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# B.6 Evaluation results for positioning for RedCap UEs

## B.6.1 Results from source [128]

### B.6.1.1 Description of evaluation scenarios

Evaluation assumptions for system level analysis are provided in Table B.6.1.1-1

Table B.6.1.1-1: NR RedCap positioning - evaluation scenarios and parameters

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | Case 1 (UMI, FR1,700 MHz, 20 MHz, RTT) | Case 2 (UMI, FR1,700 MHz, 5 MHz, RTT) | Case 3 (InF-SH, FR1,700 MHz, 20 MHz, RTT) | Case 4 (InF-SH, FR1, 700 MHz, 5 MHz, RTT) | Case 5 (InF-SH, FR1, 700 MHz, 20 MHz, DL-AoD, 4 beams) |
| Channel model (baseline, otherwise state any modifications) | Umi | Umi | InF-SH | InF-SH | InF-SH |
| Carrier frequency | 700 MHz | 700 MHz | 700 MHz | 700 MHz | 700 MHz |
| Subcarrier spacing | 15 KHz | 15 KHz | 15 KHz | 15 KHz | 15 KHz |
| Reference Signal Transmission Bandwidth | 20 MHz | 5 MHz | 20 MHz | 5 MHz | 20 MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | Comb-12/12-symbols | Comb-12/12-symbols | Comb-12/12-symbols | Comb-12/12-symbols | Comb-12/12-symbols |
| Reference signal  (type of sequence, number of ports, …) | 1 port | 1 port | 1 port | 1 port | 1 port |
| Number of sites | 19 | 19 | 18 | 18 | 18 |
| Number of symbols used per occasion | 4 | 4 | 4 | 4 | 4 |
| number of occasions used per positioning estimate | 1 | 1 | 1 | 1 | 1 |
| Power-boosting level | 0 dB | 0 dB | 0 dB | 0 dB | 0 dB |
| Uplink power control (applied/not applied) | Not applied | Not applied | Not applied | Not applied | Not applied |
| interference modelling (ideal muting, or other) | Ideal muting | Ideal muting | Ideal muting | Ideal muting | Ideal muting |
| Description of Measurement Algorithm (e.g. super resolution, interference cancellation, ….) | IFFT-based Thresholding | IFFT-based Thresholding | IFFT-based Thresholding | IFFT-based Thresholding | IFFT-based Thresholding |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) | RANSAC, RTT | RANSAC, RTT | RANSAC, RTT | RANSAC, RTT | RANSAC, RTT |
| Network synchronization assumptions | Ideal | Ideal | Ideal | Ideal | Ideal |
| UE/gNB RX and TX timing error | Ideal | Ideal | Ideal | Ideal | Ideal |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | None | None | None | None | None |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | - | - | - | - | - |
| UE antenna configuration | (1, 1, 1, 1) | (1, 1, 1, 1) | (1, 1, 1, 1) | (1, 1, 1, 1) | (1, 1, 1, 1) |
| Number of UE branches | 1Rx 1Tx | 1Rx 1Tx | 1Rx 1Tx | 1Rx 1Tx | 1Rx 1Tx |
| Description of enhancement solutions, if any | - | - | - | - | - |
| gNB antenna configuration | (2,4,2) | (2,4,2) | (2,2,2) | (2,2,2) | (2,2,2) |
| UE noise figure | 9 dB | 9 dB | 9 dB | 9 dB | 9 dB |
| UE antenna height | 1.5m | 1.5m | 1.5m | 1.5m | 1.5m |
| gNB antenna height | 10m | 10m | 8m | 8m | 8m |
| Additional notes, if any | - | - | - | - | 4 PRS resources in each TRP |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Parameter | Case 6 (InF-SH, FR1, 700 MHz, 20 MHz, DL-AoD, 2 beams) | Case 7 (UMI, FR1,3.5 MHz, 20 MHz, RTT) | Case 8 (InF-SH, FR2, 28 GHz, 100 MHz, RTT) | Case 9 (UMI, FR1,3.5 MHz, 20 MHz, DL-TDOA, 4 Hops, 3 kmh) | Case 10 (UMI, FR1,3.5 MHz, 20 MHz, MRTT, 5 Hops, 3 kmh) | Case 11 (UMI, FR1,3.5 MHz, 20 MHz, MRTT, 5 Hops, 30 kmh) | Case 12 (UMI, FR1,3.5 MHz, 20 MHz, MRTT, 5 Hops, 60 kmh) |
| Channel model (baseline, otherwise state any modifications) | InF-SH | Umi | InF-SH | Umi | Umi | Umi | Umi |
| Carrier frequency | 700 MHz | 3.5 GHz | 28 GHz | 3.5 GHz | 3.5 GHz | 3.5 GHz | 3.5 GHz |
| Subcarrier spacing | 15 KHz | 30 KHz | 120 KHz | 30 KHz | 30 KHz | 30 KHz | 30 KHz |
| Reference Signal Transmission Bandwidth | 20 MHz | 20 MHz | 100 MHz | 20 MHz | 20 MHz | 20 MHz | 20 MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | Comb-12/12-symbols | Comb-12/12-symbols | Comb-2/2 symbols | Comb-12/12-symbols | Comb-12/12-symbols | Comb-12/12-symbols | Comb-12/12-symbols |
| Reference signal  (type of sequence, number of ports, …) | 1 port | 1 port | 1 port | 1 port | 1 port | 1 port | 1 port |
| Number of sites | 18 | 19 | 18 | 19 | 19 | 19 | 19 |
| Number of symbols used per occasion | 4 | 4 | 2 | 4 | 4 | 4 | 4 |
| number of occasions used per positioning estimate | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Power-boosting level | 0 dB | 0 dB | 0 dB | 0 dB | 0 dB | 0 dB | 0 dB |
| Uplink power control (applied/not applied) | Not applied | Not applied | Not applied | Not applied | Not applied | Not applied | Not applied |
| interference modelling (ideal muting, or other) | 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 | IFFT-based Thresholding | IFFT-based Thresholding | IFFT-based Thresholding | IFFT-based Thresholding | IFFT-based Thresholding | IFFT-based Thresholding |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) | RANSAC, RTT | RANSAC, RTT | RANSAC, TDoA | RANSAC, DL-TDOA | RANSAC, MRTT | RANSAC, MRTT | RANSAC, MRTT |
| Network synchronization assumptions | Ideal | Ideal | Ideal | Ideal | Ideal | Ideal | Ideal |
| UE/gNB RX and TX timing error | Ideal | Ideal | Ideal | Ideal | Ideal | Ideal | Ideal |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | None | None | None | None | None | None | None |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | - | - | - | - | - | - | - |
| UE antenna configuration | (1, 1, 1, 1) | (1, 1, 1, 1) | (4, 2, 2, 1) | (1, 1, 1, 1) | (1, 1, 1, 1) | (1, 1, 1, 1) | (1, 1, 1, 1) |
| Number of UE branches | 1Rx 1Tx | 1Rx 1Tx | 1Rx 1Tx | 1Rx 1Tx | 1Rx 1Tx | 1Rx 1Tx | 1Rx 1Tx |
| Description of enhancement solutions, if any | - | - | - | PRS/SRS frequency hopping | PRS/SRS frequency hopping | PRS/SRS frequency hopping | PRS/SRS frequency hopping |
| gNB antenna configuration | (2,2,2) | (2,16,2) | (4, 8, 2) | (2,16,2) | (2,16,2) | (2,16,2) | (2,16,2) |
| UE noise figure | 9 dB | 9 dB | 13 dB | 9 dB | 9 dB | 9 dB | 9 dB |
| UE antenna height | 1.5m | 1.5m | 1.5m | 1.5m | 1.5m | 1.5m | 1.5m |
| gNB antenna height | 8m | 10m | 8m | 10m | 10m | 10m | 10m |
| Additional notes, if any | 2 PRS resources in each TRP | - | 1 PRS resource in each TRP | - | - | - | - |

### B.6.1.2 Positioning accuracy evaluation results

Table B.6.1.2-1: NR positioning for Redcap UEs (baseline) - horizontal location error results from [128]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cases |  | 50% | 67% | 80% | 90% | Is Requirement met or not? |
| Case 1 (UMI, FR1,700 MHz, 20 MHz, RTT) | (Optional) All UEs | 2.5 m | 3 m | 4.5 m | 6 m | No |
| Convex UEs |  | | | |
| Case 2 (UMI, FR1,700 MHz, 5 MHz, RTT) | (Optional) All UEs | 8 m | 11 m | 13 m | 16 m | No |
| Convex UEs |  | | | |
| Case 3 (InF-SH, FR1,700 MHz, 20 MHz, RTT) | (Optional) All UEs |  | | | | No |
| Convex UEs | 1 m | 1.5 m | 2 m | 3 m |
| Case 4 (InF-SH, FR1, 700 MHz, 5 MHz, RTT) | (Optional) All UEs |  | | | | No |
| Convex UEs | 2 m | 7 m | 10 m | 20 m |
| Case 5 (InF-SH, FR1, 700 MHz, 20 MHz, DL-AoD, 4 beams) | (Optional) All UEs |  | | | | No |
| Convex UEs | 1 m | 1.8 m | 2.2 m | 3.5 m |
| Case 6 (InF-SH, FR1, 700 MHz, 20 MHz, DL-AoD, 2 beams) | (Optional) All UEs |  | | | | No |
| Convex UEs | 2.3 m | 4.2 m | 5 m | 6 m |
| Case 7 (UMI, FR1,3.5 MHz, 20 MHz, RTT) | (Optional) All UEs | 3.2 m | 7 m | 8 m | 15 m | No |
| Convex UEs |  | | | |
| Case 8 (InF-SH, FR2, 28 GHz, 100 MHz, RTT) | (Optional) All UEs | 0.03m | 0.05m | 0.08m | 0.17m | Yes |
| Convex UEs |  |  |  |  |
| Case 9 (UMI, FR1,3.5 MHz, 20 MHz, DL-TDOA, 4 Hops, 3 kmh) | (Optional) All UEs | 2.1 | 2.7 | 4.4 | 10.0 | No |
| Convex UEs |  |  |  |  |
| Case 10 (UMI, FR1,3.5 MHz, 20 MHz, MRTT, 5 Hops, 3 kmh) | (Optional) All UEs | 2.1 | 2.9 | 3.7 | 4.4 | No |
| Convex UEs |  |  |  |  |
| Case 11 (UMI, FR1,3.5 MHz, 20 MHz, MRTT, 5 Hops, 30 kmh) | (Optional) All UEs | 2.2 | 3.0 | 3.9 | 4.5 | No |
| Convex UEs |  |  |  |  |
| Case 12 (UMI, FR1,3.5 MHz, 20 MHz, MRTT, 5 Hops, 60 kmh) | (Optional) All UEs | 2.4 | 3.2 | 4.0 | 4.7 | No |
| Convex UEs |  |  |  |  |

Figures B.6.1.2-1 provides the results of the above cases:

Chart, line chart

Description automatically generated

Chart, line chart

Description automatically generated

Chart, line chart

Description automatically generated

Chart, line chart

Description automatically generated

A picture containing diagram

Description automatically generated

Chart, line chart

Description automatically generated

Chart

Description automatically generated

Figure B.6.1.2-1: Results for Case 1-12 from [128]

## B.6.2 Results from source [115]

### B.6.2.1 Description of evaluation scenarios

RedCap devices with 5 MHz bandwidth in InF-SH scenarios were evaluated for different assumptions.

Evaluation assumptions for system level analysis are provided in Table B.6.2.1-1

Table B.6.2.1-1: NR RedCap positioning - evaluation scenarios and parameters

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **Case 1, InF-SH, DL-TDOA** | **Case 2, InF-SH, DL-TDOA** | **Case 3, InF-SH, DL-TDOA** | **Case 4, InF-SH, DL-TDOA** |
| Channel model (baseline, otherwise state any modifications) | InF-SH | InF-SH | InF-SH | InF-SH |
| Carrier frequency | 3.5 GHz | 3.5 GHz | 3.5 GHz | 3.5 GHz |
| Subcarrier spacing | 15 kHz | 15 kHz | 15 kHz | 15 kHz |
| Reference Signal Transmission Bandwidth | 5 MHz | 5 MHz | 5 MHz | 5 MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | 6 symbol PRS with comb 6 | 6 symbol PRS with comb 6 | 6 symbol PRS with comb 6 | 6 symbol PRS with comb 6 |
| Reference signal  (type of sequence, number of ports, …) | DL PRS | DL PRS | DL PRS | DL PRS |
| Number of sites | 18 | 18 | 18 | 18 |
| Number of symbols used per occasion | 6 | 6 | 6 | 6 |
| number of occasions used per positioning estimate | 1 | 1 | 1 | 1 |
| Power-boosting level | 6 dB | 6 dB | 6 dB | 6 dB |
| Uplink power control (applied/not applied) | n/a | N/a | N/a | n/a |
| interference modelling (ideal muting, or other) | Ideal interference | Ideal interference | Ideal interference | Ideal interference |
| Description of Measurement Algorithm (e.g. super resolution, interference cancellation, ….) | ToA estimation with thresholding | ToA estimation with thresholding | ToA estimation with thresholding | ToA estimation with thresholding |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) | Taylor Series, Least Squares | Taylor Series, Least Squares | Taylor Series, Least Squares | Taylor Series, Least Squares |
| Network synchronization assumptions | Perfect Sync | Perfect Sync | Perfect Sync | Perfect Sync |
| UE/gNB RX and TX timing error | N/a | N/a | N/a | N/a |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | N/a | N/a | N/a | N/a |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | N/a | N/a | N/a | N/a |
| Evaluated enhancements | n/a | n/a | n/a | n/a |
| Additional notes, if any | All 18 TRPs used | 8 TRPs selected | All 18 TRPs used, 4x oversampling | 8 TRPs used, 4x oversampling |

### B.6.2.2 Positioning accuracy evaluation results

Evaluation summary results for the CDF curves of case 1-4 are shown below.

Table B.6.2.2-1 provides summary of the CDF curves.

Table B.6.2.2-1: Rel.16 NR positioning (baseline) - horizontal location error results from [115]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cases |  | 50% | 67% | 80% | 90% | Requirement Met |
| Case 1, InF-SH, DL-TDOA | Convex UEs | 6.737 | 8.432 | 15.12 | 18.45 | No |
| Case 2, InF-SH, DL-TDOA | Convex UEs | 6.4149 | 8.322 | 11.52 | 16.24 | No |
| Case 3, InF-SH, DL-TDOA | Convex UEs | 6.4379 | 8.309 | 14.6 | 17.52 | No |
| Case 4, InF-SH, DL-TDOA | Convex UEs | 6.519 | 7.589 | 10.53 | 13.68 | No |

Figures B.6.2.2-1 provides the results above in CDF curve form.

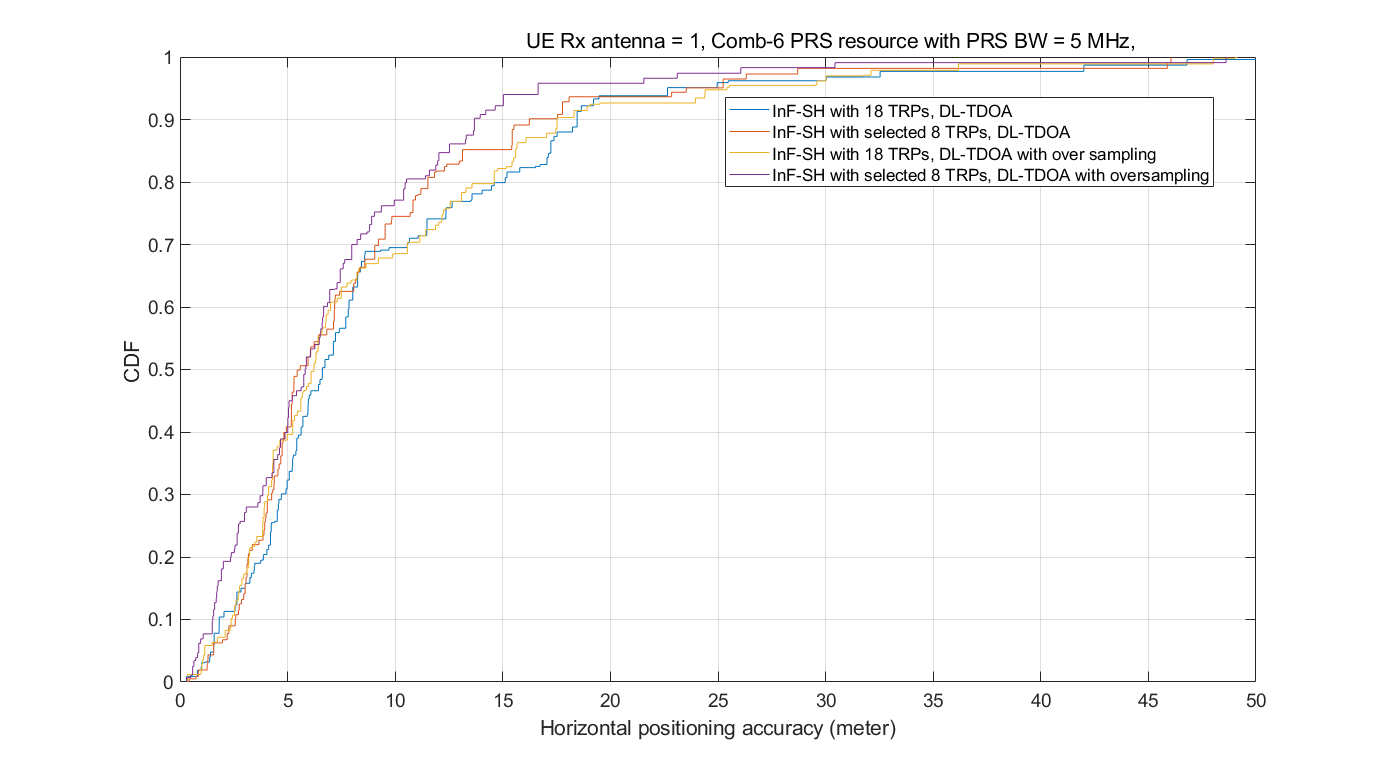


Figure B.6.2.2-1: Results from [115]

## B.6.3 Results from source [111]

### B.6.3.1 Description of evaluation scenarios

We consider an InF-SH (Indoor Factory, Sparse-clutter) scenario, where the clutter density is 20%, the clutter height is set as 2m, and the clutter size is 10m. Meanwhile, we also consider the UMi scenario according to 3GPP TR 38.901 (UMi scenario).

Evaluation assumptions for system level analysis for the baseline InF-SH scenario are provided in Table B.6.3.1-1.

Evaluation assumptions for system level analysis for the frequency hopping based enhancements with InF-SH UL-TDOA considering the time gap between hops and clock drift are provided in Table B.6.3.1-2.

Evaluation assumptions for system level analysis for the frequency hopping based enhancement with InF-SH DL-TDOA considering the time gap between hops and clock drift are provided in Table B.6.3.1-3.

Evaluation assumptions for system level analysis for the frequency hopping based enhancement with InF-SH UL-TDOA considering the UE speed are provided in Table B.6.3.1-4.

Evaluation assumptions for system level analysis for the frequency hopping based enhancement with InF-SH UL-TDOA considering the overlap size between consecutive hops are provided in Table B.6.3.1-5.

Evaluation assumptions for system level analysis for the frequency hopping based enhancement with UMi TDOA positioning are provided in Table B.6.3.1-6.

