, with averaging |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | Single differential | Single differential | Dual differential | Dual differential | Dual differential | Dual differential | Dual differential | | Dual differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error  integer ambiguity limited to ±1 | Cost function, with least distance error  integer ambiguity limited to ±2 | | Cost function, with least distance error |
| Multipath mitigation techniques  (e.g., first path detection, ...) | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection | | first path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP | | Single-measurement instance CPP |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Least squares | Least squares | Least squares | Least squares | Least squares | Least squares | Least squares | | Least squares |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns | | 0ns |
| UE/TRP Initial phase offset | [0,0.2]\* 2π | [0,1]\* 2π | [0,1]\* 2π | 0 | 0 | 0 | 0 | | [0,1]\*2π |
| CFO/Doppler | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| Oscillator-drifts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| ARP errors | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| Phase Center Offsets | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| Phase noise (FR2) | None | None | None | None | None | None | None | | None |
| PRU assumptions and additional notes, if any | Without PRU | Without PRU | With PRU | With PRU | With PRU | With PRU | With PRU | With PRU | |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **[Case 1-2-6], [InF-SH]** | **[Case 1-2-7], [InF-SH]** | **[Case 1-2-8], [InF-SH]** | **[Case 1-2-9], [InF-sH]** | **[Case 1-3-1], [InF-SH]** | **[Case 1-3-2], [InF-SH]** | **[Case 1-3-3], [InF-SH]** | **[Case 1-3-4], [InF-SH]** |
| Scenario  [TR 38.855, TR 38.857] | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 |
| Single carrier frequency, or multiple carrier frequencies, GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Multiple subcarriers in one PFL  3.5GHz | Multiple subcarriers in different PFL  3.5GHz | Multiple subcarriers in different PFL  3.5GHz | Multiple subcarriers in different PFL  3.5GHz | Multiple subcarriers in different PFL  3.5GHz |
| Bandwidth, MHz | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Subcarrier spacing, kHz | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | DL | DL | DL | DL | DL | DL | DL | DL |
| R16/R17 positioning method  (if it is used together with CPP) | TDOA | TDOA | TDOA | TDOA | TDOA | TDOA | TDOA | TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | Dual differential | Dual differential | Dual differential | Single differential | Single differential | Single differential | Single differential | Single differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | Cost function, with least distance error | Cost function, with least distance error  integer ambiguity limited to ±1 | Cost function, with least distance error  integer ambiguity limited to ±2 | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error |
| Multipath mitigation techniques  (e.g., first path detection, ...) | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Least squares | Least squares | Least squares | Least squares | Least squares | Least squares | Least squares | Least squares |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns |
| UE/TRP Initial phase offset | [0,1]\*2π | [0,1]\* 2π | [0,1]\* 2π | [0,1]\*2π | Time offset 0ns | Time offset 0.5ns | Time offset 1ns | Time offset 2ns |
| CFO/Doppler | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Oscillator-drifts | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ARP errors | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Phase Center Offsets | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Phase noise (FR2) | None | None | None | None | None | None | None | None |
| PRU assumptions and additional notes, if any | With PRU | With PRU | With PRU | Without PRU | Without PRU  The time offset of different PFLs may exert initial phase offset to UE/TRP side. | | | |

Table B.4.6.1-2: NR carrier phase positioning enhancements - evaluation scenarios and parameters with the CFO and Oscillator-drift from [85]

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **[Case 2-1-1], [InF-SH]** | **[Case 2-1-2], [InF-SH]** | **[Case 2-1-3], [InF-SH]** | **[Case 2-1-4], [InF-SH]** | **[Case 2-2-1], [InF-SH]** | **[Case 2-2-2], [InF-SH]** | **[Case 2-2-3], [InF-SH]** |
| Scenario  [TR 38.855, TR 38.857] | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 |
| Single carrier frequency, or multiple carrier frequencies, GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz |
| Bandwidth, MHz | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Subcarrier spacing, kHz | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | DL | DL | DL | DL | DL | DL | DL |
| R16/R17 positioning method  (if it is used together with CPP) | TDOA | TDOA | TDOA | TDOA | TDOA | TDOA | TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | Single differential | Single differential | Single differential | Single differential | Single differential | Single differential | Single differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error |
| Multipath mitigation techniques  (e.g., first path detection, ...) | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Least squares | Least squares | Least squares | Least squares | Least squares | Least squares | Least squares |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns |
| UE/TRP Initial phase offset | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CFO/Doppler | [-100, +100] Hz | [-1000, +1000] Hz | [-4000, +4000] Hz | [-8000, +8000] Hz | [-50, +50] Hz | [-100, +100] Hz | [-1000, +1000] Hz |
| Oscillator-drifts | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ARP errors | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Phase Center Offsets | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Phase noise (FR2) | None | None | None | None | None | None | None |
| PRU assumptions and additional notes, if any | Perfect CP estimation | | | | Practical CP estimation | | |