Table B.6.3.1-1: NR RedCap UE positioning - evaluation scenarios and parameters for baseline InF-SH from [111]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **Case 111 (InF-SH, FR1)** | **Case 112 (InF-SH, FR1)** | **Case 113 (UMi, FR1)** | **Case 114 (UMi, FR1)** |
| Scenario (baseline, otherwise state any modifications) | Baseline | Baseline | Baseline | Baseline |
| Carrier frequency | 3.5GHz | 3.5GHz | 0.7GHz | 0.7GHz |
| Subcarrier spacing | 30kHz | 30kHz | 30kHz | 30kHz |
| Reference Signal Transmission Bandwidth | 100MHz | 20MHz | 100MHz | 20MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | PosSRS (Comb-2, 1 symbol) | PosSRS (Comb-2, 1 symbol) | PosSRS (Comb-2, 1 symbol) | PosSRS (Comb-2, 1 symbol) |
| Reference signal  (type of sequence, number of ports, …) | ZC, single port | ZC, single port | ZC, single port | ZC, single port |
| Number of sites | 7 | 7 | 7 | 7 |
| Number of symbols used per occasion | 1 | 1 | 1 | 1 |
| number of occasions used per positioning estimate | 5 | 5 | 5 | 5 |
| Power-boosting level | 6dB | 6dB | 6dB | 6dB |
| Uplink power control (applied/not applied) | Not applied | Not applied | Not applied | Not applied |
| interference modelling (ideal muting, or other) | Ideal | Ideal | Ideal | Ideal |
| Description of Measurement Algorithm (e.g. super resolution, interference cancellation, ….) | Super resolution | Super resolution | Super resolution | Super resolution |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) | PSO | PSO | PSO | PSO |
| Network synchronization assumptions | Ideal | Ideal | Ideal | Ideal |
| UE/gNB RX and TX timing error | 0ns | 0ns | 0ns | 0ns |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | Tx beam sweeping | Tx beam sweeping | Tx beam sweeping | Tx beam sweeping |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | Tx codebook-based | Tx codebook-based | Tx codebook-based | Tx codebook-based |
| UE antenna configuration | (1,2,2,1,1) | (1,2,2,1,1) | (1,2,2,1,1) | (1,2,2,1,1) |
| Number of UE branches | 1 | 1 | 1 | 1 |
| Description of enhancement solutions, if any | No | No | No | No |
| gNB antenna configuration | (4,4,2,1,1) | (4,4,2,1,1) | (8,8,2,1,1) | (8,8,2,1,1) |
| UE antenna height | 1.5m | 1.5m | 1.5m | 1.5m |
| gNB antenna height | 8m | 8m | 10m | 10m |

Table B.6.3.1-2: NR RedCap UE positioning - evaluation scenarios and parameters for InF-SH UL-TDOA frequency hopping considering the time gap between hops and clock drift from [111]

|  |  |
| --- | --- |
| **Parameter** | **Case 211 ~221**  **(InF-SH, FR1)** |
| Scenario (baseline, otherwise state any modifications) | Baseline |
| Carrier frequency | 3.5GHz |
| Subcarrier spacing | 30kHz |
| Reference Signal Transmission Bandwidth | 20MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | PosSRS (Comb-2, 1 symbol) |
| Reference signal  (type of sequence, number of ports, …) | ZC, single port |
| Number of sites | 7 |
| Number of symbols used per occasion | 1 |
| number of occasions used per positioning estimate | 5 |
| Power-boosting level | 6dB |
| Uplink power control (applied/not applied) | Not applied |
| interference modelling (ideal muting, or other) | Ideal |
| Description of Measurement Algorithm (e.g. super resolution, interference cancellation, ….) | Super resolution |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) | PSO |
| Network synchronization assumptions | Ideal |
| UE/gNB RX and TX timing error | 0ns |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | Tx beam sweeping |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | Tx codebook-based |
| UE antenna configuration | (1,2,2,1,1) |
| Number of UE branches | 1 |
| Description of enhancement solutions, if any | No |
| gNB antenna configuration | (4,4,2,1,1) |
| UE antenna height | 1.5m |
| gNB antenna height | 8m |
| Time drift model | A truncated Gaussian distribution with mean = 0 and standard deviation = 0.1ns/1ms |
| Additional notes, if any | **Case 211:** w/o phase compensation  **Case 212:** w/ phase compensation, time gap: 140us, time drift: 0 ppm  **Case 213:** w/ phase compensation, time gap: 140us, time drift: 0.1 ppm  **Case 214:** w/ phase compensation, time gap: 250us, time drift: 0 ppm  **Case 215:** w/ phase compensation, time gap: 250us, time drift: 0.1 ppm  **Case 216:** w/ phase compensation, time gap: 0.5ms, time drift: 0 ppm  **Case 217:** w/ phase compensation, time gap: 0.5ms, time drift: 0.1 ppm  **Case 218:** w/ phase compensation, time gap: 1ms, time drift: 0 ppm  **Case 219:** w/ phase compensation, time gap: 1ms, time drift: 0.1 ppm  **Case 220:** w/ phase compensation, time gap: 5ms, time drift: 0 ppm  **Case 221:** w/ phase compensation, time gap: 5ms, time drift: 0.1 ppm |

Table B.6.3.1-3: NR RedCap UE positioning - evaluation scenarios and parameters for InF-SH DL-TDOA frequency hopping considering the time gap between hops and clock drift from [111]

|  |  |
| --- | --- |
| **Parameter** | **Case 311~321 (InF-SH, FR1)** |
| Scenario (baseline, otherwise state any modifications) | Baseline |
| Carrier frequency | 3.5GHz |
| Subcarrier spacing | 30kHz |
| Reference Signal Transmission Bandwidth | 20MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | PRS (Comb-2, 2 symbol) |
| Reference signal  (type of sequence, number of ports, …) | Gold, single port |
| Number of sites | 7 |
| Number of symbols used per occasion | 1 |
| number of occasions used per positioning estimate | 5 |
| Power-boosting level | 6dB |
| Uplink power control (applied/not applied) | Not applied |
| interference modelling (ideal muting, or other) | Ideal |
| Description of Measurement Algorithm (e.g. super resolution, interference cancellation, ….) | Super resolution |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) | PSO |
| Network synchronization assumptions | Ideal |
| UE/gNB RX and TX timing error | 0ns |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | Tx beam sweeping |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | Tx codebook-based |
| UE antenna configuration | (1,2,2,1,1) |
| Number of UE branches | 1 |
| Description of enhancement solutions, if any | No |
| gNB antenna configuration | (4,4,2,1,1) |
| UE antenna height | 1.5m |
| gNB antenna height | 8m |
| Time drift model | A truncated Gaussian distribution with mean = 0 and standard deviation = 0.1ns |
| Additional notes, if any | **Case 311:** w/o phase compensation  **Case 312:** w/ phase compensation, time gap: 140us, time drift: 0 ppm  **Case 313:** w/ phase compensation, time gap: 140us, time drift: 0.1 ppm  **Case 314:** w/ phase compensation, time gap: 250us, time drift: 0 ppm  **Case 315:** w/ phase compensation, time gap: 250us, time drift: 0.1 ppm  **Case 316:** w/ phase compensation, time gap: 0.5ms, time drift: 0 ppm  **Case 317:** w/ phase compensation, time gap: 0.5ms, time drift: 0.1 ppm  **Case 318:** w/ phase compensation, time gap: 1ms, time drift: 0 ppm  **Case 319:** w/ phase compensation, time gap: 1ms, time drift: 0.1 ppm  **Case 320:** w/ phase compensation, time gap: 5ms, time drift: 0 ppm  **Case 321:** w/ phase compensation, time gap: 5ms, time drift: 0.1 ppm |

Table B.6.3.1-4: NR RedCap UE positioning - evaluation scenarios and parameters for InF-SH UL-TDOA frequency hopping considering the UE speed from [111]

|  |  |
| --- | --- |
| **Parameter** | **Case 411 ~414**  **(InF-SH, FR1)** |
| Scenario (baseline, otherwise state any modifications) | Baseline |
| Carrier frequency | 3.5GHz |
| Subcarrier spacing | 30kHz |
| Reference Signal Transmission Bandwidth | 20MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | PosSRS (Comb-2, 1 symbol) |
| Reference signal  (type of sequence, number of ports, …) | ZC, single port |
| Number of sites | 7 |
| Number of symbols used per occasion | 1 |
| number of occasions used per positioning estimate | 5 |
| Power-boosting level | 6dB |
| Uplink power control (applied/not applied) | Not applied |
| interference modelling (ideal muting, or other) | Ideal |
| Description of Measurement Algorithm (e.g. super resolution, interference cancellation, ….) | Super resolution |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) | PSO |
| Network synchronization assumptions | Ideal |
| UE/gNB RX and TX timing error | 0ns |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | Tx beam sweeping |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | Tx codebook-based |
| UE antenna configuration | (1,2,2,1,1) |
| Number of UE branches | 1 |
| Description of enhancement solutions, if any | No |
| gNB antenna configuration | (4,4,2,1,1) |
| UE antenna height | 1.5m |
| gNB antenna height | 8m |
| Time drift model | No |
| Additional notes, if any | **Case 411:** w/ phase compensation, time gap: 140us, UE Speed: 3km/h  **Case 412:** w/ phase compensation, time gap: 140us, UE Speed: 30km/h  **Case 413:** w/ phase compensation, time gap: 140us, UE Speed: 60km/h  **Case 414:** w/ phase compensation, time gap: 140us, UE Speed: 120km/h |

Table B.6.3.1-5: NR RedCap UE positioning - evaluation scenarios and parameters for InF-SH UL-TDOA frequency hopping considering the overlap size between consecutive hops from [111]

|  |  |
| --- | --- |
| **Parameter** | **Case 511 ~514**  **(InF-SH, FR1)** |
| Scenario (baseline, otherwise state any modifications) | Baseline |
| Carrier frequency | 3.5GHz |
| Subcarrier spacing | 30kHz |
| Reference Signal Transmission Bandwidth | 20MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | PosSRS (Comb-2, 1 symbol) |
| Reference signal  (type of sequence, number of ports, …) | ZC, single port |
| Number of sites | 7 |
| Number of symbols used per occasion | 1 |
| number of occasions used per positioning estimate | 5 |
| Power-boosting level | 6dB |
| Uplink power control (applied/not applied) | Not applied |
| interference modelling (ideal muting, or other) | Ideal |
| Description of Measurement Algorithm (e.g. super resolution, interference cancellation, ….) | Super resolution |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) | PSO |
| Network synchronization assumptions | Ideal |
| UE/gNB RX and TX timing error | 0ns |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | Tx beam sweeping |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | Tx codebook-based |
| UE antenna configuration | (1,2,2,1,1) |
| Number of UE branches | 1 |
| Description of enhancement solutions, if any | No |
| gNB antenna configuration | (4,4,2,1,1) |
| UE antenna height | 1.5m |
| gNB antenna height | 8m |
| Time drift model | No |
| UE speed | 3km/h |
| Additional notes, if any | **Case 511:** w/ phase compensation, time gap: 140us, overlap size: 1RB  **Case 512:** w/ phase compensation, time gap: 140us, overlap size: 5RBs  **Case 513:** w/ phase compensation, time gap: 140us, overlap size: 10RBs  **Case 514:** w/ phase compensation, time gap: 140us, overlap size: 15RBs |

Table B.6.3.1-6: NR RedCap UE positioning - evaluation scenarios and parameters for UMi frequency hopping from [111]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **Case 611 (UMi, FR1)** | **Case 612 (UMi, FR1)** | **Case 613 (UMi, FR1)** | **Case 614 (UMi, FR1)** |
| Scenario (baseline, otherwise state any modifications) | Baseline | Baseline | Baseline | Baseline |
| Carrier frequency | 0.7GHz | 0.7GHz | 0.7GHz | 0.7GHz |
| Subcarrier spacing | 30kHz | 30kHz | 30kHz | 30kHz |
| Reference Signal Transmission Bandwidth | 20MHz | 20MHz | 20MHz | 20MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | PosSRS (Comb-2, 1 symbol) | PosSRS (Comb-2, 1 symbol) | PRS (Comb-2, 2 symbol) | PRS (Comb-2, 2 symbol) |
| Reference signal  (type of sequence, number of ports, …) | ZC, single port | ZC, single port | Gold, single port | Gold, single port |
| Number of sites | 7 | 7 | 7 | 7 |
| Number of symbols used per occasion | 1 | 1 | 1 | 1 |
| number of occasions used per positioning estimate | 5 | 5 | 5 | 5 |
| Power-boosting level | 6dB | 6dB | 6dB | 6dB |
| Uplink power control (applied/not applied) | Not applied | Not applied | Not applied | Not applied |
| interference modelling (ideal muting, or other) | Ideal | Ideal | Ideal | Ideal |
| Description of Measurement Algorithm (e.g. super resolution, interference cancellation, ….) | Super resolution | Super resolution | Super resolution | Super resolution |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) | PSO | PSO | PSO | PSO |
| Network synchronization assumptions | Ideal | Ideal | Ideal | Ideal |
| UE/gNB RX and TX timing error | 0ns | 0ns | 0ns | 0ns |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | Tx beam sweeping | Tx beam sweeping | Tx beam sweeping | Tx beam sweeping |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | Tx codebook-based | Tx codebook-based | Tx codebook-based | Tx codebook-based |
| UE antenna configuration | (1,2,2,1,1) | (1,2,2,1,1) | (1,2,2,1,1) | (1,2,2,1,1) |
| Number of UE branches | 1 | 1 | 1 | 1 |
| Description of enhancement solutions, if any | No | No | No | No |
| gNB antenna configuration | (8,8,2,1,1) | (8,8,2,1,1) | (8,8,2,1,1) | (8,8,2,1,1) |
| UE antenna height | 1.5m | 1.5m | 1.5m | 1.5m |
| gNB antenna height | 10m | 10m | 10m | 10m |
| Additional notes, if any | UL-TDOA,  w/o phase compensation | UL-TDOA,  w/ phase compensation  time gap: 140us | DL-TDOA, w/o phase compensation | DL-TDOA,  w/ phase compensation  time gap: 140us |

### B.6.3.2 NR RedCap UE positioning accuracy evaluation results

Table B.6.3.2-1 provides summary of evaluation results for the baseline InF-SH.

Table B.6.3.2-2 provides the summary of evaluation results for the frequency hopping based enhancement with InF-SH UL-TDOA considering the time gap between hops and clock drift.

Table B.6.3.2-3 provides the summary of evaluation results for the frequency hopping based enhancements with InF-SH DL-TDOA considering the time gap between hops and clock drift.

Table B.6.3.2-4 provides the summary of evaluation results for the frequency hopping based enhancements with InF-SH UL-TDOA considering the UE speed.

Table B.6.3.2-5 provides the summary of evaluation results for the frequency hopping based enhancements with InF-SH UL-TDOA considering the overlap size between consecutive hops.

Table B.6.3.2-6 provides the summary of evaluation results for the frequency hopping based enhancements with UMi TDOA positioning.

For better analysis, we present the performance evaluation results of the following solutions:

- Solution 1a: Non-overlapped Frequency hopping transmission without phase compensation

- Solution 1b: Non-overlapped frequency hopping reception without phase compensation

- Solution 2a: Overlapped frequency hopping transmission with phase compensation

- Solution 2b: Overlapped frequency hopping reception with phase compensation

Table B.6.3.2-1: Rel-17 NR RedCap UE positioning (baseline) - horizontal location error results from [111]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Cases** |  | **50%** | **67%** | **80%** | **90%** | **Requirements met? (Yes/No)** |
| Case 111, InF-SH, FR1, UL-TDOA, 100MHz | (Optional) All UEs | 0.028 | 0.049 | 0.081 | 0.137 | \ |
| Convex UEs | 0.018 | 0.032 | 0.052 | 0.085 | \ |
| Case 112, InF-SH, FR1, UL-TDOA, 20MHz | (Optional) All UEs | 0.632 | 1.035 | 1.677 | 3.119 | No |
| Convex UEs | 0.371 | 0.563 | 0.824 | 1.249 | No |
| Case 113, UMi, FR1, UL-TDOA, 100MHz | \ | 0.137 | 0.244 | 0.525 | 2.196 | \ |
| Case 114, UMi, FR1, UL-TDOA, 20MHz | \ | 1.725 | 3.116 | 5.526 | 18.823 | No |

Table B.6.3.2-2: Rel-17 NR RedCap UE positioning for InF-SH UL-TDOA frequency hopping considering the time gap between hops and clock drift - horizontal location error results from [111]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Cases** |  | **50%** | **67%** | **80%** | **90%** | **Requirements met? (Yes/No)** |
| Case 211, InF-SH, FR1, UL-TDOA, Solution 1a  Time gap between hops: 140us (4 symbols)  Time drift: 0 ppm (ideal) | (Optional) All UEs | 6.497 | 8.782 | 12.015 | 17.079 | No |
| Convex UEs | 5.071 | 6.846 | 9.099 | 13.241 | No |
| Case 212, InF-SH, FR1, UL-TDOA, Solution 2a  Time gap between hops: 140us (4 symbols)  Time drift: 0 ppm (ideal) | (Optional) All UEs | 0.041 | 0.067 | 0.117 | 0.251 | Yes |
| Convex UEs | 0.029 | 0.043 | 0.065 | 0.111 | Yes |
| Case 213, InF-SH, FR1, UL-TDOA, Solution 2a  Time gap between hops: 140us (4 symbols)  Time drift: 0.1 ppm | (Optional) All UEs | 0.041 | 0.068 | 0.118 | 0.262 | Yes |
| Convex UEs | 0.031 | 0.042 | 0.064 | 0.111 | Yes |
| Case 214, InF-SH, FR1, UL-TDOA, Solution 2a  Time gap between hops: 250us (7 symbols)  Time drift: 0 ppm (ideal) | (Optional) All UEs | 0.047 | 0.074 | 0.121 | 0.265 | Yes |
| Convex UEs | 0.037 | 0.052 | 0.073 | 0.113 | Yes |
| Case 215, InF-SH, FR1, UL-TDOA, Solution 2a  Time gap between hops: 250us (7 symbols)  Time drift: 0.1 ppm | (Optional) All UEs | 0.052 | 0.079 | 0.120 | 0.300 | Yes |
| Convex UEs | 0.040 | 0.054 | 0.074 | 0.138 | Yes |
| Case 216, InF-SH, FR1, UL-TDOA, Solution 2a  Time gap between hops: 0.5ms (1 slot)  Time drift: 0 ppm (ideal) | (Optional) All UEs | 0.084 | 0.122 | 0.191 | 0.394 | Yes |
| Convex UEs | 0.051 | 0.072 | 0.094 | 0.148 | Yes |
| Case 217, InF-SH, FR1, UL-TDOA, Solution 2a  Time gap between hops: 0.5ms (1 slot)  Time drift: 0.1 ppm | (Optional) All UEs | 0.084 | 0.129 | 0.195 | 0.401 | Yes |
| Convex UEs | 0.064 | 0.082 | 0.109 | 0.161 | Yes |
| Case 218, InF-SH, FR1, UL-TDOA, Solution 2a  Time gap between hops: 1ms (2 slots)  Time drift: 0 ppm (ideal) | (Optional) All UEs | 0.147 | 0.204 | 0.306 | 0.557 | Yes |
| Convex UEs | 0.117 | 0.147 | 0.190 | 0.244 | Yes |
| Case 219, InF-SH, FR1, UL-TDOA, Solution 2a  Time gap between hops: 1ms (2 slots)  Time drift: 0.1 ppm | (Optional) All UEs | 0.155 | 0.215 | 0.315 | 0.585 | Yes |
| Convex UEs | 0.124 | 0.156 | 0.200 | 0.265 | Yes |
| Case 220, InF-SH, FR1, UL-TDOA, Solution 2a  Time gap between hops: 5ms (10 slots)  Time drift: 0 ppm (ideal) | (Optional) All UEs | 0.710 | 0.967 | 1.387 | 2.313 | No |
| Convex UEs | 0.594 | 0.716 | 0.837 | 1.137 | No |
| Case 221, InF-SH, FR1, UL-TDOA, Solution 2a  Time gap between hops: 5ms (10 slots)  Time drift: 0.1 ppm | (Optional) All UEs | 0.720 | 0.971 | 1.452 | 2.449 | No |
| Convex UEs | 0.602 | 0.738 | 0.872 | 1.166 | No |