Table B.4.6.1-3: NR carrier phase positioning enhancements - evaluation scenarios and parameters with the TRP ARP error from [85]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **[Case 3-1-1], [InF-SH]** | **[Case 3-1-2], [InF-SH]** | **[Case 3-1-3], [InF-SH]** | **[Case 3-1-4], [InF-SH]** | **[Case 3-1-5], [InF-SH]** | **[Case 3-1-6], [InF-SH]** |
| Scenario  [TR 38.855, TR 38.857] | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 |
| Single carrier frequency, or multiple carrier frequencies, GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Multiple subcarriers in one PFL  3.5GHz | Multiple subcarriers in one PFL  3.5GHz | Multiple subcarriers in one PFL  3.5GHz |
| Bandwidth, MHz | 100 | 100 | 100 | 100 | 100 | 100 |
| Subcarrier spacing, kHz | 30 | 30 | 30 | 30 | 30 | 30 |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | DL | DL | DL | DL | DL | DL |
| R16/R17 positioning method  (if it is used together with CPP) | TDOA | TDOA | TDOA | TDOA | TDOA | TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | Single differential | Single differential | Single differential | Dual differential | Dual differential | Dual differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error |
| Multipath mitigation techniques  (e.g., first path detection, ...) | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Least squares | Least squares | Least squares | Least squares | Least squares | Least squares |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns |
| UE/TRP Initial phase offset | 0 | 0 | 0 | 0 | 0 | 0 |
| CFO/Doppler | 0 | 0 | 0 | 0 | 0 | 0 |
| Oscillator-drifts | 0 | 0 | 0 | 0 | 0 | 0 |
| ARP errors | T=1 | T=2 | T=5 | T=1 | T=2 | T=5 |
| Phase Center Offsets | 0 | 0 | 0 | 0 | 0 | 0 |
| Phase noise (FR2) | None | None | None | None | None | None |
| PRU assumptions and additional notes, if any | Perfect CP estimation  Note for ARP error: a zero-mean, truncated Gaussian distribution with zero mean and standard deviation of T=[1, 5] cm truncated to 2T | | | | | |
| **Parameter** | **[Case 3-2-1], [InF-SH]** | **[Case 3-2-2], [InF-SH]** | **[Case 3-2-3], [InF-SH]** | **[Case 3-2-4], [InF-SH]** | **[Case 3-2-5], [InF-SH]** | **[Case 3-2-6], [InF-SH]** |
| Scenario  [TR 38.855, TR 38.857] | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 | 38.857 |
| Single carrier frequency, or multiple carrier frequencies, GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Multiple subcarriers in one PFL  3.5GHz | Multiple subcarriers in one PFL  3.5GHz | Multiple subcarriers in one PFL  3.5GHz |
| Bandwidth, MHz | 100 | 100 | 100 | 100 | 100 | 100 |
| Subcarrier spacing, kHz | 30 | 30 | 30 | 30 | 30 | 30 |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | DL | DL | DL | DL | DL | DL |
| R16/R17 positioning method  (if it is used together with CPP) | TDOA | TDOA | TDOA | TDOA | TDOA | TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | Single differential | Single differential | Single differential | Dual differential | Dual differential | Dual differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error |
| Multipath mitigation techniques  (e.g., first path detection, ...) | first path detection | first path detection | first path detection | first path detection | first path detection | first path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Least squares | Least squares | Least squares | Least squares | Least squares | Least squares |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns |
| UE/TRP Initial phase offset | 0 | 0 | 0 | 0 | 0 | 0 |
| CFO/Doppler | 0 | 0 | 0 | 0 | 0 | 0 |
| Oscillator-drifts | 0 | 0 | 0 | 0 | 0 | 0 |
| ARP errors | T=1 | T=2 | T=5 | T=1 | T=2 | T=5 |
| Phase Center Offsets | 0 | 0 | 0 | 0 | 0 | 0 |
| Phase noise (FR2) | None | None | None | None | None | None |
| PRU assumptions and additional notes, if any | Practical CP estimation  Note for ARP error: a zero-mean, truncated Gaussian distribution with zero mean and standard deviation of T=[1, 5] cm truncated to 2T | | | | | |

Table B.4.6.1-4: NR carrier phase positioning enhancements - evaluation scenarios and parameters in perfect scenarios from [85]

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **[Case 4-1-1], [InF-SH]** | **[Case 4-1-2], [InF-SH]** | **[Case 4-2-1], [InF-DH]** |
| Scenario  [TR 38.855, TR 38.857] | 38.857 | 38.857 | 38.857 |
| Single carrier frequency, or multiple carrier frequencies, GHz | Multiple subcarriers in one PFL  3.5GHz | Single  3.5 GHz | Single  3.5 GHz |
| Bandwidth, MHz | 100 | 100 | 100 |
| Subcarrier spacing, kHz | 30 | 30 | 30 |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) | PRS (2 symbols,  Comb-2) |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | DL | DL | DL |
| R16/R17 positioning method  (if it is used together with CPP) | TDOA | TDOA | TDOA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | Freq-domain, with averaging | Freq-domain, with averaging | Freq-domain, with averaging |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | Dual differential | Single differential | Single differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | Cost function, with least distance error | Cost function, with least distance error | Cost function, with least distance error |
| Multipath mitigation techniques  (e.g., first path detection, ...) | first path detection | first path detection | first path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Least squares | Least squares | Least squares |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0ns | 0ns | 0ns |
| UE/TRP Initial phase offset | 0 | 0 | 0 |
| CFO/Doppler | 0 | 0 | 0 |
| Oscillator-drifts | 0 | 0 | 0 |
| ARP errors | 0 | 0 | 0 |
| Phase Center Offsets | 0 | 0 | 0 |
| Phase noise (FR2) | None | None | None |
| PRU assumptions and additional notes, if any | None | None | None |

### B.4.6.2 Positioning accuracy evaluation results for NR Carrier Phase Positioning

Table B.4.6.2-1 provides horizontal positioning accuracy results using NR carrier phase positioning with the initial phase offset.

Table B.4.6.2-2 provides horizontal positioning accuracy results using NR carrier phase positioning with the CFO and Oscillator-drift.

Table B.4.6.2-3 provides horizontal positioning accuracy results using NR carrier phase positioning with the TRP ARP error.

Table B.4.6.2-4 provides horizontal positioning accuracy results using NR carrier phase positioning in perfect scenarios.