Table B.6.3.2-3: Rel-17 NR RedCap UE positioning for InF-SH DL-TDOA frequency hopping considering the time gap between hops and clock drift - horizontal location error results from [111]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Cases** |  | **50%** | **67%** | **80%** | **90%** | **Requirements met? (Yes/No)** |
| Case 311, InF-SH, FR1, DL-TDOA, Solution 1b  Time gap between hops: 140us (4 symbols)  Time drift: 0 ppm (ideal) | (Optional) All UEs | 6.245 | 8.792 | 12.765 | 21.082 | No |
| Convex UEs | 4.822 | 6.306 | 8.320 | 12.382 | No |
| Case 312, InF-SH, FR1, DL-TDOA, Solution 2b  Time gap between hops: 140us (4 symbols)  Time drift: 0 ppm (ideal) | (Optional) All UEs | 0.057 | 0092 | 0.159 | 0.425 | Yes |
| Convex UEs | 0.040 | 0.062 | 0.097 | 0.194 | Yes |
| Case 313, InF-SH, FR1, DL-TDOA, Solution 2b  Time gap between hops: 140us (4 symbols)  Time drift: 0.1 ppm | (Optional) All UEs | 0.058 | 0.101 | 0.180 | 0.484 | Yes |
| Convex UEs | 0.044 | 0.065 | 0.107 | 0.249 | Yes |
| Case 314, InF-SH, FR1, DL-TDOA, Solution 2b  Time gap between hops: 250us (7 symbols)  Time drift: 0 ppm (ideal) | (Optional) All UEs | 0.061 | 0.101 | 0.185 | 0.488 | Yes |
| Convex UEs | 0.046 | 0.066 | 0.108 | 0.251 | Yes |
| Case 315, InF-SH, FR1, DL-TDOA, Solution 2b  Time gap between hops: 250us (7 symbols)  Time drift: 0.1 ppm | (Optional) All UEs | 0.072 | 0.117 | 0.222 | 0.527 | Yes |
| Convex UEs | 0.054 | 0.081 | 0.129 | 0.341 | Yes |
| Case 316, InF-SH, FR1, DL-TDOA, Solution 2b  Time gap between hops: 0.5ms (1 slot)  Time drift: 0 ppm (ideal) | (Optional) All UEs | 0.101 | 0.154 | 0.267 | 0.602 | Yes |
| Convex UEs | 0.077 | 0.102 | 0.143 | 0.271 | Yes |
| Case 317, InF-SH, FR1, DL-TDOA, Solution 2b  Time gap between hops: 0.5ms (1 slot)  Time drift: 0.1 ppm | (Optional) All UEs | 0.100 | 0.151 | 0.243 | 0.713 | Yes |
| Convex UEs | 0.077 | 0.103 | 0.145 | 0.281 | Yes |
| Case 318, InF-SH, FR1, DL-TDOA, Solution 2b  Time gap between hops: 1ms (2 slots)  Time drift: 0 ppm (ideal) | (Optional) All UEs | 0.155 | 0.223 | 0.368 | 0.788 | Yes |
| Convex UEs | 0.125 | 0.157 | 0.205 | 0.366 | Yes |
| Case 319, InF-SH, FR1, DL-TDOA, Solution 2b  Time gap between hops: 1ms (2 slots)  Time drift: 0.1 ppm | (Optional) All UEs | 0.163 | 0.229 | 0.359 | 0.838 | Yes |
| Convex UEs | 0.129 | 0.166 | 0.216 | 0.368 | Yes |
| Case 320, InF-SH, FR1, DL-TDOA, Solution 2b  Time gap between hops: 5ms (10 slots)  Time drift: 0 ppm (ideal) | (Optional) All UEs | 0.711 | 1.026 | 1.671 | 2.988 | No |
| Convex UEs | 0.589 | 0.703 | 0.906 | 1.244 | No |
| Case 321, InF-SH, FR1, DL-TDOA, Solution 2b  Time gap between hops: 5ms (10 slots)  Time drift: 0.1 ppm | (Optional) All UEs | 0.724 | 1.001 | 1.517 | 3.086 | No |
| Convex UEs | 0.593 | 0.720 | 0.909 | 1.349 | No |

Table B.6.3.2-4: Rel-17 NR RedCap UE positioning for InF-SH UL-TDOA frequency hopping considering the UE speed - horizontal location error results from [111]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Cases** |  | **50%** | **67%** | **80%** | **90%** | **Requirements met? (Yes/No)** |
| Case 411, InF-SH, FR1, UL-TDOA, Solution 2a  Time gap between hops: 140us (4 symbols)  UE speed: 3km/h | (Optional) All UEs | 0.041 | 0.067 | 0.117 | 0.251 | Yes |
| Convex UEs | 0.029 | 0.043 | 0.065 | 0.111 | Yes |
| Case 412, InF-SH, FR1, UL-TDOA, Solution 2a  Time gap between hops: 140us (4 symbols)  UE speed: 30km/h | (Optional) All UEs | 0.105 | 0.145 | 0.204 | 0.347 | Yes |
| Convex UEs | 0.086 | 0.110 | 0.137 | 0.171 | Yes |
| Case 413, InF-SH, FR1, UL-TDOA, Solution 2a  Time gap between hops: 140us (4 symbols)  UE speed: 60km/h | (Optional) All UEs | 0.199 | 0.277 | 0.397 | 0.609 | Yes |
| Convex UEs | 0.165 | 0.202 | 0.245 | 0.303 | Yes |
| Case 414, InF-SH, FR1, UL-TDOA, Solution 2a  Time gap between hops: 140us (4 symbols)  UE speed: 120km/h | (Optional) All UEs | 0.385 | 0.500 | 0.695 | 1.111 | No |
| Convex UEs | 0.316 | 0.397 | 0.472 | 0.562 | Yes |

Table B.6.3.2-5: Rel-17 NR RedCap UE positioning for InF-SH UL-TDOA frequency hopping considering the overlap size between consecutive hops - horizontal location error results from [111]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Cases** |  | **50%** | **67%** | **80%** | **90%** | **Requirements met? (Yes/No)** |
| Case 511, InF-SH, FR1, UL-TDOA, Solution 2a  Time gap between hops: 140us (4 symbols)  Overlap size: 1RB | (Optional) All UEs | 0.041 | 0.067 | 0.117 | 0.251 | Yes |
| Convex UEs | 0.029 | 0.043 | 0.065 | 0.111 | Yes |
| Case 512, InF-SH, FR1, UL-TDOA, Solution 2a  Time gap between hops: 140us (4 symbols)  Overlap size: 5RBs | (Optional) All UEs | 0.036 | 0.058 | 0.091 | 0.164 | Yes |
| Convex UEs | 0.027 | 0.036 | 0.056 | 0.089 | Yes |
| Case 513, InF-SH, FR1, UL-TDOA, Solution 2a  Time gap between hops: 140us (4 symbols)  Overlap size: 10RBs | (Optional) All UEs | 0.040 | 0.065 | 0.097 | 0.179 | Yes |
| Convex UEs | 0.030 | 0.042 | 0.060 | 0.091 | Yes |
| Case 514, InF-SH, FR1, UL-TDOA, Solution 2a  Time gap between hops: 140us (4 symbols)  Overlap size: 15RBs | (Optional) All UEs | 0.049 | 0.075 | 0.119 | 0.263 | Yes |
| Convex UEs | 0.037 | 0.053 | 0.078 | 0.126 | Yes |

Table B.6.3.2-6: Rel-17 NR RedCap UE positioning for UMi frequency hopping - horizontal location error results from [111]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Cases** | **50%** | **67%** | **80%** | **90%** | **Requirements met? (Yes/No)** |
| Case 611, UMi, FR1, UL-TDOA, Solution 1a  Time gap between hops: 140us (4 symbols) | 7.454 | 12.524 | 20.676 | 36.231 | No |
| Case 612, UMi, FR1, UL-TDOA, Solution 2a  Time gap between hops: 140us (4 symbols) | 1.787 | 6.656 | 18.834 | 36.640 | No |
| Case 613, UMi, FR1, DL-TDOA, Solution 1b  Time gap between hops: 140us (4 symbols) | 7.098 | 10.968 | 16.332 | 26.989 | No |
| Case 614, UMi, FR1, DL-TDOA, Solution 2b  Time gap between hops: 140us (4 symbols) | 0.168 | 0.291 | 0.675 | 4.285 | No |

## B.6.4 Results from source [121]

### B.6.4.1 Description of evaluation scenarios

Table B.6.4.1-1: NR RedCap UE positioning - evaluation scenarios and parameters for InF-SH

|  |  |
| --- | --- |
| **Parameter** | **FR1** |
| Scenario (baseline, otherwise state any modifications) | Baseline IIoT |
| Carrier frequency | 3.5 GHz |
| Subcarrier spacing | 30kHz |
| Reference Signal Transmission Bandwidth | 20MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | PRS, comb-2, 2-symbol |
| Reference signal  (type of sequence, number of ports, …) | PN base sequence, 1 port |
| Number of sites | 18 |
| Number of symbols used per occasion | 2 |
| number of occasions used per positioning estimate | 1 |
| Power-boosting level | 0 dB |
| Uplink power control (applied/not applied) | Not applied |
| interference modelling (ideal muting, or other) | Ideal |
| Description of Measurement Algorithm (e.g. super resolution, interference cancellation, ….) | Correlation based |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) | Chan’s algorithm |
| Network synchronization assumptions | No synchronization error |
| UE/gNB RX and TX timing error | No timing error |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | Not Applied |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | No precoding |
| UE antenna configuration | Panel model 1 dH = 0.5λ, for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) |
| Number of UE branches | 1 |
| Description of enhancement solutions, if any | Frequency hopping, 2 hops, non-overlapping bandwidth |
| gNB antenna configuration | (M, N, P, Mg, Ng) = (4, 4, 2, 1, 1), dH=dV=0.5λ |
| UE noise figure | 9 dB |
| UE antenna height | 1.5 m |
| gNB antenna height | 8 m |
| Additional notes, if any |  |

### B.6.4.2 NR RedCap UE positioning accuracy evaluation results

Table B.6.4.2-1: NR RedCap UE positioning - evaluation scenarios and parameters for horizontal error evaluation for InF-SH

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Simulation cases |  | 50% ile | 67% ile | 80% ile | 90% ile | Requirements met? (Yes/No) |
| (1) DL-TDOA, InF-SH, 20 MHz bandwidth (RedCap), no freq hopping, ideal | convex UEs | 1.2968 | 1.6847 | 2.5333 | 4.15 | No |
| (2) DL-TDOA, InF-SH, 20 MHz bandwidth (RedCap), frequency hopping over 2 hops, ideal | convex UEs | 1.0280 | 1.6992 | 2.5045 | 2.9372 | No |
| (3) DL-TDOA, InF-SH, 20 MHz bandwidth (RedCap), frequency hopping over 2 hops, random phase offset between hops in range of [-180°,180°] (without any phase compensation) | convex UEs | 1.4773 | 1.8662 | 2.4332 | 3.8311 | No |

## B.6.5 Results from source [113]

### B.6.5.1 Description of evaluation scenarios

Evaluation assumptions for system level analysis based on Rel-17 method in InF-SH scenario are provided in Table B.6.5.1-1.

Evaluation assumptions for system level analysis based on Rel-17 method in UMi scenario are provided in Table B.6.5.1-2.

Evaluation assumptions for system level analysis based on carrier phase measurement in InF-SH scenario are provided in Table B.6.5.1-3.

Evaluation assumptions for system level analysis based on frequency hopping method in InF-SH scenario are provided in Table B.6.5.1-4.

Table B.6.5.1-1: NR RedCap UE positioning - evaluation scenarios and parameters based on Rel-17 method in InF-SH [113]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Parameter | Case 1-1 ([InF-SH], [FR1,20M],  [DL-TDOA], [without RAIM,1 Rx]) | Case 1-2 ([InF-SH], [FR1,20M],  [DL-TDOA], [with RAIM,1 Rx]) | Case 1-3 ([InF-SH], [FR1,20M],  [UL-TDOA], [without RAIM,1 Rx]) | Case 1-4 ([InF-SH], [FR1,20M],  [UL-TDOA], [with RAIM,1 Rx]) | Case 1-5 ([InF-SH], [FR1,20M],  [Multi-RTT], [without RAIM,1 Rx]) | Case 1-6 ([InF-SH], [FR1,20M],  [Multi-RTT], [with RAIM,1 Rx]) |
| Scenario (baseline, otherwise state any modifications) | InF-SH | InF-SH | InF-SH | InF-SH | InF-SH | InF-SH |
| Carrier frequency | 3.5GHz | 3.5GHz | 3.5GHz | 3.5GHz | 3.5GHz | 3.5GHz |
| Subcarrier spacing | 30kHz | 30kHz | 30kHz | 30kHz | 30kHz | 30kHz |
| Reference Signal Transmission Bandwidth | 20MHz | 20MHz | 20MHz | 20MHz | 20MHz | 20MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | DL PRS  Comb-6, 6 symbols | DL PRS  Comb-6, 6 symbols | PosSRS  Comb-4, 4 symbols | PosSRS  Comb-4, 4 symbols | DL PRS  Comb-6, 6 symbols  PosSRS  Comb-4, 4 symbols | DL PRS  Comb-6, 6 symbols  PosSRS  Comb-4, 4 symbols |
| Reference signal  (type of sequence, number of ports, …) | 1 port, QPSK-PN sequence | 1 port, QPSK-PN sequence | 1 port, ZC sequence | 1 port, ZC sequence | 1 port, ZC sequence  1 port, ZC sequence | 1 port, ZC sequence  1 port, ZC sequence |
| Number of sites | 18  (4 sites are used for positioning) | 18  (4 sites are used for positioning) | 18  (4 sites are used for positioning) | 18  (4 sites are used for positioning) | 18  (4 sites are used for positioning) | 18  (4 sites are used for positioning) |
| Number of symbols used per occasion | 1 | 1 | 1 | 1 | 1 | 1 |
| number of occasions used per positioning estimate | 1 | 1 | 1 | 1 | 1 | 1 |
| Power-boosting level | 7.78dB | 7.78dB | 7.78dB | 7.78dB | 7.78dB | 7.78dB |
| Uplink power control (applied/not applied) | not applied | not applied | not applied | not applied | not applied | not applied |
| 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, ….) | super resolution | super resolution | super resolution | super resolution | super resolution | super resolution |
| Description of positioning technique / applied positioning algorithm (e.g., Least square, Taylor series, etc) | Taylor series  without RAIM | Taylor series  with RAIM | Taylor series  without RAIM | Taylor series  with RAIM | Taylor series  without RAIM | Taylor series  with RAIM |
| Network synchronization assumptions | Perfect sync | Perfect sync | Perfect sync | Perfect sync | Perfect sync | Perfect sync |
| UE/gNB RX and TX timing error | 0 | 0 | 0 | 0 | 0 | 0 |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | alignment assumptions at the tx and rx sides | alignment assumptions at the tx and rx sides | alignment assumptions at the tx and rx sides | alignment assumptions at the tx and rx sides | alignment assumptions at the tx and rx sides | alignment assumptions at the tx and rx sides |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | / | / | / | / | / | / |
| UE antenna configuration | dH = 0.5λ, Omni, 0dBi for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | dH = 0.5λ, Omni, 0dBi for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | dH = 0.5λ, Omni, 0dBi for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | dH = 0.5λ, Omni, 0dBi for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | dH = 0.5λ, Omni, 0dBi for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | dH = 0.5λ, Omni, 0dBi for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) |
| Number of UE branches | 1 Rx, 1Tx | 1 Rx, 1Tx | 1 Rx, 1Tx | 1 Rx, 1Tx | 1 Rx, 1Tx | 1 Rx, 1Tx |
| Description of enhancement solutions, if any | / | / | / | / | / | / |
| gNB antenna configuration | gNB antenna model follows TR38.855 and TR38.857 | gNB antenna model follows TR38.855 and TR38.857 | gNB antenna model follows TR38.855 and TR38.857 | gNB antenna model follows TR38.855 and TR38.857 | gNB antenna model follows TR38.855 and TR38.857 | gNB antenna model follows TR38.855 and TR38.857 |
| UE noise figure | 9dB | 9dB | 9dB | 9dB | 9dB | 9dB |
| UE antenna height | 1.5m | 1.5m | 1.5m | 1.5m | 1.5m | 1.5m |
| gNB antenna height | 8m | 8m | 8m | 8m | 8m | 8m |
| Additional notes, if any | / | / | / | / | / | / |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Case 1-7 ([InF-SH], [FR1,5M],**  **[DL-TDOA], [without RAIM,1 Rx])** | **Case 1-8 ([InF-SH], [FR1,5M],**  **[DL-TDOA], [with RAIM,1 Rx])** | **Case 1-9 ([InF-SH], [FR1,5M],**  **[UL-TDOA], [without RAIM,1 Rx])** | **Case 1-10 ([InF-SH], [FR1,5M],**  **[UL-TDOA], [with RAIM,1 Rx])** | **Case 1-11 ([InF-SH], [FR1,5M],**  **[Multi-RTT], [without RAIM,1 Rx])** | **Case 1-12 ([InF-SH], [FR1,5M],**  **[Multi-RTT], [with RAIM,1 Rx])** |
| Scenario (baseline, otherwise state any modifications) | InF-SH | InF-SH | InF-SH | InF-SH | InF-SH | InF-SH |
| Carrier frequency | 3.5GHz | 3.5GHz | 3.5GHz | 3.5GHz | 3.5GHz | 3.5GHz |
| Subcarrier spacing | 30kHz | 30kHz | 30kHz | 30kHz | 30kHz | 30kHz |
| Reference Signal Transmission Bandwidth | 5MHz | 5MHz | 5MHz | 5MHz | 5MHz | 5MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | DL PRS  Comb-6, 6 symbols | DL PRS  Comb-6, 6 symbols | PosSRS  Comb-4, 4 symbols | PosSRS  Comb-4, 4 symbols | DL PRS  Comb-6, 6 symbols  PosSRS  Comb-4, 4 symbols | DL PRS  Comb-6, 6 symbols  PosSRS  Comb-4, 4 symbols |
| Reference signal  (type of sequence, number of ports, …) | 1 port, QPSK-PN sequence | 1 port, QPSK-PN sequence | 1 port, ZC sequence | 1 port, ZC sequence | 1 port, ZC sequence  1 port, ZC sequence | 1 port, ZC sequence  1 port, ZC sequence |
| Number of sites | 18  (4 sites are used for positioning) | 18  (4 sites are used for positioning) | 18  (4 sites are used for positioning) | 18  (4 sites are used for positioning) | 18  (4 sites are used for positioning) | 18  (4 sites are used for positioning) |
| Number of symbols used per occasion | 1 | 1 | 1 | 1 | 1 | 1 |
| number of occasions used per positioning estimate | 1 | 1 | 1 | 1 | 1 | 1 |
| Power-boosting level | 7.78dB | 7.78dB | 7.78dB | 7.78dB | 7.78dB | 7.78dB |
| Uplink power control (applied/not applied) | not applied | not applied | not applied | not applied | not applied | not applied |
| 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, ….) | super resolution | super resolution | super resolution | super resolution | super resolution | super resolution |
| Description of positioning technique / applied positioning algorithm (e.g., Least square, Taylor series, etc) | Taylor series  without RAIM | Taylor series  with RAIM | Taylor series  without RAIM | Taylor series  with RAIM | Taylor series  without RAIM | Taylor series  with RAIM |
| Network synchronization assumptions | Perfect sync | Perfect sync | Perfect sync | Perfect sync | Perfect sync | Perfect sync |
| UE/gNB RX and TX timing error | 0 | 0 | 0 | 0 | 0 | 0 |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | alignment assumptions at the tx and rx sides | alignment assumptions at the tx and rx sides | alignment assumptions at the tx and rx sides | alignment assumptions at the tx and rx sides | alignment assumptions at the tx and rx sides | alignment assumptions at the tx and rx sides |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | / | / | / | / | / | / |
| UE antenna configuration | dH = 0.5λ, Omni, 0dBi for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | dH = 0.5λ, Omni, 0dBi for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | dH = 0.5λ, Omni, 0dBi for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | dH = 0.5λ, Omni, 0dBi for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | dH = 0.5λ, Omni, 0dBi for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | dH = 0.5λ, Omni, 0dBi for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) |
| Number of UE branches | 1 Rx, 1Tx | 1 Rx, 1Tx | 1 Rx, 1Tx | 1 Rx, 1Tx | 1 Rx, 1Tx | 1 Rx, 1Tx |
| Description of enhancement solutions, if any | / | / | / | / | / | / |
| gNB antenna configuration | gNB antenna model follows TR38.855 and TR38.857 | gNB antenna model follows TR38.855 and TR38.857 | gNB antenna model follows TR38.855 and TR38.857 | gNB antenna model follows TR38.855 and TR38.857 | gNB antenna model follows TR38.855 and TR38.857 | gNB antenna model follows TR38.855 and TR38.857 |
| UE noise figure | 9dB | 9dB | 9dB | 9dB | 9dB | 9dB |
| UE antenna height | 1.5m | 1.5m | 1.5m | 1.5m | 1.5m | 1.5m |
| gNB antenna height | 8m | 8m | 8m | 8m | 8m | 8m |
| Additional notes, if any | / | / | / | / | / | / |