Table B.4.6.2-1: NR carrier phase positioning - horizontal accuracy with the initial phase offset from [85]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **[Case ID], [Scenario] [additional descriptions]** | **50%** | **67%** | **80%** | **90%** | **Met 1cm accuracy @ 50%-ile or 80%-ile of the UEs?**  **(Yes/No)** | |
| **[X=1] cm**  **@50%** | **[Y=1] cm**  **@80%** |
| Case ID=1-1-1, [InF-SH], [Phase offset [0,0.001]\* 2π] | 0 | 0 | 0.105 | 0.205 | Yes | No |
| Case ID=1-1-2, [InF-SH], [Phase offset [0,0.005]\* 2π] | 0 | 0 | 0.105 | 0.211 | Yes | No |
| Case ID=1-1-3, [InF-SH], [Phase offset [0,0.01]\* 2π] | 0 | 0.002 | 0.158 | 0.243 | Yes | No |
| Case ID=1-1-4, [InF-SH], [Phase offset [0,0.02]\* 2π] | 0.002 | 0.048 | 0.201 | 0.338 | Yes | No |
| Case ID=1-1-5, [InF-SH], [Phase offset [0,0.04]\* 2π] | 0.092 | 0.241 | 0.556 | 0.782 | No | No |
| Case ID=1-1-6, [InF-SH], [Phase offset [0,0.06]\* 2π] | 0.224 | 0.392 | 0.685 | 0.837 | No | No |
| Case ID=1-1-7, [InF-SH], [Phase offset [0,0.08]\* 2π] | 0.317 | 0.598 | 0.767 | 0.895 | No | No |
| Case ID=1-1-8, [InF-SH], [Phase offset [0,0.1]\* 2π] | 0.424 | 0.609 | 0.778 | 0.944 | No | No |
| Case ID=1-1-9, [InF-SH], [Phase offset [0,0.2]\* 2π] | 0.530 | 0.704 | 0.843 | 0.931 | No | No |
| Case ID=1-1-10, [InF-SH], [Phase offset [0,1]\* 2π without PRU Phase error is at gNB.] | 0.306 | 0.379 | 0.444 | 0.520 | No | No |
| Case ID=1-1-11, [InF-SH], [Phase offset [0,1]\* 2π with PRU Phase error is at gNB.] | 0.065 | 0.174 | 0.275 | 0.471 | No | No |
| Case ID=1-2-1, [InF-DH], [Phase offset 0 with PRU] without integer ambiguity limitation | 0.513 | 0.611 | 0.821 | 1.036 | No | No |
| Case ID=1-2-2, [InF-SH], [Phase offset 0 with PRU] without integer ambiguity limitation | 0.100 | 0.219 | 0.347 | 0.494 | No | No |
| Case ID=1-2-3, [InF-SH], [Phase offset 0 with integer ambiguity limited to ±1] | 0.003 | 0.008 | 0.043 | 0.090 | Yes | No |
| Case ID=1-2-4, [InF-SH], [Phase offset 0 with integer ambiguity limited to ±2] | 0.015 | 0.193 | 0.294 | 0.396 | No | No |
| Case ID=1-2-5, [InF-DH], [Phase offset [0,1]\*2π with PRU] without integer ambiguity limitation | 0.552 | 0.694 | 0.903 | 1.250 | No | No |
| Case ID=1-2-6, [InF-SH], [Phase offset [0,1]\*2π with PRU] without integer ambiguity limitation | 0.136 | 0.273 | 0.462 | 0.595 | No | No |
| Case ID=1-2-7, [InF-SH], [Phase offset [0,1]\*2π with integer ambiguity limited to ±1] | 0.008 | 0.036 | 0.067 | 0.105 | Yes | No |
| Case ID=1-2-8, [InF-SH], [Phase offset [0,1]\*2π with integer ambiguity limited to ±2] | 0.129 | 0.261 | 0.327 | 0.388 | No | No |
| Case ID=1-2-9, [InF-SH], [Phase offset [0,1]\*2π with multiple subcarriers within one PFL] | 0.120 | 0.161 | 0.253 | 0.411 | No | No |
| Case ID=1-3-1, [InF-SH], [Time offset 0ns with multiple subcarriers within different PFL] | 0.135 | 0.239 | 0.966 | 3.468 | No | No |
| Case ID=1-3-2, [InF-SH], [Time offset 0.5ns with multiple subcarriers within different PFL] | 0.129 | 0.231 | 2.797 | 3.515 | No | No |
| Case ID=1-3-3, [InF-SH], [Time offset 1ns with multiple subcarriers within different PFL] | 0.105 | 0.177 | 0.460 | 3.174 | No | No |
| Case ID=1-3-4, [InF-SH], [Time offset 2ns with multiple subcarriers within different PFL] | 0.127 | 0.249 | 1.604 | 3.294 | No | No |

Table B.4.6.2-2: NR carrier phase positioning - horizontal accuracy with with the CFO and Oscillator-drift from [85]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **[Case ID], [Scenario] [additional descriptions]** | **50%** | **67%** | **80%** | **90%** | **Met 1cm accuracy @ 50%-ile or 80%-ile of the UEs?**  **(Yes/No)** | |
| **[X=1] cm**  **@50%** | **[Y=1] cm**  **@80%** |
| Case ID=2-1-1, [InF-SH], [for CFO/Doppler [-100, +100] Hz with perfect CP] | 0 | 0 | 0.116 | 0.205 | Yes | No |
| Case ID=2-1-2, [InF-SH], [for CFO/Doppler[-1000, +1000] Hz with perfect CP] | 0 | 0 | 0.123 | 0.210 | Yes | No |
| Case ID=2-1-3, [InF-SH], [for CFO/Doppler[-4000, +4000] Hz with perfect CP] | 0 | 0 | 0.049 | 0.192 | Yes | No |
| Case ID=2-1-4, [InF-SH], [for CFO/Doppler[-8000, +8000] Hz with perfect CP] | 0 | 0 | 0 | 0.144 | Yes | Yes |
| Case ID=2-2-1, [InF-SH], [for CFO/Doppler[-50, +50] Hz with practical CP] | 0.003 | 0.148 | 0.244 | 0.376 | Yes | No |
| Case ID=2-2-2, [InF-SH], [for CFO/Doppler[-100, +100] Hz with practical CP] | 0.003 | 0.148 | 0.244 | 0.376 | Yes | No |
| Case ID=2-2-3, [InF-SH], [for CFO/Doppler[-1000, +1000] Hz with practical CP] | 0.003 | 0.148 | 0.244 | 0.376 | Yes | No |

Table B.4.6.2-3: NR carrier phase positioning - horizontal accuracy with with the ARP error from [85]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **[Case ID], [Scenario] [additional descriptions]** | **50%** | **67%** | **80%** | **90%** | **Met 1cm accuracy @ 50%-ile or 80%-ile of the UEs?**  **(Yes/No)** | |
| **[X=1] cm**  **@50%** | **[Y=1] cm**  **@80%** |
| Case ID=3-1-1, [InF-SH], [for ARP error T=1 with perfect single CP] | 0.512 | 0.694 | 0.854 | 0.922 | No | No |
| Case ID=3-1-2, [InF-SH], [for ARP error T=2 with perfect single CP] | 0.532 | 0.726 | 0.867 | 0.991 | No | No |
| Case ID=3-1-3, [InF-SH], [for ARP error T=5 with perfect single CP] | 0.669 | 0.838 | 0.959 | 1.071 | No | No |
| Case ID=3-1-4, [InF-SH], [for ARP error T=1 with perfect dual CP] | 0.015 | 0.026 | 0.133 | 0.214 | No | No |
| Case ID=3-1-5, [InF-SH], [for ARP error T=2 with perfect dual CP] | 0.030 | 0.051 | 0.140 | 0.216 | No | No |
| Case ID=3-1-6, [InF-SH], [for ARP error T=5 with perfect dual CP] | 0.076 | 0.122 | 0.158 | 0.235 | No | No |
| Case ID=3-2-1, [InF-SH], [for ARP error T=1 with practical single CP] | 0.243 | 0.354 | 0.440 | 0.526 | No | No |
| Case ID=3-2-2, [InF-SH], [for ARP error T=2 with practical single CP] | 0.303 | 0.376 | 0.477 | 0.598 | No | No |
| Case ID=3-2-3, [InF-SH], [for ARP error T=5 with practical single CP] | 0.280 | 0.378 | 0.443 | 0.515 | No | No |
| Case ID=3-2-4, [InF-SH], [for ARP error T=1 with practical dual CP] | 0.116 | 0.171 | 0.251 | 0.403 | No | No |
| Case ID=3-2-5, [InF-SH], [for ARP error T=2 with practical dual CP] | 0.118 | 0.174 | 0.245 | 0.394 | No | No |
| Case ID=3-2-6, [InF-SH], [for ARP error T=5 with practical dual CP] | 0.153 | 0.214 | 0.297 | 0.496 | No | No |

Table B.4.6.2-4: NR carrier phase positioning - horizontal accuracy in perfect scenarios from [85]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **[Case ID], [Scenario] [additional descriptions]** | **50%** | **67%** | **80%** | **90%** | **Met 1cm accuracy @ 50%-ile or 80%-ile of the UEs?**  **(Yes/No)** | |
| **[X=1] cm**  **@50%** | **[Y=1] cm**  **@80%** |
| Case ID=4-1-1, [InF-SH],[Multiple subcarriers in one PFL] | 0.110 | 0.185 | 0.513 | 3.174 | No | No |
| Case ID=4-1-2, [InF-SH],[Single carriers] | 0.003 | 0.116 | 0.211 | 0.346 | Yes | No |
| Case ID=4-2-1, [InF-DH],[Single carriers] | 0.332 | 0.438 | 0.656 | 0.778 | No | No |

Figure B.4.6.2-1 to Figure B.4.6.2-4 provide horizontal positioning accuracy results using NR carrier phase positioning with different initial phase errors.