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Case 1-13 ([InF-SH], [FR1,20M],**  **[DL-TDOA], [without RAIM,2 Rx])** | **Case 1-14 ([InF-SH], [FR1,20M],**  **[Multi-RTT], [without RAIM,2 Rx])** |
| Scenario (baseline, otherwise state any modifications) | InF-SH | InF-SH |
| Carrier frequency | 3.5GHz | 3.5GHz |
| Subcarrier spacing | 30kHz | 30kHz |
| Reference Signal Transmission Bandwidth | 5MHz | 5MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | DL PRS  Comb-6, 6 symbols | DL PRS  Comb-6, 6 symbols  PosSRS  Comb-4, 4 symbols |
| Reference signal  (type of sequence, number of ports, …) | 1 port, QPSK-PN sequence | 1 port, ZC sequence  1 port, ZC sequence |
| Number of sites | 18  (4 sites are used for positioning) | 18  (4 sites are used for positioning) |
| Number of symbols used per occasion | 1 | 1 |
| number of occasions used per positioning estimate | 1 | 1 |
| Power-boosting level | 7.78dB | 7.78dB |
| Uplink power control (applied/not applied) | not applied | not applied |
| interference modelling (ideal muting, or other) | ideal muting | ideal muting |
| Description of Measurement Algorithm (e.g., super resolution, interference cancellation, ….) | super resolution | super resolution |
| Description of positioning technique / applied positioning algorithm (e.g., Least square, Taylor series, etc) | Taylor series  without RAIM | Taylor series  without RAIM |
| Network synchronization assumptions | Perfect sync | Perfect sync |
| UE/gNB RX and TX timing error | 0 | 0 |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | alignment assumptions at the tx and rx sides | alignment assumptions at the tx and rx sides |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | / | / |
| UE antenna configuration | dH = 0.5λ, Omni, 0dBi for 2Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 2, 1, 1) | dH = 0.5λ, Omni, 0dBi for 2Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 2, 1, 1) |
| Number of UE branches | 2 Rx, 1Tx | 2 Rx, 1Tx |
| Description of enhancement solutions, if any | / | / |
| gNB antenna configuration | gNB antenna model follows TR38.855 and TR38.857 | gNB antenna model follows TR38.855 and TR38.857 |
| UE noise figure | 9dB | 9dB |
| UE antenna height | 1.5m | 1.5m |
| gNB antenna height | 8m | 8m |
| Additional notes, if any | / | / |

Table B.6.5.1-2: NR RedCap UE positioning - evaluation scenarios and parameters based on Rel-17 method in UMi [113]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Case 2-1 ([UMi], [FR1,20M],**  **[DL-TDOA], [without RAIM,1 Rx])** | **Case 2-2 ([UMi], [FR1,20M],**  **[DL-TDOA], [with RAIM,1 Rx])** | **Case 2-3 ([UMi], [FR1,20M],**  **[UL-TDOA], [without RAIM,1 Rx])** | **Case 2-4 ([UMi], [FR1,20M],**  **[UL-TDOA], [with RAIM,1 Rx])** | **Case 2-5 ([UMi], [FR1,20M],**  **[Multi-RTT], [without RAIM,1 Rx])** | **Case 2-6 ([UMi], [FR1,20M],**  **[Multi-RTT], [with RAIM,1 Rx])** |
| Scenario (baseline, otherwise state any modifications) | UMi | UMi | UMi | UMi | UMi | UMi |
| Carrier frequency | 3.5GHz | 3.5GHz | 3.5GHz | 3.5GHz | 3.5GHz | 3.5GHz |
| Subcarrier spacing | 30kHz | 30kHz | 30kHz | 30kHz | 30kHz | 30kHz |
| Reference Signal Transmission Bandwidth | 20MHz | 20MHz | 20MHz | 20MHz | 20MHz | 20MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | DL PRS  Comb-6, 6 symbols | DL PRS  Comb-6, 6 symbols | PosSRS  Comb-4, 4 symbols | PosSRS  Comb-4, 4 symbols | DL PRS  Comb-6, 6 symbols  PosSRS  Comb-4, 4 symbols | DL PRS  Comb-6, 6 symbols  PosSRS  Comb-4, 4 symbols |
| Reference signal  (type of sequence, number of ports, …) | 1 port, QPSK-PN sequence | 1 port, QPSK-PN sequence | 1 port, ZC sequence | 1 port, ZC sequence | 1 port, ZC sequence  1 port, ZC sequence | 1 port, ZC sequence  1 port, ZC sequence |
| Number of sites | 18  (4 sites are used for positioning) | 18  (4 sites are used for positioning) | 18  (4 sites are used for positioning) | 18  (4 sites are used for positioning) | 18  (4 sites are used for positioning) | 18  (4 sites are used for positioning) |
| Number of symbols used per occasion | 1 | 1 | 1 | 1 | 1 | 1 |
| number of occasions used per positioning estimate | 1 | 1 | 1 | 1 | 1 | 1 |
| Power-boosting level | 7.78dB | 7.78dB | 7.78dB | 7.78dB | 7.78dB | 7.78dB |
| Uplink power control (applied/not applied) | not applied | not applied | not applied | not applied | not applied | not applied |
| 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, ….) | super resolution | super resolution | super resolution | super resolution | super resolution | super resolution |
| Description of positioning technique / applied positioning algorithm (e.g., Least square, Taylor series, etc) | Taylor series  without RAIM | Taylor series  with RAIM | Taylor series  without RAIM | Taylor series  with RAIM | Taylor series  without RAIM | Taylor series  with RAIM |
| Network synchronization assumptions | Perfect sync | Perfect sync | Perfect sync | Perfect sync | Perfect sync | Perfect sync |
| UE/gNB RX and TX timing error | 0 | 0 | 0 | 0 | 0 | 0 |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | alignment assumptions at the tx and rx sides | alignment assumptions at the tx and rx sides | alignment assumptions at the tx and rx sides | alignment assumptions at the tx and rx sides | alignment assumptions at the tx and rx sides | alignment assumptions at the tx and rx sides |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | / | / | / | / | / | / |
| UE antenna configuration | dH = 0.5λ, Omni, 0dBi for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | dH = 0.5λ, Omni, 0dBi for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | dH = 0.5λ, Omni, 0dBi for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | dH = 0.5λ, Omni, 0dBi for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | dH = 0.5λ, Omni, 0dBi for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | dH = 0.5λ, Omni, 0dBi for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) |
| Number of UE branches | 1 Rx, 1Tx | 1 Rx, 1Tx | 1 Rx, 1Tx | 1 Rx, 1Tx | 1 Rx, 1Tx | 1 Rx, 1Tx |
| Description of enhancement solutions, if any | / | / | / | / | / | / |
| gNB antenna configuration | gNB antenna model follows TR38.855 and TR38.857 | gNB antenna model follows TR38.855 and TR38.857 | gNB antenna model follows TR38.855 and TR38.857 | gNB antenna model follows TR38.855 and TR38.857 | gNB antenna model follows TR38.855 and TR38.857 | gNB antenna model follows TR38.855 and TR38.857 |
| UE noise figure | 9dB | 9dB | 9dB | 9dB | 9dB | 9dB |
| UE antenna height | 1.5m | 1.5m | 1.5m | 1.5m | 1.5m | 1.5m |
| gNB antenna height | 10m | 10m | 10m | 10m | 10m | 10m |
| Additional notes, if any | / | / | / | / | / | / |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Case 2-7 ([UMi], [FR1,5M],**  **[DL-TDOA], [without RAIM,1 Rx])** | **Case 2-8 ([UMi], [FR1,5M],**  **[DL-TDOA], [with RAIM,1 Rx])** | **Case 2-9 ([UMi], [FR1,5M],**  **[UL-TDOA], [without RAIM,1 Rx])** | **Case 2-10 ([UMi], [FR1,5M],**  **[UL-TDOA], [with RAIM,1 Rx])** | **Case 2-11 ([UMi], [FR1,5M],**  **[Multi-RTT], [without RAIM,1 Rx])** | **Case 2-12 ([UMi], [FR1,5M],**  **[Multi-RTT], [with RAIM,1 Rx])** |
| Scenario (baseline, otherwise state any modifications) | UMi | UMi | UMi | UMi | UMi | UMi |
| Carrier frequency | 3.5GHz | 3.5GHz | 3.5GHz | 3.5GHz | 3.5GHz | 3.5GHz |
| Subcarrier spacing | 30kHz | 30kHz | 30kHz | 30kHz | 30kHz | 30kHz |
| Reference Signal Transmission Bandwidth | 5MHz | 5MHz | 5MHz | 5MHz | 5MHz | 5MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | DL PRS  Comb-6, 6 symbols | DL PRS  Comb-6, 6 symbols | PosSRS  Comb-4, 4 symbols | PosSRS  Comb-4, 4 symbols | DL PRS  Comb-6, 6 symbols  PosSRS  Comb-4, 4 symbols | DL PRS  Comb-6, 6 symbols  PosSRS  Comb-4, 4 symbols |
| Reference signal  (type of sequence, number of ports, …) | 1 port, QPSK-PN sequence | 1 port, QPSK-PN sequence | 1 port, ZC sequence | 1 port, ZC sequence | 1 port, ZC sequence  1 port, ZC sequence | 1 port, ZC sequence  1 port, ZC sequence |
| Number of sites | 18  (4 sites are used for positioning) | 18  (4 sites are used for positioning) | 18  (4 sites are used for positioning) | 18  (4 sites are used for positioning) | 18  (4 sites are used for positioning) | 18  (4 sites are used for positioning) |
| Number of symbols used per occasion | 1 | 1 | 1 | 1 | 1 | 1 |
| number of occasions used per positioning estimate | 1 | 1 | 1 | 1 | 1 | 1 |
| Power-boosting level | 7.78dB | 7.78dB | 7.78dB | 7.78dB | 7.78dB | 7.78dB |
| Uplink power control (applied/not applied) | not applied | not applied | not applied | not applied | not applied | not applied |
| 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, ….) | super resolution | super resolution | super resolution | super resolution | super resolution | super resolution |
| Description of positioning technique / applied positioning algorithm (e.g., Least square, Taylor series, etc) | Taylor series  without RAIM | Taylor series  with RAIM | Taylor series  without RAIM | Taylor series  with RAIM | Taylor series  without RAIM | Taylor series  with RAIM |
| Network synchronization assumptions | Perfect sync | Perfect sync | Perfect sync | Perfect sync | Perfect sync | Perfect sync |
| UE/gNB RX and TX timing error | 0 | 0 | 0 | 0 | 0 | 0 |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | alignment assumptions at the tx and rx sides | alignment assumptions at the tx and rx sides | alignment assumptions at the tx and rx sides | alignment assumptions at the tx and rx sides | alignment assumptions at the tx and rx sides | alignment assumptions at the tx and rx sides |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | / | / | / | / | / | / |
| UE antenna configuration | dH = 0.5λ, Omni, 0dBi for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | dH = 0.5λ, Omni, 0dBi for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | dH = 0.5λ, Omni, 0dBi for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | dH = 0.5λ, Omni, 0dBi for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | dH = 0.5λ, Omni, 0dBi for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | dH = 0.5λ, Omni, 0dBi for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) |
| Number of UE branches | 1 Rx, 1Tx | 1 Rx, 1Tx | 1 Rx, 1Tx | 1 Rx, 1Tx | 1 Rx, 1Tx | 1 Rx, 1Tx |
| Description of enhancement solutions, if any | / | / | / | / | / | / |
| gNB antenna configuration | gNB antenna model follows TR38.855 and TR38.857 | gNB antenna model follows TR38.855 and TR38.857 | gNB antenna model follows TR38.855 and TR38.857 | gNB antenna model follows TR38.855 and TR38.857 | gNB antenna model follows TR38.855 and TR38.857 | gNB antenna model follows TR38.855 and TR38.857 |
| UE noise figure | 9dB | 9dB | 9dB | 9dB | 9dB | 9dB |
| UE antenna height | 1.5m | 1.5m | 1.5m | 1.5m | 1.5m | 1.5m |
| gNB antenna height | 10m | 10m | 10m | 10m | 10m | 10m |
| Additional notes, if any | / | / | / | / | / | / |

Table B.6.5.1-3: NR RedCap UE positioning - evaluation scenarios and parameters based on carrier phase measurement in InF-SH [113]

|  |  |  |
| --- | --- | --- |
| **Parameter** | **[Case 3-1], [InF-SH], [DL-TDOA], [Carrier phase]** | **[Case 3-2], [InF-SH], [DL-TDOA], [Carrier phase]** |
| Channel model  [TS 38.855, TS 38.857] | TS 38.857 | TS 38.857 |
| Carrier frequency, or Multiple carrier frequencies, GHz | 3.5G | 3.5G |
| Bandwidth, MHz | 20M | 20M |
| Subcarrier spacing, kHz | 30kHZ | 30kHZ |
| RS signal descriptions  (PRS or posSRS, Number of OFDM symbols, Comb size) | DL PRS  Comb-6, 6 symbols | DL PRS  Comb-6, 6 symbols |
| NR Carrier phase positioning method  (DL, UL, or DL+UL(RTT)) | DL | DL |
| 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.) | single differential | single differential |
| Integer ambiguity resolution techniques  (e.g., virtual Integer ambiguity, LAMBDA, cost functions,…) | Ideal integer cycle | 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 instance | Single-measurement instance |
| UE position calculation algorithm (e.g. Least squares, Taylor series, …) | Taylor series | Taylor series |
| Network synchronization assumption (e.g., 0ns, 10ns, ..) | 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.6.5.1-4: NR RedCap UE positioning - evaluation scenarios and parameters based on frequency hopping in InF-SH [113]

|  |  |
| --- | --- |
| **Parameter** | **Case 4 (Frequency hopping, DL-TDOA)** |
| Scenario (baseline, otherwise state any modifications) | InF-SH |
| Carrier frequency | 3.5GHz |
| Subcarrier spacing | 30kHz |
| Reference Signal Transmission Bandwidth | 20MHz for each hop |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | DL PRS |
| Reference signal  (type of sequence, number of ports, …) | 1 port, QPSK-PN sequence |
| Number of sites | 18  (4 sites are used for positioning) |
| Number of symbols used per occasion | 1 |
| number of occasions used per positioning estimate | 1 |
| Power-boosting level | 7.78dB |
| Uplink power control (applied/not applied) | not applied |
| interference modelling (ideal muting, or other) | ideal muting |
| Description of Measurement Algorithm (e.g., super resolution, interference cancellation, ….) | super resolution |
| Description of positioning technique / applied positioning algorithm (e.g., Least square, Taylor series, etc) | Taylor series  without RAIM |
| Network synchronization assumptions | Perfect sync |
| UE/gNB RX and TX timing error | 0 |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | alignment assumptions at the tx and rx sides |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | / |
| UE antenna configuration | dH = 0.5λ, Omni, 0dBi for 1Rx UEs: (M, N, P, Mg, Ng) = (1, 1, 2, 1, 1) |
| Number of UE branches | 2 Rx, 1Tx |
| Description of enhancement solutions, if any | / |
| gNB antenna configuration | gNB antenna model follows TR38.855 and TR38.857 |
| UE noise figure | 9dB |
| UE antenna height | 1.5m |
| gNB antenna height | 8m |
| Number of hops | 5 |
| Multi-hop bandwidth span | 100MHz |
| Overlapping bandwidth | 4PRB |
| Time gap for adjacent hops | Baseline: 1 slot  Optional: 4 symbols, 4 slots, 8 slots, 10 slots |
| UE speed | Baseline: 3 km/h  Optional: 30km/h, 60km/h |
| Rx timing errors between hops | Baseline: No Rx timing errors between hops  Optional: 1ns, 3ns, 5ns |
| Phase errors between hops | uniformly distribution between [-pi, pi] between hops |
| Phase compensation | With/without phase compensation |
| Additional notes, if any | Fixed UE location is assumed for channel generation of different hops  Case 4-1: Frequency hopping performance with the case of 1 slot gap, UE speed of 3km/h, with/without phase compensation  Case 4-2: Frequency hopping performance with the case of different time gaps, UE speed of 3km/h, with/without phase compensation  Case 4-3: Frequency hopping performance with the case of large time gaps, large UE speed, with phase compensation  Case 4-4: Frequency hopping performance with the case of 1 slot gap, UE speed of 3km/h, Rx timing error, with phase compensation |

### B.6.5.2 NR RedCap UE positioning accuracy evaluation results

Table B.6.5.2-1 provides summary of evaluation results based on Rel-17 method in InF-SH scenario with 20MHz/5MHz bandwidth and/or 1Rx/2Rx branches.

Table B.6.5.2-2 provides summary of evaluation results based on Rel-17 method in UMi scenario with 20MHz/5MHz bandwidth.

Table B.6.5.2-3 provides summary of evaluation results based on carrier phase measurement in InF-SH scenarios.

Table B.6.5.2-4~7 provides summary of evaluation results based on frequency hopping in InF-SH scenarios.

Table B.6.5.2-1 Horizontal accuracy results (m) of 20MHz and 5MHz bandwidth in InF-SH without RAIM and with RAIM [113]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Cases** |  | **50%** | **67%** | **80%** | **90%** | **Requirements met? (Yes/No)** |
| [Case 1-1], [InF-SH], [FR1,20M],  [DL-TDOA], [without RAIM,1 Rx] | Convex UEs | 0.185 | 0.244 | 0.388 | 1.69 | No |
| [Case 1-2], [InF-SH], [FR1,20M],  [DL-TDOA], [with RAIM,1 Rx] | Convex UEs | 0.15 | 0.197 | 0.23 | 0.32 | Yes |
| [Case 1-3], [InF-SH], [FR1,20M],  [UL-TDOA], [without RAIM,1 Rx] | Convex UEs | 0.184 | 0.244 | 0.388 | 1.68 | No |
| [Case 1-4], [InF-SH], [FR1,20M],  [UL-TDOA], [with RAIM,1 Rx] | Convex UEs | 0.16 | 0.21 | 0.256 | 0.35 | Yes |
| [Case 1-5], [InF-SH], [FR1,20M], [Multi-RTT], [without RAIM,1 Rx] | Convex UEs | 0.184 | 0.244 | 0.388 | 1.68 | No |
| [Case 1-6], [InF-SH], [FR1,20M], [Multi-RTT], [with RAIM,1 Rx] | Convex UEs | 0.158 | 0.207 | 0.254 | 0.34 | Yes |
| [Case 1-7], [InF-SH], [FR1,5M],  [DL-TDOA], [without RAIM,1 Rx] | Convex UEs | 0.678 | 1.15 | 2.58 | 4.96 | No |
| [Case 1-8], [InF-SH], [FR1,5M],  [DL-TDOA], [with RAIM,1 Rx] | Convex UEs | 0.63 | 0.771 | 0.933 | 1.251 | No |
| [Case 1-9], [InF-SH], [FR1,5M],  [UL-TDOA], [without RAIM,1 Rx] | Convex UEs | 0.664 | 1.04 | 2.72 | 4.97 | No |
| [Case 1-10], [InF-SH], [FR1,5M], [UL-TDOA], [with RAIM,1 Rx] | Convex UEs | 0.63 | 0.738 | 0.934 | 1.265 | No |
| [Case 1-11], [InF-SH], [FR1,5M], [Multi-RTT], [without RAIM,1 Rx] | Convex UEs | 0.614 | 0.99 | 2.82 | 4.963 | No |
| [Case 1-12], [InF-SH], [FR1,5M], [Multi-RTT], [with RAIM,1 Rx] | Convex UEs | 0.61 | 0.797 | 0.942 | 1.263 | No |
| [Case 1-13], [InF-SH], [FR1,20M], [DL-TDOA], [without RAIM, 2 Rx] | Convex UEs | 0.174 | 0.225 | 0.378 | 1.32 | No |
| [Case 1-14], [InF-SH], [FR1,20M], [Multi-RTT], [without RAIM, 2 Rx] | Convex UEs | 0.174 | 0.222 | 0.32 | 1.26 | No |

Table B.6.5.2-2 Horizontal accuracy results (m) of 20MHz and 5MHz bandwidth in UMi without RAIM and with RAIM [113]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Cases** |  | **50%** | **67%** | **80%** | **90%** | **Requirements met? (Yes/No)** |
| [Case 2-1], [UMi], [FR1,20M],  [DL-TDOA], [without RAIM,1 Rx] | Convex UEs | 5.55 | 6.83 | 10.03 | 14.66 | No |
| [Case 2-2], [UMi], [FR1,20M],  [DL-TDOA], [with RAIM,1 Rx] | Convex UEs | 1.768 | 2.74 | 3.98 | 5.71 | No |
| [Case 2-3], [UMi], [FR1,20M],  [UL-TDOA], [without RAIM,1 Rx] | Convex UEs | 5.914 | 9.07 | 12.8 | 20.88 | No |
| [Case 2-4], [UMi], [FR1,20M],  [UL-TDOA], [with RAIM,1 Rx] | Convex UEs | 2.216 | 3.36 | 4.7 | 6.62 | No |
| [Case 2-5], [UMi], [FR1,20M], [Multi-RTT], [without RAIM,1 Rx] | Convex UEs | 5.413 | 7.51 | 11.01 | 17.23 | No |
| [Case 2-6], [UMi], [FR1,20M], [Multi-RTT], [with RAIM,1 Rx] | Convex UEs | 2.138 | 3.02 | 4.327 | 6.28 | No |
| [Case 2-7], [UMi], [FR1,5M],  [DL-TDOA], [without RAIM,1 Rx] | Convex UEs | 6.13 | 8.93 | 13.15 | 20.78 | No |
| [Case 2-8], [UMi], [FR1,5M],  [DL-TDOA], [with RAIM,1 Rx] | Convex UEs | 2.41 | 3.69 | 5.59 | 9.11 | No |
| [Case 2-9], [UMi], [FR1,5M],  [UL-TDOA], [without RAIM,1 Rx] | Convex UEs | 9.2 | 13.77 | 21.13 | 30.58 | No |
| [Case 2-10], [UMi], [FR1,5M],  [UL-TDOA], [with RAIM,1 Rx] | Convex UEs | 3.49 | 5.25 | 7.02 | 10.55 | No |
| [Case 2-11], [UMi], [FR1,5M], [Multi-RTT], [without RAIM,1 Rx] | Convex UEs | 7.48 | 11.8 | 16.66 | 24.44 | No |
| [Case 2-12], [UMi], [FR1,5M], [Multi-RTT], [with RAIM,1 Rx] | Convex UEs | 3.03 | 4.53 | 6.49 | 9.92 | No |