Figure B.4.6.2-5 provides horizontal positioning accuracy results using NR carrier phase positioning with different CFO errors.

Figure B.4.6.2-6 and Figure B.4.6.2-7 provide horizontal positioning accuracy results using NR carrier phase positioning with different ARP errors.



Figure B.4.6.2-1: Positioning accuracy with different phase errors [without PRU] (cases 1-1-1 to 1-1-9)



Figure B.4.6.2-2: Positioning accuracy with different phase errors [with PRU & without integer ambiguity limitation] (cases 1-2-1, 1-2-2, 1-2-5, 1-2-6)



Figure B.4.6.2-3: Positioning accuracy with different phase errors [with PRU & with integer ambiguity limitation (left: N is limited to ±1, right: N is limited to ±2)] (cases 1-2-3, 1-2-4, 1-2-7, 1-2-8)



Figure B.4.6.2-4: Positioning accuracy with different phase errors [with PRU & with multiple subcarriers in different PFL] (cases 1-3-1 to 1-3-4)



Figure B.4.6.2-5: Positioning accuracy with different CFO (cases 2-2-1 to 2-2-3)

Figure B.4.6.2-6: Positioning accuracy with different ARP errors [Perfect CP] (cases 3-1-1 to 3-1-6)

Figure B.4.6.2-7: Positioning accuracy with different ARP errors [Practical CP] (cases 3-2-1 to 3-2-6)

## B.4.7 Results from source [88]

### B.4.7.1 Description of evaluation scenarios

Evaluation scenarios, key techniques, and assumptions for performance analysis of NR carrier phase positioning are provided in Table B.4.7.1-1.

Table B.4.7.1-1: NR carrier phase positioning - evaluation scenarios and parameters [88]