Table B.6.5.2-3 Horizontal accuracy results (m) of 20MHz bandwidth in InF-SH using carrier phase measurements [113]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Cases** |  | **50%** | **67%** | **80%** | **90%** | **Requirements met? (Yes/No)** |
| [Case 3-1], [InF-SH], [FR1,20M],  [DL-TDOA], [CPP], [Ideal integer cycle] | Convex UEs | 0.0022 | 0.0031 | 0.0077 | 0.031 | Yes |
| [Case 3-1], [InF-SH], [FR1,20M],  [DL-TDOA], [CPP], [Cost function] | Convex UEs | 0.26 | 0.36 | 0.6 | 1.06 | No |

Table B.6.5.2-4 Evaluation results for frequency hopping of baseline case [113]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| [Case 4-1], [InF-SH], [Frequency hopping], [1 slot gap], [3km/h], [No timing error] | 50% | 67% | 80% | 90% | Requirements met? (Yes/No) |
| Baseline bandwidth (100MHz) without hopping | 0.033 | 0.044 | 0.054 | 0.078 | / |
| 20MHz bandwidth | 0.174 | 0.225 | 0.378 | 1.32 | No |
| Hopping without phase error compensation | 0.83 | 1.39 | 2.01 | 3.11 | No |
| Hopping with phase error compensation | 0.05 | 0.06 | 0.07 | 0.14 | Yes |

Table B.6.5.2-5 Evaluation results for frequency hopping with different time gaps [113]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| [Case 4-2], [InF-SH], [Frequency hopping], [different time gaps], [3km/h], [No timing error] | Time gap between hops | 50% | 67% | 80% | 90% | Requirements met? (Yes/No) |
| Hopping without phase error compensation | 4 symbols (140us) | 0.87 | 1.51 | 1.98 | 2.94 | No |
| 1 slot | 0.83 | 1.44 | 1.99 | 3.11 | No |
| 4 slots | 1.1 | 1.63 | 2.42 | 3.28 | No |
| 8 slots | 1.03 | 1.73 | 2.51 | 3.69 | No |
| 10 slots | 1.12 | 1.64 | 2.73 | 4.33 | No |
| Hopping with phase error compensation | 4 symbols (140us) | 0.05 | 0.06 | 0.07 | 0.11 | Yes |
| 1 slot | 0.05 | 0.06 | 0.07 | 0.14 | Yes |
| 4 slots | 0.06 | 0.09 | 0.14 | 0.22 | Yes |
| 8 slots | 0.05 | 0.06 | 0.14 | 0.29 | Yes |
| 10 slots | 0.16 | 0.23 | 0.33 | 0.43 | Yes |

Table B.6.5.2-6 Evaluation results for frequency hopping with large time gap and large UE speed [113]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| [Case 4-3], [InF-SH], [Frequency hopping], [ large time gaps], [large UE speed], [No timing error] | UE speed | 50% | 67% | 80% | 90% | Requirements met? (Yes/No) |
| Hopping with phase error compensation with 4 slots time gap | 30km/h | 0.09 | 0.16 | 0.31 | 0.74 | Yes |
| 60km/h | 0.12 | 0.19 | 0.44 | 1.22 | No |
| Hopping with phase error compensation with 8 slots time gap | 30km/h | 0.14 | 0.23 | 0.49 | 0.93 | Yes |
| 60km/h | 0.13 | 0.23 | 0.52 | 1.33 | No |
| Hopping with phase error compensation with 10 slots time gap | 30km/h | 0.54 | 0.73 | 0.99 | 1.45 | No |
| 60km/h | 0.85 | 1.26 | 1.65 | 2.19 | No |

Table B.6.5.2-7 Evaluation results for frequency hopping with Rx timing errors [113]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| [Case 4-4], [InF-SH], [Frequency hopping], [1 slot gap], [3km/h], [with timing error] | Rx timing errors between hops | 50% | 67% | 80% | 90% | Requirements met? (Yes/No) |
| Hopping with phase error compensation | No timing error | 0.05 | 0.06 | 0.07 | 0.14 | Yes |
| 1ns | 0.16 | 0.19 | 0.24 | 0.32 | Yes |
| 3ns | 0.47 | 0.59 | 0.74 | 1.03 | No |
| 5ns | 0.85 | 1.16 | 1.36 | 1.74 | No |

Figure B.6.5.2-1 provides the results based on Rel-17 method of 20MHz and 5MHz bandwidth in InF-SH without RAIM and with RAIM.



Figure B.6.5.2-1 Horizontal accuracy performance based on Rel-17 method of 20MHz (left) and 5MHz (right) bandwidth in InF-SH without RAIM and with RAIM (case 1-1~case 1-12) [113]

Figure B.6.5.2-2 provides the results based on Rel-17 method of 20MHz with different Rx branches in InF-SH without RAIM.



Figure B.6.5.2-2 Horizontal accuracy performance based on Rel-17 method of 20MHz bandwidth in InF-SH without RAIM (case 1-13~case 1-14) [113]

Figure B.6.5.2-3 provides the results based on Rel-17 method of 20MHz and 5MHz bandwidth in UMi without RAIM and with RAIM.



Figure B.6.5.2-3 Horizontal accuracy performance based on Rel-17 method of 20MHz (left) and 5MHz (right) bandwidth in UMi without RAIM and with RAIM (case 2-1~case 2-12) [113]

Figure B.6.5.2-4 provides the results based on carrier phase measurement of 20MHz bandwidth in InF-SH.



Figure B.6.5.2-4 Horizontal accuracy performance based on carrier phase measurement of 20MHz bandwidth in InF-SH (case 3-1, case 3-2) [113]

Figure B.6.5.2-5~ Figure B.6.5.2-8 provide the results based on frequency hopping.



Figure B.6.5.2-5 Evaluation results for frequency hopping of baseline case (case 4-1) [113]



Figure B.6.5.2-6 Evaluation results for frequency hopping with different time gaps (case 4-2) [113]



Figure B.6.5.2-7 Evaluation results for frequency hopping with large time gap and UE speed (case 4-3) [113]



Figure B.6.5.2-8 Evaluation results for frequency hopping with Rx timing error (case 4-4) [113]

## B.6.6 Results from source [127]

### B.6.6.1 Description of evaluation scenarios

Table B.6.6.1-1: NR RedCap UE positioning - evaluation scenarios and parameters for InF-SH and UMi

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Case 1 (FR1)** | **Case 2(FR1)** | **Case 3(FR1)** | **Case 4 (FR1)** | **Case 5(FR1)** | **Case 6(FR1)** |
| Scenario (baseline, otherwise state any modifications) | InF-SH | InF-SH | InF-SH | UMi | InF-SH | InF-SH |
| Carrier frequency | 3.5G Hz | 3.5G Hz | 3.5G Hz | 4G Hz | 3.5G Hz | 3.5G Hz |
| Subcarrier spacing | 30Khz | 30Khz | 30Khz | 30Khz | 30Khz | 30Khz |
| Reference Signal Transmission Bandwidth | 20MHz | 20MHz | 20MHz | 20MHz | 20MHz | 20MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | Comb-4 | Comb-4 | Comb-4 | Comb-4 | Comb-4 | Comb-4 |
| Reference signal  (type of sequence, number of ports, …) | PRS | PRS | PRS | PRS | PRS | PRS |
| Number of sites | 18(4 used) | 18(4 used) | 18(4 used) | 19\*3 | 18(4 used) | 18(4 used) |
| Number of symbols used per occasion | 4 | 4 | 4 | 4 | 4 | 4 |
| number of occasions used per positioning estimate |  |  |  |  |  |  |
| Power-boosting level | NA | NA | NA | NA | NA | NA |
| Uplink power control (applied/not applied) | NA | NA | NA | NA | NA | NA |
| interference modelling (ideal muting, or other) | NA | NA | NA | NA | NA | NA |
| Description of Measurement Algorithm (e.g. super resolution, interference cancellation, ….) | Super Resolution | Super Resolution+ Carrier phase  Small search of integer N | Super Resolution+ Carrier phase  Large search of integer N | Super Resolution | MUSIC | MUSIC |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) | Taylor series | Taylor series | Taylor series | Taylor series | Taylor series | Taylor series |
| Network synchronization assumptions | Perfect | Perfect | Perfect | Perfect | Perfect | Perfect |
| UE/gNB RX and TX timing error | Ideal | Ideal | Ideal | Ideal | Ideal | Ideal |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | NA | NA | NA | NA | NA | NA |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | NA | NA | NA | NA | NA | NA |
| UE antenna configuration |  |  |  |  |  |  |
| Number of UE branches | 1 | 1 | 1 | 1 (best link) | 1 | 1 |
| Description of enhancement solutions, if any | NA | NA | NA | NA | NA | Rx FH, each hop UE receives 20Mhz and in total 4 hops |
| gNB antenna configuration |  |  |  |  |  |  |
| UE noise figure | NA | NA | NA | NA | NA | NA |
| UE antenna height | 1.5m | 1.5m | 1.5m | 1.5m | 1.5m | 1.5m |
| gNB antenna height | 8m | 8m | 8m | 8m | 8m | 8m |
| Additional notes, if any |  |  |  |  |  |  |

### B.6.6.2 NR RedCap UE positioning accuracy evaluation results

Table B.6.6.2-1: NR RedCap UE positioning - evaluation scenarios and parameters for InF-SH and UMi

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cases |  | 50% | 67% | 80% | 90% | Met the requirement |
| Case 1,InF-SH FR1, DL-TDOA | (Optional) All UEs |  |  |  |  |  |
| Convex UEs | 0.92 | 1.17 | 1.46 | 1.79 | NO |
| Case 2, InF-SH FR1, DL-TDOA +CPP | (Optional) All UEs |  |  |  |  |  |
| Convex UEs | 0 | 0 | 1.34 | 2.47 | NO |
| Case 3, InF-SH FR1, DL-TDOA +CPP | (Optional) All UEs |  |  |  |  |  |
| Convex UEs | 0.03 | 0.04 | 0.05 | 0.06 | Yes |
| Case 4, UMi FR1, DL-TDOA | All UEs | 5.8 | 7.1 | 8.9 | 11.9 | NO |
| Convex UEs |  |  |  |  |  |
| Case 5,InF-SH FR1, DL-TDOA, MUSIC | (Optional) All UEs | 0.37 | 0.48 | 0.61 | 1.35 | No |
| Convex UEs |  |  |  |  |  |
| Case 6,InF-SH FR1, DL-TDOA, Rx FH+ MUSIC | (Optional) All UEs | 0.37 | 0.45 | 0.56 | 0.76 | Yes |
| Convex UEs |  |  |  |  |  |

Figures B.6.6.2-1~5 provide the results based on case 1~case 6 as described in Table B.6.6.1-1.



**Fig. B.6.6.2-1:** Positioning performance under case 1 **Fig. B.6.6.2-2:** Positioning performance under case 2



**Fig. B.6.6.2-3:** Positioning performance under case 3 **Fig. B.6.6.2-4:** Positioning performance under case 4



Fig. B.6.6.2-5: Positioning performance of case 5 and case 6

## B.6.7 Results from source [118]

### B.6.7.1 Description of evaluation scenarios

Evaluation assumptions for system level analysis are provided in Table B.6.7.1-1 to Table B.6.7.1-9.

Evaluation assumptions for system level analysis for the FR1 InF-SH scenario including the frequency hopping based enhancements with DL-TDOA are provided in Table B.6.7.1-1.

Evaluation assumptions for system level analysis for the frequency hopping based enhancements with FR1 InF-SH DL-TDOA considering the Doppler impact are provided in Table B.6.7.1-2.

Evaluation assumptions for system level analysis for the frequency hopping based enhancement with FR1 InF-SH DL-TDOA considering phase offset impact are provided in Table B.6.7.1-3.

Evaluation assumptions for system level analysis for the frequency hopping based enhancement with InF-SH DL-TDOA considering timing offset impact are provided in Table B.6.7.1-4.

Evaluation assumptions for system level analysis for the FR2 InF-SH scenario including the frequency hopping based enhancements with DL-TDOA are provided in Table B.6.7.1-5.

Evaluation assumptions for system level analysis for the frequency hopping based enhancement with InF-SH DL-TDOA considering switching gap are provided in Table B.6.7.1-6.

Evaluation assumptions for system level analysis for the carrier phase based enhancement with FR1 InF-DH DL-TDOA positioning are provided in Table B.6.7.1-.7

Evaluation assumptions for system level analysis for the frequency hopping based enhancement with FR1 InF-DH DL-TDOA positioning are provided in Table B.6.7.1-8.

Evaluation assumptions for system level analysis for the frequency hopping based enhancement with FR1 UMi DL-TDOA positioning are provided in Table B.6.7.1-9.

Table B.6.7.1-1: NR RedCap UE positioning - evaluation scenarios and parameters for FR1 InF-SH (for comparing frequency hopping performance)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Parameter | Case 1 (InF-SH, FR1, 20MHz Only) | Case 2 (InF-SH, FR1, 3x20 MHz, without Φ adjustment) | Case 3 (InF-SH, FR1, 3x20 MHz, with Φ adjustment) | Case 4 (InF-SH, FR1, Full 60MHz | Case 5 (InF-SH, FR1, 5x20 MHz, without Φ adjustment) | Case 6 (InF-SH, FR1, 5x20 MHz, with Φ adjustment) | Case 7 (InF-SH, FR1, Full 100MHz |
| Scenario (baseline, otherwise state any modifications) | InF-SH | | | | | | |
| Carrier frequency | 3.5GHz | | | | | | |
| Subcarrier spacing | 30kHz | | | | | | |
| Reference Signal Transmission Bandwidth | 20MHz | 3x20MHz | | 60MHz | 5x20MHz | | 100MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | CombSize=2 | | | | | | |
| Reference signal  (type of sequence, number of ports, …) | DL PRS | | | | | | |
| Number of sites | 18 | | | | | | |
| Number of symbols used per occasion | 2 | | | | | | |
| number of occasions used per positioning estimate | 1 | | | | | | |
| Power-boosting level | Not applied | | | | | | |
| Uplink power control (applied/not applied) | Not applied | | | | | | |
| interference modelling (ideal muting, or other) | ideal muting | | | | | | |
| Description of Measurement Algorithm (e.g., super resolution, interference cancellation, ….) | MUSIC | | | | | | |
| Description of positioning technique / applied positioning algorithm (e.g., Least square, Taylor series, etc) | Least square | | | | | | |
| Network synchronization assumptions | Perfect synchronization | | | | | | |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | N/A | | | | | | |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | N/A | | | | | | |
| UE antenna configuration | (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | | | | | | |
| Number of UE branches | 1Rx 1Tx | | | | | | |
| Description of enhancement solutions, if any | None | Frequency hopping, 3 hops without phase adjustment;  Phase between hops satisfy uniform random, (-π, +π) | Frequency hopping, 3 hops with phase adjustment; Phase between hops satisfy uniform random, (-π, +π); 4PRB used for practical phase estimation | None | Frequency hopping, 5 hops without phase adjustment;  Phase between hops satisfy uniform random, (-π, +π) | Frequency hopping, 5 hops with phase adjustment; Phase between hops satisfy uniform random, (-π, +π); 4PRB used for practical phase estimation | None |
| gNB antenna configuration | (M, N, P, Mg, Ng) = (4, 4, 2, 1, 1), dH=dV=0.5λ | | | | | | |
| UE noise figure | 9dB | | | | | | |
| UE antenna height | 1.5m | | | | | | |
| gNB antenna height | 8m | | | | | | |

Table B.6.7.1-2: NR RedCap UE positioning - evaluation scenarios and parameters for FR1 InF-SH (Impact of Doppler)

|  |  |
| --- | --- |
| Parameter | Case 8 ~ Case 27 |
| Scenario (baseline, otherwise state any modifications) | InF-SH |
| Carrier frequency | 3.5GHz |
| Subcarrier spacing | 30kHz |
| Reference Signal Transmission Bandwidth | 5x20MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | CombSize=2 |
| Reference signal  (type of sequence, number of ports, …) | DL PRS |
| Number of sites | 18 |
| Number of symbols used per occasion | 2 |
| number of occasions used per positioning estimate | 1 |
| Power-boosting level | Not applied |
| Uplink power control (applied/not applied) | Not applied |
| interference modelling (ideal muting, or other) | ideal muting |
| Description of Measurement Algorithm (e.g., super resolution, interference cancellation, ….) | MUSIC |
| Description of positioning technique / applied positioning algorithm (e.g., Least square, Taylor series, etc) | Least square |
| Network synchronization assumptions | Perfect synchronization |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | N/A |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | N/A |
| UE antenna configuration | (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) |
| Number of UE branches | 1Rx 1Tx |
| Description of enhancement solutions, if any | Frequency hopping |
| gNB antenna configuration | (M, N, P, Mg, Ng) = (4, 4, 2, 1, 1), dH=dV=0.5λ |
| UE noise figure | 9dB |
| UE antenna height | 1.5m |
| gNB antenna height | 8m |
| Additional notes, if any | Case 8, InF-SH FR1, 5x20 MHz, Doppler 0 Hz  Case 9, InF-SH FR1, 5x20 MHz, Doppler 10 Hz, TimeGap=0.1ms  Case 10, InF-SH FR1, 5x20 MHz, Doppler 100 Hz, TimeGap=0.1ms  Case 11, InF-SH FR1, 5x20 MHz, Doppler 200Hz, TimeGap=0.1ms  Case 12, InF-SH FR1, 5x20 MHz, Doppler 500Hz, TimeGap=0.1ms  Case 13, InF-SH FR1, 5x20 MHz, Doppler 1000Hz, TimeGap=0.1ms  Case 14, InF-SH FR1, 5x20 MHz, Doppler 10 Hz, TimeGap=0.2ms  Case 15, InF-SH FR1, 5x20 MHz, Doppler 100 Hz, TimeGap=0.2ms  Case 16, InF-SH FR1, 5x20 MHz, Doppler 200Hz, TimeGap=0.2ms  Case 17, InF-SH FR1, 5x20 MHz, Doppler 500Hz, TimeGap=0.2ms  Case 18, InF-SH FR1, 5x20 MHz, Doppler 1000Hz, TimeGap=0.2ms  Case 19, InF-SH FR1, 5x20 MHz, Doppler 10 Hz, TimeGap=0.5ms  Case 20, InF-SH FR1, 5x20 MHz, Doppler 100 Hz, TimeGap=0.5ms  Case 21, InF-SH FR1, 5x20 MHz, Doppler 200Hz, TimeGap=0.5ms  Case 22, InF-SH FR1, 5x20 MHz, Doppler 10 Hz, TimeGap=1 ms  Case 23, InF-SH FR1, 5x20 MHz, Doppler 100 Hz, TimeGap=1 ms  Case 24, InF-SH FR1, 5x20 MHz, Doppler 200Hz, TimeGap=1 ms  Case 25, InF-SH FR1, 5x20 MHz, Doppler 10 Hz, TimeGap=2 ms  Case 26, InF-SH FR1, 5x20 MHz, Doppler 100 Hz, TimeGap=2 ms  Case 27, InF-SH FR1, 5x20 MHz, Doppler 10 Hz, TimeGap=5 ms |