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Case 1 (InF-SH, FR2, 28 GHz, 400 MHz)** | **Case 2 (InF-SH, FR2, 28 GHz, 400 MHz)** | **Case 3 (InF-SH, FR2, 28 GHz, 400 MHz)** | **Case 4 (InF-SH, FR2, 28 GHz, 400 MHz)** | **Case 5 (InF-SH, FR2, 28 GHz, 400 MHz)** | **Case 6 (InF-SH, FR2, 28 GHz, 400 MHz)** | **Case 7 (InF-SH, FR2, 28 GHz, 400 MHz)** | **Case 8 (InF-SH, FR2, 28 GHz, 400 MHz)** | **Case 9 (InF-SH, FR2, 28 GHz, 400 MHz)** |
| Channel model (baseline, otherwise state any modifications) | InF-SH | InF-SH | InF-SH | InF-SH | InF-SH | InF-SH | InF-SH | InF-SH | InF-SH |
| Carrier frequency | 28 GHz | 28 GHz | 28 GHz | 28 GHz | 28 GHz | 28 GHz | 28 GHz | 28 GHz | 28 GHz |
| Subcarrier spacing | 120 KHz | 120 KHz | 120 KHz | 120 KHz | 120 KHz | 120 KHz | 120 KHz | 120 KHz | 120 KHz |
| Reference Signal Transmission Bandwidth | 400 MHz | 400 MHz | 400 MHz | 400 MHz | 400 MHz | 400 MHz | 400 MHz | 400 MHz | 400 MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | Comb-2/2 symbols | Comb-2/2 symbols | Comb-2/2 symbols | Comb-2/2 symbols | Comb-2/2 symbols | Comb-2/2 symbols | Comb-2/2 symbols | Comb-2/2 symbols | Comb-2/2 symbols |
| Number of sites | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| Number of symbols used per occasion | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| number of occasions used per positioning estimate | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Power-boosting level | 0 dB | 0 dB | 0 dB | 0 dB | 0 dB | 0 dB | 0 dB | 0 dB | 0 dB |
| interference modelling (ideal muting, or other) | Ideal muting | Ideal muting | Ideal muting | Ideal muting | Ideal muting | Ideal muting | Ideal muting | Ideal muting | Ideal muting |
| Description of Measurement Algorithm (e.g. super resolution, interference cancellation, ….) | IFFT-based Thresholding , Phase estimation of the first path in CIR | IFFT-based Thresholding , Phase estimation of the first path in CIR | IFFT-based Thresholding , Phase estimation of the first path in CIR | IFFT-based Thresholding , Phase estimation of the first path in CIR | IFFT-based Thresholding , Phase estimation of the first path in CIR | IFFT-based Thresholding , Phase estimation of the first path in CIR | IFFT-based Thresholding , Phase estimation of the first path in CIR | IFFT-based Thresholding , Phase estimation of the first path in CIR | IFFT-based Thresholding , Phase estimation of the first path in CIR |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) | TDoA, RANSAC, Brute-force based IAR | TDoA, RANSAC, Brute-force based IAR | TDoA, RANSAC, Brute-force based IAR | TDoA, RANSAC, Brute-force based IAR | TDoA, RANSAC, Brute-force based IAR | TDoA, RANSAC, Brute-force based IAR | TDoA, RANSAC, Brute-force based IAR | TDoA, RANSAC, Brute-force based IAR | TDoA, RANSAC, Brute-force based IAR |
| UE antenna configuration | Rel-17 InF-SH | Rel-17 InF-SH | Rel-17 InF-SH | Rel-17 InF-SH | Rel-17 InF-SH | Rel-17 InF-SH | Rel-17 InF-SH | Rel-17 InF-SH | Rel-17 InF-SH |
| UE antenna phase response | Ideal (Uniform on the sphere) | Ideal (Uniform on the sphere) | Ideal (Uniform on the sphere) | Ideal (Uniform on the sphere) | Ideal (Uniform on the sphere) | Ideal (Uniform on the sphere) | Ideal (Uniform on the sphere) | Ideal (Uniform on the sphere) | Ideal (Uniform on the sphere) |
| gNB antenna configuration | Rel-17 InF-SH | Rel-17 InF-SH | Rel-17 InF-SH | Rel-17 InF-SH | Rel-17 InF-SH | Rel-17 InF-SH | Rel-17 InF-SH | Rel-17 InF-SH | Rel-17 InF-SH |
| gNB antenna phase response | Ideal (Uniform on the sphere) | Ideal (Uniform on the sphere) | Ideal (Uniform on the sphere) | Ideal (Uniform on the sphere) | Ideal (Uniform on the sphere) | Ideal (Uniform on the sphere) | Ideal (Uniform on the sphere) | Ideal (Uniform on the sphere) | Ideal (Uniform on the sphere) |
| PRU Drop and selection | #Common LOS links | #Common LOS links | #Common LOS links | #Common LOS links | #Common LOS links | Randomly dropped within UE proximity | #Common LOS links | #Common LOS links | #Common LOS links |
| Potential enhancements | None | None | None | None | None | None | None | Wide lane combination using 2 100 MHz sub-bands within one compoment carrier | Wide lane combination using 2X [100 200] MHz sub-bands within one compoment carrier |
| Error modeled | None | Residual Doppler:  D = [2 4 8 16] Hz | Residual CFO:  UE = [120 400] Hz, TRP = 40 Hz | Phase center offset: a = [0 1 3], w = [2 5] | PRU location error:  T = [0.01 0.05]m | TRP location error:  T = [0.01] m  PRU-UE range:  R = [0 0.0001 0001 0.01 0.1 1] m | Residual Doppler D = 2Hz, Residual TRP CFO 40Hz,  Residual UE CFO 120Hz, Phase center offset Modeling with a = 1, and X in U{-2,2],   PRU & TRP location error modeling with T = 1cm | None | None |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Case 10 (InF-SH, FR1, 4 GHz, 100 MHz)** | **Case 11 (InF-SH, FR1, 4 GHz, 100 MHz, CFO Error)** | **Case 12 (InF-SH, FR1, 4 GHz, 100 MHz, CPO Modelling)** | **Case 13 (InF-SH, FR1, 4 GHz, 100 MHz, PRU Location Error)** | **Case 14 (InF-SH, FR1, 4 GHz, 100 MHz, TRP Location Error)** | **Case 15 (InF-SH, FR1, 4 GHz, 100 MHz, Combined Errors)** |
| Channel model (baseline, otherwise state any modifications) | InF-SH | InF-SH | InF-SH | InF-SH | InF-SH | InF-SH |
| Carrier frequency | 4 GHz | 4 GHz | 4 GHz | 4 GHz | 4 GHz | 4 GHz |
| Subcarrier spacing | 30 KHz | 30 KHz | 30 KHz | 30 KHz | 30 KHz | 30 KHz |
| Reference Signal Transmission Bandwidth | 100 MHz | 100 MHz | 100 MHz | 100 MHz | 100 MHz | 100 MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | Comb-2/2 symbols | Comb-2/2 symbols | Comb-2/2 symbols | Comb-2/2 symbols | Comb-2/2 symbols | Comb-2/2 symbols |
| Number of sites | 18 | 18 | 18 | 18 | 18 | 18 |
| Number of symbols used per occasion | 2 | 2 | 2 | 2 | 2 | 2 |
| number of occasions used per positioning estimate | 1 | 1 | 1 | 1 | 1 | 1 |
| Power-boosting level | 0 dB | 0 dB | 0 dB | 0 dB | 0 dB | 0 dB |
| interference modelling (ideal muting, or other) | Ideal muting | Ideal muting | Ideal muting | Ideal muting | Ideal muting | Ideal muting |
| Description of Measurement Algorithm (e.g. super resolution, interference cancellation, ….) | IFFT-based Thresholding , Phase estimation of the first path in CIR | IFFT-based Thresholding , Phase estimation of the first path in CIR | IFFT-based Thresholding , Phase estimation of the first path in CIR | IFFT-based Thresholding , Phase estimation of the first path in CIR | IFFT-based Thresholding , Phase estimation of the first path in CIR | IFFT-based Thresholding , Phase estimation of the first path in CIR |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) | TDoA, RANSAC, Brute-force based IAR | TDoA, RANSAC, Brute-force based IAR | TDoA, RANSAC, Brute-force based IAR | TDoA, RANSAC, Brute-force based IAR | TDoA, RANSAC, Brute-force based IAR | TDoA, RANSAC, Brute-force based IAR |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | Unprecoded Transmission | Unprecoded Transmission | Unprecoded Transmission | Unprecoded Transmission | Unprecoded Transmission | Unprecoded Transmission |
| UE antenna configuration | Rel-17 InF-SH | Rel-17 InF-SH | Rel-17 InF-SH | Rel-17 InF-SH | Rel-17 InF-SH | Rel-17 InF-SH |
| UE antenna phase response | Ideal (Uniform on the sphere) | Ideal (Uniform on the sphere) | CPO a=1, X=2  CPO a=3, X=2  CPO a=1, X=5  CPO a=3, X=5 | Ideal (Uniform on the sphere) | Ideal (Uniform on the sphere) | Ideal (Uniform on the sphere) |
| gNB antenna configuration | Rel-17 InF-SH | Rel-17 InF-SH | Rel-17 InF-SH | Rel-17 InF-SH | Rel-17 InF-SH | Rel-17 InF-SH |
| gNB antenna phase response | Ideal (Uniform on the sphere) | Ideal (Uniform on the sphere) | CPO a=1, X=2  CPO a=3, X=2  CPO a=1, X=5  CPO a=3, X=5 | Ideal (Uniform on the sphere) | Ideal (Uniform on the sphere) | Ideal (Uniform on the sphere) |
| PRU Drop and selection | Nearest | Nearest | Nearest | Nearest | Nearest | Nearest |
| Potential enhancements | None | None | None | None | None | None |
| Modeled error | None | UE residual CFO [-30,30] Hz, [-100,100] Hz | None | PRU location error: T = {1, } cm | TRP location error: T = 1 cm | CFO, PCO, PRU Loc Error |

### B.4.7.2 Positioning accuracy evaluation results for NR Carrier Phase Positioning

Table B.4.7.2-1 provides accuracy results using NR carrier phase positioning.