Table B.6.7.1-3: NR RedCap UE positioning - evaluation scenarios and parameters for FR1 InF-SH (Impact of phase offset)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Parameter | Case 28 (InF-SH, FR1, 5x20 MHz, Phase offset 0.01\*2π) | Case 29 (InF-SH, FR1, 5x20 MHz, Phase offset 0.05\*2π) | Case 30 (InF-SH, FR1, 5x20 MHz, Phase offset 0.1\*2π) | Case 31 (InF-SH, FR1, 5x20 MHz, Phase offset 0.2\*2π) | Case 32 (InF-SH, FR1, 5x20 MHz, Phase offset 0.5\*2π) | Case 33 (InF-SH, FR1, 5x20 MHz, Phase offset 1\*2π) |
| Scenario (baseline, otherwise state any modifications) | InF-SH | | | | | |
| Carrier frequency | 3.5GHz | | | | | |
| Subcarrier spacing | 30kHz | | | | | |
| Reference Signal Transmission Bandwidth | 5x20MHz | | | | | |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | CombSize=2 | | | | | |
| Reference signal  (type of sequence, number of ports, …) | DL PRS | | | | | |
| Number of sites | 18 | | | | | |
| Number of symbols used per occasion | 2 | | | | | |
| number of occasions used per positioning estimate | 1 | | | | | |
| Power-boosting level | Not applied | | | | | |
| Uplink power control (applied/not applied) | Not applied | | | | | |
| interference modelling (ideal muting, or other) | ideal muting | | | | | |
| Description of Measurement Algorithm (e.g., super resolution, interference cancellation, ….) | MUSIC | | | | | |
| Description of positioning technique / applied positioning algorithm (e.g., Least square, Taylor series, etc) | Least square | | | | | |
| Network synchronization assumptions | Perfect synchronization | | | | | |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | N/A | | | | | |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | N/A | | | | | |
| UE antenna configuration | (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | | | | | |
| Number of UE branches | 1Rx 1Tx | | | | | |
| Description of enhancement solutions, if any | Frequency hopping  Random phase offset | | | | | |
| gNB antenna configuration | (M, N, P, Mg, Ng) = (4, 4, 2, 1, 1), dH=dV=0.5λ | | | | | |
| UE noise figure | 9dB | | | | | |
| UE antenna height | 1.5m | | | | | |
| gNB antenna height | 8m | | | | | |

Table B.6.7.1-4: NR RedCap UE positioning - evaluation scenarios and parameters for FR1 InF-SH (Impact of timing offset)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Parameter | Case 34 (InF-SH, FR1, 5x20 MHz, STD=0) | Case 35 (InF-SH, FR1, 5x20 MHz, STD=0.5 ns) | Case 36 (InF-SH, FR1, 5x20 MHz, STD=1 ns) | Case 37 (InF-SH, FR1, 5x20 MHz, STD=2 ns) | Case 38 (InF-SH, FR1, 5x20 MHz, STD=3 ns) | Case 39 (InF-SH, FR1, 5x20 MHz, STD=4 ns) |
| Scenario (baseline, otherwise state any modifications) | InF-SH | | | | | |
| Carrier frequency | 3.5GHz | | | | | |
| Subcarrier spacing | 15kHz | | | | | |
| Reference Signal Transmission Bandwidth | 5x20MHz | | | | | |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | CombSize=2 | | | | | |
| Reference signal  (type of sequence, number of ports, …) | DL PRS | | | | | |
| Number of sites | 18 | | | | | |
| Number of symbols used per occasion | 2 | | | | | |
| number of occasions used per positioning estimate | 1 | | | | | |
| Power-boosting level | Not applied | | | | | |
| Uplink power control (applied/not applied) | Not applied | | | | | |
| interference modelling (ideal muting, or other) | ideal muting | | | | | |
| Description of Measurement Algorithm (e.g., super resolution, interference cancellation, ….) | MUSIC | | | | | |
| Description of positioning technique / applied positioning algorithm (e.g., Least square, Taylor series, etc) | Least square | | | | | |
| Network synchronization assumptions | Perfect synchronization | | | | | |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | N/A | | | | | |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | N/A | | | | | |
| UE antenna configuration | (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | | | | | |
| Number of UE branches | 1Rx 1Tx | | | | | |
| Description of enhancement solutions, if any | Frequency hopping  Random timing offset | | | | | |
| gNB antenna configuration | (M, N, P, Mg, Ng) = (4, 4, 2, 1, 1), dH=dV=0.5λ | | | | | |
| UE noise figure | 9dB | | | | | |
| UE antenna height | 1.5m | | | | | |
| gNB antenna height | 8m | | | | | |

Table B.6.7.1-5: NR RedCap UE positioning - evaluation scenarios and parameters for FR2 InF-SH

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Parameter | Case 40 (InF-SH, FR2, 100MHz Only) | Case 41 (InF-SH, FR2, 100+100 MHz, with Φ adjustment | Case 42 (InF-SH, FR2, 100+100 MHz, w/o Φ adjustment | Case 43 (InF-SH, FR2, Full 200MHz) | Case 44 (InF-SH, FR2, 100+100+100 MHz, with Φ adjustment) | Case 45 (InF-SH, FR2, Full 300MHz) | Case 46 (InF-SH, FR2, 100+100+100 MHz, w/o Φ adjustment) |
| Scenario (baseline, otherwise state any modifications) | InF-SH | | | | | | |
| Carrier frequency | 28 GHz | | | | | | |
| Subcarrier spacing | 120 kHz | | | | | | |
| Reference Signal Transmission Bandwidth | N x 20MHz (N is the hopping number) | | | | | | |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | CombSize=2 | | | | | | |
| Reference signal  (type of sequence, number of ports, …) | DL PRS | | | | | | |
| Number of sites | 18 | | | | | | |
| Number of symbols used per occasion | 2 | | | | | | |
| number of occasions used per positioning estimate | 1 | | | | | | |
| Power-boosting level | Not applied | | | | | | |
| Uplink power control (applied/not applied) | Not applied | | | | | | |
| interference modelling (ideal muting, or other) | ideal muting | | | | | | |
| Description of Measurement Algorithm (e.g., super resolution, interference cancellation, ….) | MUSIC | | | | | | |
| Description of positioning technique / applied positioning algorithm (e.g., Least square, Taylor series, etc) | Least square | | | | | | |
| Network synchronization assumptions | Perfect synchronization | | | | | | |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | N/A | | | | | | |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | N/A | | | | | | |
| UE antenna configuration | (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | | | | | | |
| Number of UE branches | 1Rx 1Tx | | | | | | |
| Description of enhancement solutions, if any | Frequency hopping  Random timing offset  4PRB used for practical phase estimation if phase adjustment is applied | | | | | | |
| gNB antenna configuration | (M, N, P, Mg, Ng) = (4, 4, 2, 1, 1), dH=dV=0.5λ | | | | | | |
| UE noise figure | 9dB | | | | | | |
| UE antenna height | 1.5m | | | | | | |
| gNB antenna height | 8m | | | | | | |

Table B.6.7.1-6: NR RedCap UE positioning - evaluation scenarios and parameters for FR1 InF-SH (Impact of switching gap)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Parameter | Case 47 (InF-SH, FR1, 5x20 MHz, gap=0) | Case 48 (InF-SH, FR1, 5x20 MHz, gap=0.1ms) | Case 49 (InF-SH, FR1, 5x20 MHz, gap=0.2ms) | Case 50 (InF-SH, FR1, 5x20 MHz, gap=0.5ms) | Case 51 (InF-SH, FR1, 5x20 MHz, gap=1ms) | Case 52 (InF-SH, FR1, 5x20 MHz, gap=2ms) | Case 53 (InF-SH, FR1, 5x20 MHz, gap=5ms) |
| Scenario (baseline, otherwise state any modifications) | InF-SH | | | | | | |
| Carrier frequency | 3.5GHz | | | | | | |
| Subcarrier spacing | 30kHz | | | | | | |
| Reference Signal Transmission Bandwidth | 5x20MHz | | | | | | |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | CombSize=2 | | | | | | |
| Reference signal  (type of sequence, number of ports, …) | DL PRS | | | | | | |
| Number of sites | 18 | | | | | | |
| Number of symbols used per occasion | 2 | | | | | | |
| number of occasions used per positioning estimate | 1 | | | | | | |
| Power-boosting level | Not applied | | | | | | |
| Uplink power control (applied/not applied) | Not applied | | | | | | |
| interference modelling (ideal muting, or other) | ideal muting | | | | | | |
| Description of Measurement Algorithm (e.g., super resolution, interference cancellation, ….) | MUSIC | | | | | | |
| Description of positioning technique / applied positioning algorithm (e.g., Least square, Taylor series, etc) | Least square | | | | | | |
| Network synchronization assumptions | Perfect synchronization | | | | | | |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | N/A | | | | | | |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | N/A | | | | | | |
| UE antenna configuration | (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | | | | | | |
| Number of UE branches | 1Rx 1Tx | | | | | | |
| Description of enhancement solutions, if any | Frequency hopping, 5 hops | | | | | | |
| gNB antenna configuration | (M, N, P, Mg, Ng) = (4, 4, 2, 1, 1), dH=dV=0.5λ | | | | | | |
| UE noise figure | 9dB | | | | | | |
| UE antenna height | 1.5m | | | | | | |
| gNB antenna height | 8m | | | | | | |
| Additional notes, if any | UE speed: 3km/h | | | | | | |

Table B.6.7.1-7: NR RedCap UE positioning - evaluation scenarios and parameters for FR1 InF-SH (carrier phase based solution)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Parameter | Case 54 (InF-SH, FR1, 20 MHz, perfect Φ, N1) | Case 55 (InF-SH, FR1, 20 MHz, perfect Φ, N2) | Case 56 (InF-SH, FR1, 20 MHz, perfect Φ, N4) | Case 57 (InF-SH, FR1, 20 MHz, perfect Φ, N6) | Case 58 (InF-SH, FR1, 20 MHz, perfect Φ, N8) | Case 59 (InF-SH, FR1, 20 MHz, perfect Φ, N10) | Case 60 (InF-SH, FR1, 20 MHz, perfect Φ, N12) | Case 61 (InF-SH, FR1, 20 MHz, perfect Φ, N14) |
| Scenario (baseline, otherwise state any modifications) | InF-SH | | | | | | | |
| Carrier frequency | 3.5GHz | | | | | | | |
| Subcarrier spacing | 30kHz | | | | | | | |
| Reference Signal Transmission Bandwidth | 20MHz | | | | | | | |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | CombSize=2 | | | | | | | |
| Reference signal  (type of sequence, number of ports, …) | DL PRS | | | | | | | |
| Number of sites | 18 | | | | | | | |
| Number of symbols used per occasion | 2 | | | | | | | |
| number of occasions used per positioning estimate | 1 | | | | | | | |
| Power-boosting level | Not applied | | | | | | | |
| Uplink power control (applied/not applied) | Not applied | | | | | | | |
| interference modelling (ideal muting, or other) | ideal muting | | | | | | | |
| Description of Measurement Algorithm (e.g., super resolution, interference cancellation, ….) | MUSIC | | | | | | | |
| Description of positioning technique / applied positioning algorithm (e.g., Least square, Taylor series, etc) | Least square | | | | | | | |
| Network synchronization assumptions | Perfect synchronization | | | | | | | |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | N/A | | | | | | | |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | N/A | | | | | | | |
| UE antenna configuration | (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | | | | | | | |
| Number of UE branches | 1Rx 1Tx | | | | | | | |
| Description of enhancement solutions, if any | Carrier phase based positioning  Integer N searching range | | | | | | | |
| gNB antenna configuration | (M, N, P, Mg, Ng) = (4, 4, 2, 1, 1), dH=dV=0.5λ | | | | | | | |
| UE noise figure | 9dB | | | | | | | |
| UE antenna height | 1.5m | | | | | | | |
| gNB antenna height | 8m | | | | | | | |

Table B.6.7.1-8: NR RedCap UE positioning - evaluation scenarios and parameters for FR1 InF-DH

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter | Case 62, InF-DH FR1, 20MHz Only | Case 63, InF-DH FR1, 5x20 MHz, without Φ adjustment | Case 64, InF-DH FR1, 5x20 MHz, with Φ adjustment | Case 65, InF-DH FR1, Full 100MHz |
| Scenario (baseline, otherwise state any modifications) | InF-DH | | | |
| Carrier frequency | 3.5GHz | | | |
| Subcarrier spacing | 30kHz | | | |
| Reference Signal Transmission Bandwidth | 20MHz | 5x20 MHz | 5x20 MHz | 100 MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | CombSize=2 | | | |
| Reference signal  (type of sequence, number of ports, …) | DL PRS | | | |
| Number of sites | 18 | | | |
| Number of symbols used per occasion | 2 | | | |
| number of occasions used per positioning estimate | 1 | | | |
| Power-boosting level | Not applied | | | |
| Uplink power control (applied/not applied) | Not applied | | | |
| interference modelling (ideal muting, or other) | ideal muting | | | |
| Description of Measurement Algorithm (e.g., super resolution, interference cancellation, ….) | MUSIC | | | |
| Description of positioning technique / applied positioning algorithm (e.g., Least square, Taylor series, etc) | Least square | | | |
| Network synchronization assumptions | Perfect synchronization | | | |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | N/A | | | |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | N/A | | | |
| UE antenna configuration | (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | | | |
| Number of UE branches | 1Rx 1Tx | | | |
| Description of enhancement solutions, if any | None | Frequency hopping, 5 hops without phase adjustment;  Phase between hops satisfy uniform random, (-π, +π) | Frequency hopping, 5 hops with phase adjustment; Phase between hops satisfy uniform random, (-π, +π); 4PRB used for practical phase estimation | None |
| gNB antenna configuration | (M, N, P, Mg, Ng) = (4, 4, 2, 1, 1), dH=dV=0.5λ | | | |
| UE noise figure | 9dB | | | |
| UE antenna height | 1.5m | | | |
| gNB antenna height | 8m | | | |

Table B.6.7.1-9: NR RedCap UE positioning - evaluation scenarios and parameters for FR1 UMi

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter | Case 66, UMi FR1, 20MHz Only | Case 67, UMi FR1, 5x20 MHz, without Φ adjustment | Case 68, UMi FR1, 5x20 MHz, with Φ adjustment | Case 69, UMi FR1, Full 100MHz |
| Scenario (baseline, otherwise state any modifications) | UMi | | | |
| Carrier frequency | 3.5GHz | | | |
| Subcarrier spacing | 30kHz | | | |
| Reference Signal Transmission Bandwidth | 20MHz | 5x20 MHz | 5x20 MHz | 100 MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | CombSize=2 | | | |
| Reference signal  (type of sequence, number of ports, …) | DL PRS | | | |
| Number of sites | 21 | | | |
| Number of symbols used per occasion | 2 | | | |
| number of occasions used per positioning estimate | 1 | | | |
| Power-boosting level | Not applied | | | |
| Uplink power control (applied/not applied) | Not applied | | | |
| interference modelling (ideal muting, or other) | ideal muting | | | |
| Description of Measurement Algorithm (e.g., super resolution, interference cancellation, ….) | MUSIC | | | |
| Description of positioning technique / applied positioning algorithm (e.g., Least square, Taylor series, etc) | Least square | | | |
| Network synchronization assumptions | Perfect synchronization | | | |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | N/A | | | |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | N/A | | | |
| UE antenna configuration | (M, N, P, Mg, Ng) = (1, 1, 1, 1, 1) | | | |
| Number of UE branches | 1Rx 1Tx | | | |
| Description of enhancement solutions, if any | None | Frequency hopping, 5 hops without phase adjustment;  Phase between hops satisfy uniform random, (-π, +π) | Frequency hopping, 5 hops with phase adjustment; Phase between hops satisfy uniform random, (-π, +π); 4PRB used for practical phase estimation | None |
| gNB antenna configuration | (M, N, P, Mg, Ng) = (4, 4, 2, 1, 1), dH=dV=0.5λ | | | |
| UE noise figure | 9dB | | | |
| UE antenna height | 1.5m | | | |
| gNB antenna height | 10m | | | |

### B.6.7.2 NR RedCap UE positioning accuracy evaluation results

The simulation results for FR1 in InF-SH scenario for comparing with and without frequency hopping are shown in Figure B.6.7.2-1, Figure B.6.7.2-2 and Table B.6.7.2-1.

The evaluation results for FR1 in InF-SH scenario for assessing Doppler impact are shown in Figure B.6.7.2-3 and Table B.6.7.2-2.

The evaluation results for FR1 in InF-SH scenario for assessing phase offset impact (without adjustment) are shown in Figure B.6.7.2-4 and Table B.6.7.2-3.

The evaluation results for FR1 in InF-SH scenario for assessing timing offset impact are shown in Figure B.6.7.2-5 and Table B.6.7.2-4.

The simulation results for FR2 in InF-SH scenario are shown in Figure B.6.7.2-6, Figure B.6.7.2-7 and Table B.6.7.2-5.

The simulation results for FR1 in InF-SH scenario for evaluating the switching gap impact of frequency hopping are shown in the following Figure B.6.7.2-8 and Table B.6.7.2-6.

The simulation results for FR1 in InF-SH scenario for evaluating carrier phase based positioning for RedCap UE are shown in the following Figure B.6.7.2-9 and Table B.6.7.2-7.

The simulation results for FR1 in InF-DH scenario for comparing with and without frequency hopping are shown in the following Figure B.6.7.2-10 and Table B.6.7.2-8.

The simulation results for FR1 in UMi scenario for comparing with and without frequency hopping are shown in the following Figure B.6.7.2-11 and Table B.6.7.2-9.

Table B.6.7.2-1 Simulation results for hopping in FR 1, InF-SH scenario

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cases |  | 50% | 67% | 80% | 90% | Requirements met? (Yes/No) |
| Case 1, InF-SH FR1, 20MHz Only | Convex UEs | 1.24 | 1.55 | 1.86 | 2.60 | No |
| Case 2, InF-SH FR1, 20+20+20 MHz, without Φ adjustment | Convex UEs | 1.56 | 2.01 | 2.45 | 3.05 | No |
| Case 3, InF-SH FR1, 20+20+20 MHz, with Φ adjustment | Convex UEs | 0.72 | 1.07 | 1.35 | 1.77 | No |
| Case 4, InF-SH FR1, Full 60MHz | Convex UEs | 0.61 | 0.83 | 1.17 | 1.79 | No |
| Case 5, InF-SH FR1, 5x20 MHz, without Φ adjustment | Convex UEs | 2.14 | 2.89 | 3.77 | 4.98 | No |
| Case 6, InF-SH FR1, 5x20 MHz, with Φ adjustment | Convex UEs | 0.27 | 0.37 | 0.45 | 0.57 | Yes |
| Case 7, InF-SH FR1, Full 100MHz | Convex UEs | 0.17 | 0.24 | 0.32 | 0.42 | Yes |

Table B.6.7.2-2 Simulation results for hopping for RedCap UE with Doppler impact in FR 1, InF-SH scenario

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cases |  | 50% | 67% | 80% | 90% | Requirements met? (Yes/No) |
| Case 8, InF-SH FR1, 5x20 MHz, Doppler 0 Hz | Convex UEs | 0.179 | 0.238 | 0.325 | 0.428 | Yes |
| Case 9, InF-SH FR1, 5x20 MHz, Doppler 10 Hz, TimeGap=0.1ms | Convex UEs | 0.210 | 0.283 | 0.341 | 0.419 | Yes |
| Case 10, InF-SH FR1, 5x20 MHz, Doppler 100 Hz, TimeGap=0.1ms | Convex UEs | 0.221 | 0.270 | 0.335 | 0.439 | Yes |
| Case 11, InF-SH FR1, 5x20 MHz, Doppler 200Hz, TimeGap=0.1ms | Convex UEs | 0.275 | 0.349 | 0.420 | 0.520 | Yes |
| Case 12, InF-SH FR1, 5x20 MHz, Doppler 500Hz, TimeGap=0.1ms | Convex UEs | 0.444 | 0.558 | 0.683 | 0.813 | Yes |
| Case 13, InF-SH FR1, 5x20 MHz, Doppler 1000Hz, TimeGap=0.1ms | Convex UEs | 0.603 | 0.773 | 1.033 | 1.242 | No |
| Case 14, InF-SH FR1, 5x20 MHz, Doppler 10 Hz, TimeGap=0.2ms | Convex UEs | 0.210 | 0.273 | 0.323 | 0.394 | Yes |
| Case 15, InF-SH FR1, 5x20 MHz, Doppler 100 Hz, TimeGap=0.2ms | Convex UEs | 0.297 | 0.367 | 0.440 | 0.560 | Yes |
| Case 16, InF-SH FR1, 5x20 MHz, Doppler 200Hz, TimeGap=0.2ms | Convex UEs | 0.388 | 0.490 | 0.568 | 0.701 | Yes |
| Case 17, InF-SH FR1, 5x20 MHz, Doppler 500Hz, TimeGap=0.2ms | Convex UEs | 0.603 | 0.773 | 1.033 | 1.235 | No |
| Case 18, InF-SH FR1, 5x20 MHz, Doppler 1000Hz, TimeGap=0.2ms | Convex UEs | 1.044 | 1.412 | 2.209 | 3.078 | No |
| Case 19, InF-SH FR1, 5x20 MHz, Doppler 10 Hz, TimeGap=0.5ms | Convex UEs | 0.213 | 0.262 | 0.313 | 0.408 | Yes |
| Case 20, InF-SH FR1, 5x20 MHz, Doppler 100 Hz, TimeGap=0.5ms | Convex UEs | 0.445 | 0.572 | 0.684 | 0.814 | Yes |
| Case 21, InF-SH FR1, 5x20 MHz, Doppler 200Hz, TimeGap=0.5ms | Convex UEs | 0.595 | 0.768 | 1.011 | 1.235 | No |
| Case 22, InF-SH FR1, 5x20 MHz, Doppler 10 Hz, TimeGap=1 ms | Convex UEs | 0.221 | 0.269 | 0.335 | 0.439 | Yes |
| Case 23, InF-SH FR1, 5x20 MHz, Doppler 100 Hz, TimeGap=1 ms | Convex UEs | 0.589 | 0.757 | 0.964 | 1.217 | No |
| Case 24, InF-SH FR1, 5x20 MHz, Doppler 200Hz, TimeGap=1 ms | Convex UEs | 1.034 | 1.412 | 2.134 | 2.988 | No |
| Case 25, InF-SH FR1, 5x20 MHz, Doppler 10 Hz, TimeGap=2 ms | Convex UEs | 0.275 | 0.349 | 0.420 | 0.520 | Yes |
| Case 26, InF-SH FR1, 5x20 MHz, Doppler 100 Hz, TimeGap=2 ms | Convex UEs | 1.034 | 1.398 | 2.236 | 3.347 | No |
| Case 27, InF-SH FR1, 5x20 MHz, Doppler 10 Hz, TimeGap=5 ms | Convex UEs | 0.444 | 0.558 | 0.683 | 0.813 | Yes |

Table B.6.7.2-3 Simulation results for hopping for RedCap UE with phase error in FR 1, InF-SH scenario

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cases |  | 50% | 67% | 80% | 90% | Requirements met? (Yes/No) |
| Case 28, InF-SH FR1, 5x20 MHz, Phase offset 0.01\*2 | Convex UEs | 0.180 | 0.249 | 0.347 | 0.452 | Yes |
| Case 29, InF-SH FR1, 5x20 MHz, Phase offset 0.05\*2 | Convex UEs | 0.198 | 0.273 | 0.361 | 0.441 | Yes |
| Case 30, InF-SH FR1, 5x20 MHz, Phase offset 0.1\*2 | Convex UEs | 0.262 | 0.323 | 0.440 | 0.567 | Yes |
| Case 31, InF-SH FR1, 5x20 MHz, Phase offset 0.2\*2 | Convex UEs | 0.422 | 0.563 | 0.677 | 0.968 | Yes |
| Case 32, InF-SH FR1, 5x20 MHz, Phase offset 0.5\*2 | Convex UEs | 0.915 | 1.386 | 1.784 | 2.324 | No |
| Case 33, InF-SH FR1, 5x20 MHz, Phase offset 1\*2 | Convex UEs | 2.145 | 2.874 | 3.769 | 4.981 | No |

Table B.6.7.2-4 Simulation results for hopping for RedCap UE with timing error in FR 1, InF-SH scenario

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cases |  | 50% | 67% | 80% | 90% | Requirements met? (Yes/No) |
| Case 34, InF-SH FR1, 5x20 MHz, STD=0 | Convex UEs | 0.179 | 0.238 | 0.325 | 0.428 | Yes |
| Case 35, InF-SH FR1, 5x20 MHz, STD=0.5 ns | Convex UEs | 0.205 | 0.273 | 0.333 | 0.497 | Yes |
| Case 36, InF-SH FR1, 5x20 MHz, STD=1 ns | Convex UEs | 0.254 | 0.327 | 0.465 | 0.558 | Yes |
| Case 37, InF-SH FR1, 5x20 MHz, STD=2 ns | Convex UEs | 0.375 | 0.497 | 0.618 | 0.873 | Yes |
| Case 38, InF-SH FR1, 5x20 MHz, STD=3 ns | Convex UEs | 0.496 | 0.659 | 0.910 | 1.146 | No |
| Case 39, InF-SH FR1, 5x20 MHz, STD=4 ns | Convex UEs | 0.645 | 0.832 | 1.106 | 1.336 | No |

Table B.6.7.2-5 Simulation results for hopping in FR 2, InF-SH scenario

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cases |  | 50% | 67% | 80% | 90% | Requirements met? (Yes/No) |
| Case 40, InF-SH FR2,100MHz Only | Convex UEs | 0.26 | 0.35 | 0.41 | 0.50 | Yes |
| Case 41, InF-SH FR2, 100+100 MHz, with Φ adjustment | Convex UEs | 0.11 | 0.13 | 0.16 | 0.186 | Yes |
| Case 42, InF-SH FR2, 100+100 MHz, w/o Φ adjustment | Convex UEs | 0.10 | 0.13 | 0.16 | 0.19 | Yes |
| Case 43, InF-SH FR2, Full 200MHz | Convex UEs | 0.092 | 0.12 | 0.15 | 0.185 | Yes |
| Case 44, InF-SH FR2,100+100+100 MHz, with Φ adjustment | Convex UEs | 0.065 | 0.088 | 0.10 | 0.12 | Yes |
| Case 45, InF-SH FR2, Full 300MHz | Convex UEs | 0.054 | 0.069 | 0.088 | 0.11 | Yes |
| Case 46, InF-SH FR2,100+100+100 MHz, w/o Φ adjustment | Convex UEs | 0.36 | 0.46 | 0.58 | 0.74 | Yes |

Table B.6.7.2-6 Simulation results for hopping with switching gap in FR 1, InF-SH scenario

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cases |  | 50% | 67% | 80% | 90% | Requirements met? (Yes/No) |
| Case 47, InF-SH FR1, 5x20 MHz, gap 0ms | Convex UEs | 0.25 | 0.34 | 0.48 | 0.62 | Yes |
| Case 48, InF-SH FR1, 5x20 MHz, gap 0.1ms | Convex UEs | 0.24 | 0.33 | 0.45 | 0.62 | Yes |
| Case 49, InF-SH FR1, 5x20 MHz, gap 0.2ms | Convex UEs | 0.25 | 0.37 | 0.48 | 0.61 | Yes |
| Case 50, InF-SH FR1, 5x20 MHz, gap 0.5ms | Convex UEs | 0.27 | 0.37 | 0.57 | 0.75 | Yes |
| Case 51, InF-SH FR1, 5x20 MHz, gap 1ms | Convex UEs | 0.35 | 0.48 | 0.63 | 0.77 | Yes |
| Case 52, InF-SH FR1, 5x20 MHz, gap 2ms | Convex UEs | 0.60 | 0.71 | 0.86 | 1.02 | No |
| Case 53, InF-SH FR1, 5x20 MHz, gap 5ms | Convex UEs | 1.36 | 1.58 | 1.78 | 2.18 | No |

Table B.6.7.2-7 Simulation results for carrier phase based positioning in FR 1, InF-SH scenario

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cases |  | 50% | 67% | 80% | 90% | Requirements met? (Yes/No) |
| Case 54, InF-SH FR1, perfect Φ, N1 | Convex UEs | 1.14 | 1.42 | 1.73 | 2.18 | No |
| Case 55, InF-SH FR1, perfect Φ, N | Convex UEs | 1.12 | 1.46 | 1.81 | 2.21 | No |
| Case 56, InF-SH FR1, perfect Φ, N4 | Convex UEs | 1.19 | 1.49 | 1.81 | 2.39 | No |
| Case 57, InF-SH FR1, perfect Φ, N | Convex UEs | 1.11 | 1.46 | 1.74 | 2.35 | No |
| Case 58, InF-SH FR1, perfect Φ, N | Convex UEs | 1.15 | 1.56 | 1.89 | 2.46 | No |
| Case 59, InF-SH FR1, perfect Φ, N10 | Convex UEs | 1.02 | 1.55 | 1.97 | 2.46 | No |
| Case 60, InF-SH FR1, perfect Φ, N12 | Convex UEs | 0 | 1.34 | 1.86 | 2.58 | No |
| Case 61, InF-SH FR1, perfect Φ, N14 | Convex UEs | 0 | 1.05 | 1.65 | 2.65 | No |

Table B.6.7.2-8 Simulation results for frequency hopping based positioning in FR 1, InF-DH scenario

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cases |  | 50% | 67% | 80% | 90% | Requirements met? (Yes/No) |
| Case 62, InF-DH FR1, 20MHz Only | Convex UEs | 2.41 | 3.61 | 5.63 | 7.56 | No |
| Case 63, InF-DH FR1, 5x20 MHz, without Φ adjustment | Convex UEs | 5.41 | 6.72 | 8.43 | 11.83 | No |
| Case 64, InF-DH FR1, 5x20 MHz, with Φ adjustment | Convex UEs | 1.02 | 1.58 | 2.49 | 4.44 | No |
| Case 65, InF-DH FR1, Full 100MHz | Convex UEs | 0.39 | 0.70 | 2.15 | 3.89 | No |

Table B.6.7.2-9 Simulation results for frequency hopping based positioning in FR 1, UMi scenario

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cases |  | 50% | 67% | 80% | 90% | Requirements met? (Yes/No) |
| Case 66, UMi FR1, 20MHz Only | Convex UEs | 5.08 | 7.13 | 9.91 | 13.91 | No |
| Case 67, UMi FR1, 5x20 MHz, without Φ adjustment | Convex UEs | 5.76 | 7.33 | 9.30 | 12.59 | No |
| Case 68, UMi FR1, 5x20 MHz, with Φ adjustment | Convex UEs | 1.14 | 2.14 | 4.36 | 7.97 | No |
| Case 69, UMi FR1, Full 100MHz | Convex UEs | 0.59 | 1.96 | 4.60 | 7.65 | No |

|  |  |
| --- | --- |
| Figure B.6.7.2-1: Simulation results for hopping for RedCap UE (3 hops, 60MHz) | Figure B.6.7.2-2: Simulation results for hopping for RedCap UE (5 hops, 100MHz) |







Figure B.6.7.2-3: Simulation results for hopping for RedCap UE with Doppler impact with switching gap (FR1, InF-SH scenario)

|  |  |
| --- | --- |
| Figure B.6.7.2-4: Simulation results for hopping for RedCap UE with phase error (FR 1, InF-SH scenario) | Figure B.6.7.2-5: Simulation results for hopping for RedCap UE with timing error |

|  |  |
| --- | --- |
| Figure B.6.7.2-6: Simulation results for hopping for RedCap UE in FR2 InF-SH scenario (2 hops, 200MHz) | Figure B.6.7.2-7: Simulation results for hopping for RedCap UE in FR2 InF-SH scenario (3 hops, 300MHz) |

|  |  |
| --- | --- |
| Figure B.6.7.2-8: Simulation results for hopping with switching gap for RedCap UE (5 hops, FR 1, InF-SH scenario) | Figure B.6.7.2-9: Simulation results for carrier phase based positioning for RedCap UE (FR 1, InF-SH scenario) |

|  |  |
| --- | --- |
| Figure B.6.7.2-10: Simulation results frequency for hopping based positioning (FR 1, InF-DH scenario) | Figure B.6.7.2-11: Simulation results frequency for hopping based positioning (FR 1, UMi scenario) |

## B.6.8 Results from source [114]

### B.6.8.1 Description of evaluation scenarios

We evaluate the performance of positioning for RedCap UEs in IIoT use case ( InF-SH ) with NR DL-TDOA method and NR carrier phase positioning method.

Base station deployment for InF-SH is illustrates in Figure B.6.8.1-1: (L=300m x W=150m, D=50m)

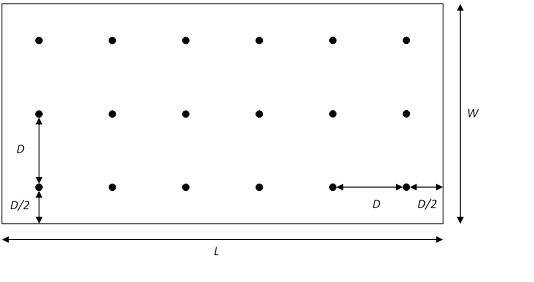


Figure B.6.8.1-1: Base station deployment (InF-SH) from [114]

Evaluation assumptions for system level analysis of positioning for RedCap UEs in InF-SH scenario with NR DL-TDOA method and NR carrier phase positioning method are provided in Table B.6.8.1-1.

Table B.6.8.1-1: NR RedCap UE positioning - evaluation scenarios and parameters for InF-SH from [114]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter | Case 1  (InF-SH) | Case 2  (InF-SH) | Case 3  (InF-SH) | Case 4  (InF-SH) |
| Scenario (baseline, otherwise state any modifications) | Baseline | Baseline | Baseline | Baseline |
| Carrier frequency | 3.5GHz | 3.5GHz | 3.5GHz | 3.45/3.55GHz |
| Subcarrier spacing | 30kHz | 120kHz | 120kHz | 30kHz |
| Reference Signal Transmission Bandwidth | 20MHz | 100MHz | 100MHz | 20MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | PRS (Comb-6) | PRS (Comb-6) | PRS (Comb-6) | PRS (Comb-6) |
| Reference signal  (type of sequence, number of ports, …) | ZC, single port | ZC, single port | ZC, single port | ZC, single port |
| Number of sites | 6 | 6 | 6 | 6 |
| Number of symbols used per occasion | 1 | 1 | 1 | 1 |
| number of occasions used per positioning estimate | 1 | 1 | 1 | 5 |
| Power-boosting level | 7.8dB | 7.8dB | 7.8dB | 7.8dB |
| Downlink power control (applied/not applied) | Not applied | Not applied | Not applied | Not applied |
| interference modelling (ideal muting, or other) | Ideal | Ideal | Ideal | Ideal |
| TOA Measurement Algorithm | MUSIC | MUSIC | MUSIC | FH + MUSIC |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) | Chan | Chan | Chan | Chan |
| Network synchronization assumptions | Ideal | Ideal | Ideal | Ideal |
| UE/gNB RX and TX timing error | 0ns | 0ns | 0ns | 0ns |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | None | None | None | None |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | None | None | None | None |
| UE antenna configuration | (1,1,1,1,1) | (1,1,1,1,1) | (1,2,2,1,1) | (1,1,1,1,1) |
| Number of UE branches | 1 | 1 | 2 | 1 |
| Description of enhancement solutions, if any | No | No | No | DL-CPP |
| gNB antenna configuration | (1,1,4,4,2) | (1,1,4,4,2) | (1,1,4,4,2) | (1,1,4,4,2) |
| UE antenna height | 1.5m | 1.5m | 1.5m | 1.5m |
| gNB antenna height | 8m | 8m | 10m | 10m |
| ARP errors | No | No | No | No |
| Phase Center Offsets | / | / | / | No |
| Carrier phase estimation techniques | / | / | / | freq-domain |
| Integer ambiguity resolution techniques | / | / | / | Virtual Integer ambiguity |
| Note 1: Frequency hopping is used in the Case4 without CFO and oscillator-drift, to get the TOA of combined PRS signal with effective 100MHz.  Note 2: Double differential technique is used to eliminate the impact of TRP timing errors, UE/TRP initial phase offset, and frequency errors. | | | | |

### B.6.8.2 NR RedCap UE positioning accuracy evaluation results

Table B.6.8.2-1 provides summary of evaluation results of positioning for RedCap UEs in InF-SH scenario with NR DL-TDOA method and NR carrier phase positioning method.

Table B.6.8.2-1: NR RedCap UE positioning - evaluation scenarios and parameters for InF-SH from [114]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cases |  | 50% | 67% | 80% | 90% | Whether the requirement is met or not met |
| **Case 1 (RedCap UEs)**  InF-SH, FR1, DL-TDOA, 20MHz, 1Rx | Convex UEs | 0.531 | 0.798 | 1.245 | 1.91 | No |
| **Case 2 (eMBB UEs)**  InF-SH, FR2, DL-TDOA, 100MHz, 1Rx | Convex UEs | 0.106 | 0.132 | 0.182 | 0.243 | Yes |
| **Case 3 (eMBB UEs)**  InF-SH, FR2, DL-TDOA, 100MHz, 2Rx | Convex UEs | 0.106 | 0.131 | 0.162 | 0.213 | Yes |
| **Case 4 (RedCap UEs)**  InF-SH, FR1, DL-CPP, 20MHz ,1Rx | Convex UEs | 0.006 | 0.008 | 0.031 | 0.048 | Yes |

## B.6.9 Results from source [116]

### B.6.9.1 Description of evaluation scenarios

We evaluate the performance of positioning for RedCap UEs in IIoT use case (InF-SH) with NR DL-TDOA method.

Table B.6.9.1-1: NR RedCap UE positioning - evaluation scenarios and parameters for InF-SH from [116]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter | Case 1  (InF-SH) | Case 2  (InF-SH) | Case 3  (InF-SH) | Case 4  (InF-SH) |
| Scenario (baseline, otherwise state any modifications) | Baseline | Baseline | Baseline | Baseline |
| Carrier frequency | 3.5GHz | 3.5GHz | 3.5GHz | 3.5GHz |
| Subcarrier spacing | 30kHz | 30kHz | 30kHz | 30kHz |
| Reference Signal Transmission Bandwidth | 20MHz | 20MHz | 100MHz | 100MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | PRS (Comb-2) | PRS (Comb-2) | PRS (Comb-2) | PRS (Comb-2) |
| Reference signal  (type of sequence, number of ports, …) | PRS, single port | PRS, single port | PRS, single port | PRS, single port |
| Number of sites | 18 | 18 | 18 | 18 |
| Number of symbols used per occasion | 2 | 2 | 2 | 2 |
| number of occasions used per positioning estimate | 1 | 1 | 1 | 1 |
| Power-boosting level | 3dB | 3dB | 3dB | 3dB |
| Downlink power control (applied/not applied) | Not applied | Not applied | Not applied | Not applied |
| interference modelling (ideal muting, or other) | Ideal | Ideal | Ideal | Ideal |
| TOA Measurement Algorithm | FAP | MUSIC | FAP | MUSIC |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) | Taylor series | Taylor series | Taylor series | Taylor series |
| Network synchronization assumptions | Ideal | Ideal | Ideal | Ideal |
| UE/gNB RX and TX timing error | 0ns | 0ns | 0ns | 0ns |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | None | None | None | None |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | None | None | None | None |
| UE antenna configuration | (1,1,1,1,1) | (1,1,1,1,1) | (1,2,2,1,1) | (1,2,2,1,1) |
| Number of UE branches | 1 | 1 | 1 | 1 |
| Description of enhancement solutions, if any | No | No | No | No |
| gNB antenna configuration | (4,4,2,1,1) | (4,4,2,1,1) | (4,4,2,1,1) | (4,4,2,1,1) |
| UE antenna height | 1.5m | 1.5m | 1.5m | 1.5m |
| gNB antenna height | 8m | 8m | 8m | 8m |
| ARP errors | No | No | No | No |
| Phase Center Offsets | / | / | / | / |
| Carrier phase estimation techniques | / | / | / | / |
| Integer ambiguity resolution techniques | / | / | / | / |

### B.6.9.2 NR RedCap UE positioning accuracy evaluation results

Table B.6.9.2-1 provides summary of evaluation results of positioning for RedCap UEs in InF-SH scenario with NR DL-TDOA method.

Table B.6.9.2-1: NR RedCap UE positioning - evaluation scenarios and parameters for InF-SH from [116]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cases |  | 50% | 67% | 80% | 90% | Whether the requirement is met or not met |
| Case 1 (RedCap UEs)  InF-SH, FR1, DL-TDOA, 20MHz, 1Rx | Convex UEs | 2.7862 | 3.7437 | 4.5173 | 5.2377 | No |
| Case 2 (RedCap UEs)  InF-SH, FR1, DL-TDOA, 20MHz, 1Rx | Convex UEs | 1.0722 | 1.5408 | 1.9693 | 2.4456 | No |
| Case 3 (eMBB UEs)  InF-SH, FR1, DL-TDOA, 100MHz, 4Rx | Convex UEs | 0.7997 | 0.9877 | 1.1608 | 1.3961 | No |
| Case 4 (eMBB UEs)  InF-SH, FR1, DL-TDOA, 100MHz, 4Rx | Convex UEs | 0.4476 | 0.6257 | 0.7988 | 0.9767 | Yes |

## B.6.10 Results from source [119]

### B.6.10.1 Description of evaluation scenarios

We evaluate the performance of positioning for RedCap UEs in IIoT use case (InF-SH and InF-DH) with NR DL-TDOA method.

Table B.6.10.1-1 provides NR RedCap UE positioning assumption – evaluation scenarios and parameters.