Table B.4.7.2-1: Carrier phase evaluation results (horizontal positioning accuracy in meters)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Case | Other modeling details | 50% [m] | 80% [m] | 90% [m] |
| Case 1 Ideal | Ideal | 0.00002 | 0.00005 | 0.00087 |
| Case 2 Doppler | D =2 | 0.00002 | 0.00010 | 0.00052 |
| D=4 | 0.00002 | 0.00008 | 0.00125 |
| D = 8 | 0.00004 | 0.00015 | 0.00128 |
| D= 16 | 0.00007 | 0.00029 | 0.00130 |
| Case 3 CFO | TRP CFO = 40Hz,  UE CFO = 120Hz | 0.00026 | 0.00075 | 0.02207 |
| TRP CFO = 40Hz,  UE CFO = 400Hz | 0.00071 | 0.00204 | 0.02778 |
| Case 4 PCV | a = 0, w = 2 | 0.00006 | 0.00030 | 0.00131 |
| a = 0, w = 5 | 0.00014 | 0.00063 | 0.02106 |
| a = 1, w = 2 | 0.00006 | 0.00019 | 0.00089 |
| a = 1, w = 5 | 0.00015 | 0.00076 | 0.02231 |
| a = 3, w = 2 | 0.00006 | 0.00032 | 0.02089 |
| a = 3, w = 5 | 0.00014 | 0.00064 | 0.00270 |
| Case 5 PRU location error | T = 0.01 | 0.04228 | 0.07777 | 0.11134 |
| T= 0.05 | 0.07749 | 0.14225 | 0.21780 |
| Case 6 TRP location error | R = 0.0001 | 0.00004 | 0.00055 | 0.01432 |
| R = 0.001 | 0.01067 | 0.05380 | 0.10185 |
| R = 0.01 | 0.03436 | 0.08498 | 0.13299 |
| R = 0.1 | 0.03474 | 0.07303 | 0.12629 |
| R = 1 | 0.03487 | 0.07907 | 0.12454 |
| Case 7 All combined |  | 0.10837 | 0.17721 | 0.27778 |
| Case 8 wide-lane | 2 X 100MHz | 0.05526 | 1.42119 | 3.25750 |
| Case 9 narrow-lane | 2 X 100MHz | 0.00003 | 0.00027 | 0.01181 |
| 2 X 200MHz | 0.00003 | 0.00013 | 0.00093 |
| Case 10 (InF-SH, FR1, 4 GHz, 100 MHz) | Ideal | 0.012 | 0.065 | 0.13 |
| Case 11 (InF-SH, FR1, 4 GHz, 100 MHz, CFO Error) | UE residual CFO [-30,30] Hz | 0.012 | 0.067 | 0.13 |
| UE residual CFO [-100,100] Hz | 0.016 | 0.069 | 0.13 |
| Case 12 (InF-SH, FR1, 4 GHz, 100 MHz, CPO Modelling) | CPO a=1, X=2 | 0.02 | 0.07 | 0.13 |
| CPO a=3, X=2 | 0.022 | 0.07 | 0.13 |
| CPO a=1, X=5 | 0.04 | 0.08 | 0.13 |
| CPO a=3, X=5 | 0.04 | 0.08 | 0.13 |
| Case 13 (InF-SH, FR1, 4 GHz, 100 MHz, PRU Location Error) | PRU location error: T = 1 cm | 0.02 | 0.07 | 0.13 |
| PRU location error: T = 5 cm | 0.05 | 0.08 | 0.13 |
| Case 14 (InF-SH, FR1, 4 GHz, 100 MHz, TRP Location Error) | TRP location error: T = 1 cm | 0.05 | 0.12 | 0.18 |
| Case 15 (InF-SH, FR1, 4 GHz, 100 MHz, Combined Errors) | UE residual CFO [-30,30] Hz  CPO a=1, X=2  PRU location error: T = 1 cm | 0.04 | 0.07 | 0.15 |

## B.4.8 Results from source [89]

### B.4.8.1 Description of evaluation scenarios

The case 1 and case 2 in the evaluation results capture the effects of multi-path, and initial phase offset, respectively, on the carrier phase measurement under the assumption of ideal integer ambiguity resolution for the InF-DH scenario for FR1 operations.

The case 3 in the evaluation results captures the gains of using the carrier phase measured over multiple subcarriers for distance estimation over the carrier phase measured over a single carrier/subcarrier for distance estimation in the InF-DH scenario for FR1 operation.

Evaluation scenarios, key techniques, and assumptions for performance analysis of NR carrier phase positioning are provided in Table B.4.8.1-1.

Table B.4.8.1-1: NR positioning enhancements - evaluation scenarios and parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Case1,InF-DH** | **Case2, InF-DH** | **Case 3, InF-DH** |
| Scenario  [TS 38.855, TS 38.857] | InF-DH | InF-DH | InF-DH |
| Single carrier frequency, or multiple carrier frequencies, GHz | 3.5GHz | 3.5GHz | 3.5GHz |
| Bandwidth, MHz | 100MHz | 100MHz | 100MHz |
| Subcarrier spacing, kHz | 30KHz | 30KHz | 30KHz |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | PRS | PRS | PRS |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | DL | DL | DL |
| R16/R17 positioning method  (if it is used together with CPP) | - | - | - |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | Frequency Domain  Single carrier frequency | Frequency Domain  Single carrier frequency | Frequency Domain  Multiple subcarrier frequencies |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | NA | NA | NA |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | Ideal (accurate IAR) | Ideal (accurate IAR) | Ideal (accurate IAR) |
| Multipath mitigation techniques  (e.g., first path detection, ...) | First path detection | First path detection | First path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | NA | NA | NA |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | Perfect | Perfect | Perfect |
| UE/TRP Initial phase offset | Not considered | Assumed to be uniformly distributed between [0,2pi] | Not considered |
| CFO/Doppler | Not considered | Not considered | Not considered |
| *Oscillator-drifts* | Not considered | Not considered | Not considered |
| ARP errors | Not considered | Not considered | Not considered |
| Phase Center Offsets | Not considered | Not considered | Not considered |
| Phase noise (FR2) | Not considered | Not considered | Not considered |
| Additional notes, if any |  |  |  |

### B.4.8.2 Positioning accuracy evaluation results for NR Carrier Phase Positioning

Table B.4.8.2-1 provides distance accuracy results using NR carrier phase positioning for scenarios described in table B.4.8.1-1.

Table B.4.8.2-1 NR carrier phase positioning - distance accuracy

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **[Case ID], [Scenario]**  **[additional descriptions]** | **50%** | **67%** | **80%** | **90%** | **Met 1cm accuracy @ 50%-ile or 80%-ile of the UEs?**  **(Y/N)** | | **Additional comments** |
| **[X = 1 cm, 50%]** | **[X = 1 cm, 80%]** |
| Case 1, InF\_DH, multipath effect | 0.8cm | 2 cm | 5.2cm | 6.8cm | Yes | No | Results without considering the initial phase offset |
| Case 2, InF\_DH,  Initial phase offset | 3.3cm | 4.8cm | 5.9cm | 6.8cm | No | No | Results after considering the initial phase offset |
| Case 3, InF\_DH,  Single multicarrier method | 0.44cm | .50cm | 0.55cm | 0.63cm | Yes | Yes | Single and multi subcarrier based methods |

Figure B.4.8.2-1 provides distance accuracy CDF using NR carrier phase positioning for scenarios described in Table B.4.8.1-1 case 1.

Figure B.4.8.2-2 provides distance accuracy CDF using NR carrier phase positioning for scenarios described in Table B.4.8.1-1 case 2.

Figure B.4.8.2-3 provides distance accuracy CDF using NR carrier phase positioning for scenarios described in Table B.4.8.1-1 case 3.

Chart, line chart

Description automatically generated

Figure B.4.8.2-1: Results show the effect of the LOS-NLOS condition of the link between gNB and UE on carrier phase measurement in the InF-DH scenario.

Chart, line chart

Description automatically generated

Figure B.4.8.2-2: Results show the effect of initial phase offset between gNB and UE on carrier phase measurement in the InF-DH scenario.

Chart, line chart

Description automatically generated

Figure B.4.8.2-3: Results show the effect of single and multiple subcarrier based carrier phase measurement in InF-DH scenario.

## B.4.9 Results from source [86]

### B.4.9.1 Description of evaluation scenarios

Evaluation scenarios, key techniques, and assumptions for performance analysis of NR carrier phase positioning are provided in Table B.4.9.1-1.

Table B.4.9.1-1: NR positioning enhancements - evaluation scenarios and parameters

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **[Case 1],**  **[InF-SH]** | **[Case 2],**  **[InF-SH]** | **[Case 3],**  **[InF-SH]** | **[Case 4],**  **[InF-SH]** | **[Case 5],**  **[InF-SH]** | **[Case 6],**  **[InF-SH]** | **[Case 7],**  **[InF-SH]** |
| Scenario  [TS 38.855, TS 38.857] | 38.855 | 38.855 | 38.855 | 38.855 | 38.855 | 38.855 | 38.855 |
| Single carrier frequency, or multiple carrier frequencies, GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz | Single  3.5 GHz |
| Bandwidth, MHz | 20 | 50 | 100 | 100 | 100 | 100 | 100 |
| Subcarrier spacing, kHz | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | DL PRS,  2 symbols with Comb-2 | DL PRS,  2 symbols with Comb-2 | DL PRS,  2 symbols with Comb-2 | DL PRS,  2 symbols with Comb-2 | DL PRS,  2 symbols with Comb-2 | DL PRS,  2 symbols with Comb-2 | DL PRS,  2 symbols with Comb-2 |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | DL | DL | DL | None | DL | DL | DL |
| R16/R17 positioning method  (if it is used together with CPP) | ToA(Note 1) | ToA(Note 1) | ToA(Note 1) | TDoA | TDoA | TDoA | TDoA |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | Freq-domain | Freq-domain | Freq-domain | Freq-domain | Freq-domain | Freq-domain | Freq-domain |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | Single Differential | Single Differential | Single Differential | Double Differential | Double Differential | Double Differential | Double Differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | Cost function | Cost function | Cost function | Brute-force based IAR | Brute-force based IAR | Brute-force based IAR | Brute-force based IAR |
| Multipath mitigation techniques  (e.g., first path detection, ...) | First path detection | First path detection | First path detection | First path detection | First path detection | First path detection | First path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single measurement | Single measurement | Single measurement | Single measurement | Single measurement | Single measurement | Single measurement |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Least square | Least square | Least square | Least square | Least square | Least square | Least square |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns | 0ns |
| UE/TRP Initial phase offset | none | none | none | none | none | none | none |
| CFO/Doppler | none | none | none | none | 30Hz | 100Hz | none |
| *Oscillator-drifts* | none | none | none | none | none | None | none |
| ARP errors | none | none | none | none | none | none | 1cm |
| Phase Center Offsets | none | none | none | none | none | none | none |
| Phase noise (FR2) | none | none | none | none | none | none | none |
| PRU Assumptions | None | None | None | PRU with LOS condition is available | PRU with LOS condition is available | PRU with LOS condition is available | PRU with LOS condition is available |
| Additional notes, if any | Note 1:To estimate DL ToA based on carrier phase differentials across multiple subcarriers within a carrier is used | Note 1:To estimate DL ToA based on carrier phase differentials across multiple subcarriers within a carrier is used | Note 1:To estimate DL ToA based on carrier phase differentials across multiple subcarriers within a carrier is used |  |  |  |  |

### B.4.9.2 Positioning accuracy evaluation results for NR Carrier Phase Positioning

Table B.4.9.2-1 provides horizontal / vertical positioning accuracy results using NR carrier phase.

Table B.4.9.2-1: NR carrier phase positioning – horizontal/vertical accuracy

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **[Case ID], [Scenario] [additional descriptions]** | **50%** | **67%** | **80%** | **90%** | **Additional comments** |
|
| Case 1, InF-SH,  20MHz, SD CPP, Horizontal | 0.003m | 0.780m | - | - |  |
| Case 1, InF-SH,  20MHz, SD CPP, Vertical | 0.019m | 0.645m | - | - |  |
| Case 2, InF-SH,  50MHz, SD CPP, Horizontal | 0.001m | 0.001m | 0.003m | 0.170m |  |
| Case 2, InF-SH,  50MHz, SD CPP, Vertical | 0.003m | 0.007m | 0.016m | 0.529m |  |
| Case 3, InF-SH,  100MHz, SD CPP, Horizontal | 0.001m | 0.001m | 0.002m | 0.003m |  |
| Case 3, InF-SH,  100MHz, SD CPP, Vertical | 0.003m | 0.005m | 0.009m | 0.016m |  |
| Case 4, InF-SH,  100MHz, Baseline TDoA, Vertical | 0.0449m | 0.0704m | 0.1065m | 0.1775m |  |
| Case 5, InF-SH,  100MHz, DD CPP, Ideal | 0.0010m | 0.0021m | 0.0046m | 0.0226m |  |
| Case 6, InF-SH,  100MHz, DD CPP, CFO 30Hz | 0.0018m | 0.0051m | 0.0208m | 0.1736m |  |
| Case 7, InF-SH,  100MHz, DD CPP, CFO 100Hz | 0.0027m | 0.0067m | 0.0440m | 0.2168m |  |
| Case 8, InF-SH,  100MHz, DD CPP, ARP 1cm | 0.1880m | 0.2737m | 0.3860m | 0.5538m |  |

## B.4.10 Results from source [90]

### B.4.10.1 Description of evaluation scenarios

The simulation results presented here focus on the impact of PRU density and ARP errors. Evaluation scenarios, key techniques, and assumptions for performance analysis of NR carrier phase positioning are provided in Table B.4.10.1-1. Notice that the evaluations are performed with Hybrid UL-TDOA and CPP based positioning, where in a first step, UL-TDOA is used to estimate a rough UE position which is later refined by carrier phase-based methodology.

Table B.4.10.1-1 NR positioning enhancements - evaluation scenarios and parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Case 1** | **Case 2** | **Case 3** |
| Scenario  [TS 38.855, TS 38.857] | InF-SH | InF-SH | InF-SH |
| Single carrier frequency, or multiple carrier frequencies, GHz | Single carrier frequency | Single carrier frequency | Single carrier frequency |
| Bandwidth, MHz | 100 MHz | 100 MHz | 100 MHz |
| Subcarrier spacing, kHz | 30 kHz | 30 kHz | 30 kHz |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | UL-SRS for positioning, 4 OFDM symbols, Comb 4, Tx Power boosting (23 dBm) | UL-SRS for positioning, 4 OFDM symbols, Comb 4, Tx Power boosting (23 dBm) | UL-SRS for positioning, 4 OFDM symbols, Comb 4, Tx Power boosting (23 dBm) |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | UL | UL | UL |
| R16/R17 positioning method  (if it is used together with CPP) | Hybrid positioning with UL-TDOA providing initial coarse UE position estimate | Hybrid positioning with UL-TDOA providing initial coarse UE position estimate | Hybrid positioning with UL-TDOA providing initial coarse UE position estimate |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | Time domain \*\* | Time domain \*\* | Time domain \*\* |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | Double-differentiation using PRU. PRU deployment density is configurable. | Double-differentiation using PRU. PRU deployment density is configurable. | Double-differentiation using PRU. PRU deployment density is configurable. |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | Multi-hypothesis IAR\* | Multi-hypothesis IAR\* | Multi-hypothesis IAR\* |
| Multipath mitigation techniques  (e.g., first path detection, ...) | First path detection | First path detection | First path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Robust (to outliers) least squares | Robust (to outliers) least squares | Robust (to outliers) least squares |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | For UL-TDOA we assume no sync. errors (for coarse UE position). | For UL-TDOA we assume no sync. errors (for coarse UE position). | For UL-TDOA we assume no sync. errors (for coarse UE position). |
| UE/TRP Initial phase offset | Random uniform [0 2pi] | Random uniform [0 2pi] | Random uniform [0 2pi] |
| CFO/Doppler | No | No | No |
| *Oscillator-drifts* | No | No | No |
| ARP errors | No | No | No |
| Phase Center Offsets | No | No | No |
| Phase noise (FR2) | No | No | No |
| Additional notes, if any | Distance from target UE to PRU is 1m | Distance from target UE to PRU is 3m | Distance from target UE to PRU is 5m |
| (\*) The Multi-hypothesis IAR we use is described in [90].  (\*\*) The carrier phase is estimated from the complex argument of the estimated channel impulse response at the time delay of the first peak. See [90] for details. | | | |

Table B.4.10.1-2 NR positioning enhancements - evaluation scenarios and parameters

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Case 4** | **Case 5** | **Case 6** |
| Scenario  [TS 38.855, TS 38.857] | InF-SH | InF-SH | InF-SH |
| Single carrier frequency, or multiple carrier frequencies, GHz | Single carrier frequency | Single carrier frequency | Single carrier frequency |
| Bandwidth, MHz | 100 MHz | 100 MHz | 100 MHz |
| Subcarrier spacing, kHz | 30 kHz | 30 kHz | 30 kHz |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | UL-SRS for positioning, 4 OFDM symbols, Comb 4, Tx Power boosting (23 dBm) | UL-SRS for positioning, 4 OFDM symbols, Comb 4, Tx Power boosting (23 dBm) | UL-SRS for positioning, 4 OFDM symbols, Comb 4, Tx Power boosting (23 dBm) |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | UL | UL | UL |
| R16/R17 positioning method  (if it is used together with CPP) | Hybrid positioning with UL-TDOA providing initial coarse UE position estimate | Hybrid positioning with UL-TDOA providing initial coarse UE position estimate | Hybrid positioning with UL-TDOA providing initial coarse UE position estimate |
| Carrier phase estimation techniques  (time-domain, freq-domain, references) | Time domain \*\* | Time domain \*\* | Time domain \*\* |
| Differential positioning techniques if used  (e.g., single differential, double differential, etc.) | Double-differentiation using PRU. PRU deployment density is configurable. | Double-differentiation using PRU. PRU deployment density is configurable. | Double-differentiation using PRU. PRU deployment density is configurable. |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions, Least squares, …) | Multi-hypothesis IAR\* | Multi-hypothesis IAR\* | Multi-hypothesis IAR\* |
| Multipath mitigation techniques  (e.g., first path detection, ...) | First path detection | First path detection | First path detection |
| Single-measurement instance CPP, or multiple measurement instances CPP | Single-measurement instance CPP | Single-measurement instance CPP | Single-measurement instance CPP |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Robust (to outliers) least squares | Robust (to outliers) least squares | Robust (to outliers) least squares |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | For UL-TDOA we assume no sync. errors (for coarse UE position). | For UL-TDOA we assume no sync. errors (for coarse UE position). | For UL-TDOA we assume no sync. errors (for coarse UE position). |
| UE/TRP Initial phase offset | Random uniform [0 2pi] | Random uniform [0 2pi] | Random uniform [0 2pi] |
| CFO/Doppler | No | No | No |
| *Oscillator-drifts* | No | No | No |
| ARP errors | Yes, 1 cm | Yes, 2 cm | Yes, 5 cm |
| Phase Center Offsets | No | No | No |
| Phase noise (FR2) | No | No | No |
| Additional notes, if any | Distance from target UE to PRU is 1m | Distance from target UE to PRU is 1m | Distance from target UE to PRU is 1m |

### B.4.10.2 Positioning accuracy evaluation results for NR Carrier Phase Positioning

Table B.4.10.2-1 provides accuracy results using NR carrier phase positioning

Table B.4.10.2-1 NR carrier phase positioning - distance accuracy in meters.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| [Case ID], [Scenario]  [additional descriptions] | 50% | 67% | 80% | 90% | **Met 1cm accuracy @ 50%-ile or 80%-ile of the UEs?** | | Additional comments |
| **50%** | **80%** |
| Case 1, PRU to UE distance 1m | 0.007 | 0.011 | 0.018 | 0.105 | Yes | No |  |
| Case 2, PRU to UE distance 3m | 0.114 | 0.382 | 0.529 | 0.675 | No | No |  |
| Case 3, PRU to UE distance 5m | 0.442 | 0.571 | 0.686 | 0.821 | No | No |  |
| Case 4, ARP Error 1cm | 0.018 | 0.023 | 0.030 | 0.167 | No | No |  |
| Case 5, ARP Error 2cm | 0.038 | 0.045 | 0.066 | 0.402 | No | No |  |
| Case 6, ARP Error 5cm | 0.100 | 0.164 | 0.438 | 0.662 | No | No |  |

Figures B.4.10.2-1 and B.4.10.2-2 provide distance accuracy CDF using NR carrier phase positioning for case 1-3 and case 4-6, respectively.

Chart

Description automatically generated

Figure B.4.10.2-1: Positioning accuracy, Hybrid UL-TDOA and UL CPP based positioning. Due to spatial channel variations the positioning performance is better if the PRU is nearby.

Chart

Description automatically generated

Figure B.4.10.2-2: Positioning error CDFs, Hybrid UL-TDOA and UL CPP based positioning with ARP errors.