Table B.6.10.1-2 provides NR RedCap UE positioning assumption – evaluation scenarios and parameters, particularly to evaluate the impact of phase offset.

Table B.6.10.1-1: NR RedCap UE positioning assumption – evaluation scenarios and parameters

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Case 1** | **Case 2** | **Case 3** | **Case 4** | **Case 5** | **Case 6** |
| Frequency range | FR1 | FR1 | FR1 | FR1 | FR1 | FR1 |
| Scenario | InF-SH | InF-DH | InF-SH | InF-SH | InF-SH | InF-SH |
| UE antenna model, array configuration (M, N, P, Mg, Ng) | (1, 1, 1, 1, 1) | (1, 1, 1, 1, 1) | (1, 1, 1, 1, 1) | (1, 1, 1, 1, 1) | (1, 1, 1, 1, 1) | (1, 1, 1, 1, 1) |
| Channel model (baseline, otherwise state any modifications) | baseline | baseline | baseline | baseline | baseline | baseline |
| Carrier frequency | 3.5GHz | 3.5GHz | 3.5GHz | 3.5GHz | 3.5GHz | 3.5GHz |
| Subcarrier spacing | 30kHz | 30kHz | 30kHz | 30kHz | 30kHz | 30kHz |
| Reference Signal Transmission Bandwidth | 20MHz | 20MHz | 100MHz (Extended bandwidth) | 5 X 20MHz  (Band stitching) | 60MHz (Extended bandwidth) | 3 X 20MHz  (Band stitching) |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | Comb-2 | Comb-2 | Comb-2 | Comb-2 | Comb-2 | Comb-2 |
| Reference signal  (type of sequence, number of ports, …) | Gold sequence | Gold sequence | Gold sequence | Gold sequence | Gold sequence | Gold sequence |
| Number of sites | 18 sites | | | | | |
| Number of symbols used per occasion | 2 symbols | 2 symbols | 2 symbols | 2 symbols | 2 symbols | 2 symbols |
| number of occasions used per positioning estimate | 1 | 1 | 1 | 1 | 1 | 1 |
| Power-boosting level | 0dB | 0dB | 0dB | 0dB | 0dB | 0dB |
| Uplink power control (applied/not applied) | not applied | not applied | not applied | not applied | not applied | not applied |
| 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, ….) | Super resolution in channel estimation.  Threshold based first path detection | | | | | |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) | Maximum likelihood estimator for coordinate calculation | | | | | |
| Network synchronization assumptions | Ideal synchronization | Ideal synchronization | Ideal synchronization | Ideal synchronization | Ideal synchronization | Ideal synchronization |
| UE/gNB RX and TX timing error | Ideal timing error calibration | Ideal timing error calibration | Ideal timing error calibration | Ideal timing error calibration | Ideal timing error calibration | Ideal timing error calibration |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | Tx Beam sweeping at Tx side | | | | | |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | Codebook based | Codebook based | Codebook based | Codebook based | Codebook based | Codebook based |
| Evaluated enhancements | None | None | None | Frequency hopping, Stitch multiple hops into one | None | Frequency hopping, Stitch multiple hops into one |
| Additional notes, if any |  |  | Using extended Bandwidth for comparison with performance by band stitching | Ideal phase error compensation | Using extended Bandwidth for comparison with performance by band stitching | Ideal phase error compensation |

Table B.6.10.1-2: NR RedCap UE positioning – evaluation of impact of phase offset

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Case 7** | **Case 8** | **Case 9** |
| Frequency range | FR1 | FR1 | FR1 |
| Scenario | InF-SH | InF-SH | InF-SH |
| UE antenna model, array configuration (M, N, P, Mg, Ng) | (1, 1, 1, 1, 1) | (1, 1, 1, 1, 1) | (1, 1, 1, 1, 1) |
| Channel model (baseline, otherwise state any modifications) | baseline | baseline | baseline |
| Carrier frequency | 3.5GHz | 3.5GHz | 3.5GHz |
| Subcarrier spacing | 30kHz | 30kHz | 30kHz |
| Reference Signal Transmission Bandwidth | 3 X 20MHz  (Band stitching) | 3 X 20MHz  (Band stitching) | 3 X 20MHz  (Band stitching) |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | Comb-2 | Comb-2 | Comb-2 |
| Reference signal  (type of sequence, number of ports, …) | Gold sequence | Gold sequence | Gold sequence |
| Number of sites | 18 sites | | |
| Number of symbols used per occasion | 2 symbols | 2 symbols | 2 symbols |
| number of occasions used per positioning estimate | 1 | 1 | 1 |
| Power-boosting level | 0dB | 0dB | 0dB |
| Uplink power control (applied/not applied) | not applied | not applied | not applied |
| interference modelling (ideal muting, or other) | ideal muting | ideal muting | ideal muting |
| Description of Measurement Algorithm (e.g. super resolution, interference cancellation, ….) | Super resolution in channel estimation. | | |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) | Maximum likelihood estimator for coordinate calculation | | |
| Network synchronization assumptions | Ideal synchronization | Ideal synchronization | Ideal synchronization |
| UE/gNB RX and TX timing error | Ideal timing error calibration | Ideal timing error calibration | Ideal timing error calibration |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | Tx Beam sweeping at Tx side | | |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | Codebook based | Codebook based | Codebook based |
| Evaluated enhancements | None | None | None |
| Additional notes, if any | With phase offset between two adjacent frequency bands with random distribution truncated at 0.2π, | With phase offset between two adjacent frequency bands with random distribution truncated at 0.5π, | With phase offset between two adjacent frequency bands with random distribution truncated at 1π, |

### B.6.10.2 NR RedCap UE positioning accuracy evaluation results

Table B.6.10.2-1 provides summary of evaluation results of positioning for RedCap UEs without bandwidth stitching in InF-SH and InF-DH scenario with using NR DL-TDOA method (InF-SH and InF-DH).

Table B.6.10.2-2 provides summary of evaluation results of positioning for RedCap UEs with Frequency Hopping (FH) and bandwidth stitching without phase offset among hops (InF-SH and InF-DH). For comparison purpose, the results of positioning for legacy UE are also captured in the table.

Table B.6.10.2-3 provides summary of evaluation results of positioning for RedCap UEs with FH and bandwidth stitching with phase offset among hops (InF-SH). The phase offset model is described in the assumption table.

Table B.6.10.2-1: Horizontal error given by RedCap UE using DL-TDOA positioning in InF-SH and InF-DH

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Test case assumptions | Error 50% | Error 67% | Error 80% | Error 90% | Whether meet the requirement of commercial use cases (<3m) | Whether meet the requirement of IIoT use cases (<1m) |
| Case 1, InF-SH, FR1, DL-TDOA | 0.59 | 0.93 | 1.41 | 2.47 | Yes | No |
| Case 2, InF-DH, FR1, DL-TDOA | 1.35 | 2.76 | 5.03 | 9.52 | No | No |

Table B.6.10.2-2: Horizontal error given by legacy UE positioning, and RedCap UE positioning using FH and bandwidth stitching without phase offset (InF-SH and InF-DH).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Test case assumptions | Error 50% | Error 67% | Error 80% | Error 90% | Whether meet the requirement of commercial use cases(<3m) | Whether meet the requirement of IIoT use cases(<1m) |
| Case 3, InF-SH, FR1, DL-TDOA, no FH, one native 100MHz bandwidth | 0.08 | 0.12 | 0.18 | 0.3 | Yes | Yes |
| Case 4, InF-DH, FR1, DL-TDOA, with FH and band stitching 5 X 20MHz | 0.10 | 0.17 | 0.29 | 0.52 | Yes | Yes |
| Case 5, InF-SH, FR1, DL-TDOA, no FH, one native 60MHz bandwidth | 0.16 | 0.23 | 0.36 | 0.66 | Yes | Yes |
| Case 6, InF-DH, FR1, DL-TDOA, with FH and band stitching 3 X 20MHz | 0.18 | 0.27 | 0.43 | 0.80 | Yes | Yes |

Table B.6.10.2-3: Horizontal error given by Redcap UE positioning using FH and bandwidth stitching with phase offset (InF-SH).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Test case assumptions | Error 50% | Error 67% | Error 80% | Error 90% | Whether meet the requirement of commercial use cases(<3m) | Whether meet the requirement of IIoT use cases(<1m) |
| Case 7, InF-SH, FR1, DL-TDOA, band stitching 3 X 20 MHz with random PO, | 0.45 | 0.66 | 0.88 | 1.27 | Yes | No |
| Case 8, InF-SH, FR1, DL-TDOA, band stitching 3 X 20 MHz with random PO, | 1.26 | 1.84 | 2.67 | 3.71 | No | No |
| Case 9, InF-SH, FR1, DL-TDOA, band stitching 3 X 20 MHz with random PO, | 1.59 | 2.32 | 3.02 | 3.88 | No | No |

## B.6.11 Results from source [72]

### B.6.11.1 Description of evaluation scenarios

The scenarios to be presented in this section include:

- Baseline scenarios with UMi, UMa, IOO and InF-SH.

- IOO with the enhancements of PRS frequency hopping and SRS frequency hopping.

Evaluation assumptions for system level analysis are provided in Table B.6.11.1-1 to Table B.6.11.1-1-7.

Table B.6.11.1-1: Positioning in UMi (Case 1), FR1 - evaluation scenarios and parameters

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Case 101 (UMi, FR1)** | **Case 102 (UMi, FR1)** | **Case 103**  **(UMi, FR1)** | **Case 104 (UMi, FR1)** | **Case 105 (UMi, FR1)** | **Case 106 (UMi, FR1)** | **Case 107 (UMi, FR1)** | **Case 108 (UMi, FR1)** | **Case 109 (UMi, FR1)** |
| Scenario (baseline, otherwise state any modifications) | UMi | | | | | | | | |
| Carrier frequency | 3.5GHz | | | | | | | | |
| Subcarrier spacing | 30kHz | | | | | | | | |
| Reference Signal Transmission Bandwidth | 5MHz | 20MHz | 100MHz | 5MHz | 20MHz | 100MHz | 5MHz | 20MHz | 100MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | DL-PRS (Comb-6, 6 symbols) | | | PosSRS (Comb-8, 8 symbols) | | | DL-PRS (Comb-6, 6 symbols), PosSRS (Comb-8, 8 symbols) | | |
| Reference signal  (type of sequence, number of ports, …) | Gold, single port | | | ZC, single port | | | Gold/ZC, single port | | |
| Number of sites | 19 | | | | | | | | |
| Number of symbols used per occasion | 48 | | | 8 | | | 48 in DL and 8 in UL | | |
| number of occasions used per positioning estimate | 1 | | | | | | | | |
| Power-boosting level | 15.6dB | | | 18dB | | | 15.6dB in DL and 18dB in UL | | |
| Uplink power control (applied/not applied) | not applied | | | | | | | | |
| interference modelling (ideal muting, or other) | ideal muting | | | | | | | | |
| Description of Measurement Algorithm (e.g. super resolution, interference cancellation, ….) | high resolution  no LOS/NLOS detection | | | | | | | | |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) | DL-TDOA  PSO | | | UL-TDOA  PSO | | | Multi-RTT  PSO | | |
| Network synchronization assumptions | ideal | | | | | | | | |
| UE/gNB RX and TX timing error | ideal | | | | | | | | |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | - | | | | | | | | |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | Tx codebook-based | | | | | | | | |
| UE antenna configuration | (M, N, P, Mg, Ng) = (1,1,2,1,1), dH = 0.5λ | | | | | | | | |
| Number of UE branches | 1 | | | | | | | | |
| Description of enhancement solutions, if any | - | | | | | | | | |
| gNB antenna configuration | (M, N, P, Mg, Ng) = (8, 8, 2, 1, 1), (dH, dV) = (0.5, 0.8)λ | | | | | | | | |
| UE noise figure | 9dB | | | | | | | | |
| UE antenna height | 1.5m | | | | | | | | |
| gNB antenna height | 5m-20m, random | | | | | | | | |
| Additional notes, if any |  | | | | | | | | |

Table B.6.11.1-2: Positioning in UMa (Case 2), FR1 - evaluation scenarios and parameters

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Case 201**  **(UMa, FR1)** | **Case 202**  **(UMa, FR1)** | **Case 203**  **(UMa, FR1)** | **Case 204**  **(UMa, FR1)** | **Case 205**  **(UMa, FR1)** | **Case 206**  **(UMa, FR1)** |
| Scenario (baseline, otherwise state any modifications) | UMa | | | | | |
| Carrier frequency | 3.5GHz | | | | | |
| Subcarrier spacing | 30kHz | | | | | |
| Reference Signal Transmission Bandwidth | 5MHz | 20MHz | 100MHz | 5MHz | 20MHz | 100MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | DL-PRS (Comb-6, 6 symbols) | | | PosSRS (Comb-8, 8 symbols) | | |
| Reference signal  (type of sequence, number of ports, …) | Gold, single port | | | ZC, single port | | |
| Number of sites | 19 | | | | | |
| Number of symbols used per occasion | 48 | | | 8 | | |
| number of occasions used per positioning estimate | 1 | | | | | |
| Power-boosting level | 15.6dB | | | 18dB | | |
| Uplink power control (applied/not applied) | not applied | | | | | |
| interference modelling (ideal muting, or other) | ideal muting | | | | | |
| Description of Measurement Algorithm (e.g. super resolution, interference cancellation, ….) | high resolution  no LOS/NLOS detection | | | | | |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) | DL-TDOA  PSO | | | UL-TDOA  PSO | | |
| Network synchronization assumptions | ideal | | | | | |
| UE/gNB RX and TX timing error | ideal | | | | | |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | - | | | | | |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | Tx codebook-based | | | | | |
| UE antenna configuration | (M, N, P, Mg, Ng) = (1,1,2,1,1), dH = 0.5λ | | | | | |
| Number of UE branches | 1 | | | | | |
| Description of enhancement solutions, if any | - | | | | | |
| gNB antenna configuration | (M, N, P, Mg, Ng) = (8, 8, 2, 1, 1), (dH, dV) = (0.5, 0.8)λ | | | | | |
| UE noise figure | 9dB | | | | | |
| UE antenna height | 1.5m | | | | | |
| gNB antenna height | 20m-50m, random | | | | | |
| Additional notes, if any |  | | | | | |

Table B.6.11.1-3: Positioning in IOO (Case 3), FR1 - evaluation scenarios and parameters

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Case 301 (IOO, FR1)** | **Case 302 (IOO, FR1)** | **Case 303 (IOO, FR1)** | **Case 304 (IOO, FR1)** | **Case 305 (IOO, FR1)** | **Case 306 (IOO, FR1)** | **Case 307 (IOO, FR1)** | **Case 308 (IOO, FR1)** | **Case 309 (IOO, FR1)** | **Case 310 (IOO, FR1)** |
| Scenario (baseline, otherwise state any modifications) | IOO | | | | | | | | | |
| Carrier frequency | 3.5GHz | | | | | | | | | |
| Subcarrier spacing | 30kHz | | | | | | | | | |
| Reference Signal Transmission Bandwidth | 5MHz | 20MHz | 5MHz | 20MHz | 100MHz | 5MHz | 20MHz | 5MHz | 20MHz | 100MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | DL-PRS (Comb-6, 6 symbols) | | | | | PosSRS (Comb-2, 2 symbols) | | | | |
| Reference signal  (type of sequence, number of ports, …) | Gold, single port | | | | | ZC, single port | | | | |
| Number of sites | 12 | | | | | | | | | |
| Number of symbols used per occasion | 48 | | | | | 2 | | | | |
| number of occasions used per positioning estimate | 1 | | | | | | | | | |
| Power-boosting level | - | | | | | | | | | |
| Uplink power control (applied/not applied) | not applied | | | | | | | | | |
| interference modelling (ideal muting, or other) | ideal muting | | | | | | | | | |
| Description of Measurement Algorithm (e.g. super resolution, interference cancellation, ….) | high resolution  no LOS/NLOS detection | | | | | | | | | |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) | DL-TDOA  PSO | | | | | UL-TDOA  PSO | | | | |
| Network synchronization assumptions | ideal | | | | | | | | | |
| UE/gNB RX and TX timing error | ideal | | | | | | | | | |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | - | | | | | | | | | |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | Tx codebook-based | | | | | | | | | |
| UE antenna configuration | (M, N, P, Mg, Ng) = (1,1,2,1,1), dH = 0.5λ | | | | | | | | | |
| Number of UE branches | 1 | | | | | | | | | |
| Description of enhancement solutions, if any |  | | frequency hopping over 100MHz | |  |  |  | frequency hopping over 100MHz | |  |
| gNB antenna configuration | (M, N, P, Mg, Ng) = (4, 4, 2, 1, 1), dH=dV=0.5λ | | | | | | | | | |
| UE noise figure | 9dB | | | | | | | | | |
| UE antenna height | 1.5m | | | | | | | | | |
| gNB antenna height | 3m | | | | | | | | | |
| Additional notes, if any |  | | | | | | | | | |
| **Parameter** | **Case 311 (IOO, FR1)** | **Case 312 (IOO, FR1)** | **Case 313 (IOO, FR1)** | **Case 314 (IOO, FR1)** | **Case 315 (IOO, FR1)** |  | | | | |
| Reference Signal Transmission Bandwidth | 5MHz | 20MHz | 5MHz | 20MHz | 100MHz |  | | | | |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | DL-PRS (Comb-6, 6 symbols), PosSRS (Comb-8, 8 symbols) | | | | |  | | | | |
| Reference signal  (type of sequence, number of ports, …) | Gold/ZC, single port | | | | |  | | | | |
| Number of symbols used per occasion | 48 in DL and 8 in UL | | | | |  | | | | |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) | Multi-RTT  PSO | | | | |  | | | | |

Table B.6.11.1-4: Positioning in InF-SH (Case 4), FR1 - evaluation scenarios and parameters

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Case 401 (InF-SH, FR1)** | **Case 402 (InF-SH, FR1)** | **Case 403 (InF-SH, FR1)** | **Case 404 (InF-SH, FR1)** | **Case 405 (InF-SH, FR1)** | **Case 406 (InF-SH, FR1)** | **Case 407 (InF-SH, FR1)** | **Case 408 (InF-SH, FR1)** | **Case 409 (InF-SH, FR1)** | **Case 410 (InF-SH, FR1)** |
| Scenario (baseline, otherwise state any modifications) | InF-SH | | | | | | | | | |
| Carrier frequency | 3.5GHz | | | | | | | | | |
| Subcarrier spacing | 30kHz | | | | | | | | | |
| Reference Signal Transmission Bandwidth | 5MHz | 20MHz | 5MHz | 20MHz | 100MHz | 5MHz | 20MHz | 5MHz | 20MHz | 100MHz |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | DL-PRS (Comb-6, 6 symbols) | | | | | PosSRS (Comb-2, 2 symbols) | | | | |
| Reference signal  (type of sequence, number of ports, …) | Gold, single port | | | | | ZC, single port | | | | |
| Number of sites | 18 | | | | | | | | | |
| Number of symbols used per occasion | 48 | | | | | 2 | | | | |
| number of occasions used per positioning estimate | 1 | | | | | | | | | |
| Power-boosting level | - | | | | | | | | | |
| Uplink power control (applied/not applied) | not applied | | | | | | | | | |
| interference modelling (ideal muting, or other) | ideal muting | | | | | | | | | |
| Description of Measurement Algorithm (e.g. super resolution, interference cancellation, ….) | high resolution  no LOS/NLOS detection | | | | | | | | | |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) | DL-TDOA  PSO | | | | | UL-TDOA  PSO | | | | |
| Network synchronization assumptions | Ideal | | | | | | | | | |
| UE/gNB RX and TX timing error | Ideal | | | | | | | | | |
| Beam-related assumption (beam sweeping / alignment assumptions at the tx and rx sides) | - | | | | | | | | | |
| Precoding assumptions (codebook, nrof antenna elements used, etc) | Tx codebook-based | | | | | | | | | |
| UE antenna configuration | (M, N, P, Mg, Ng) = (1,1,2,1,1), dH = 0.5λ | | | | | | | | | |
| Number of UE branches | 1 | | | | | | | | | |
| Description of enhancement solutions, if any |  | | frequency hopping over 100MHz | |  |  |  | frequency hopping over 100MHz | |  |
| gNB antenna configuration | (M, N, P, Mg, Ng) = (4, 4, 2, 1, 1), dH=dV=0.5λ | | | | | | | | | |
| UE noise figure | 9dB | | | | | | | | | |
| UE antenna height | 1.5m | | | | | | | | | |
| gNB antenna height | 8m | | | | | | | | | |
| Additional notes, if any |  | | | | | | | | | |
| **Parameter** | **Case 411 (InF-SH, FR1)** | **Case 412 (InF-SH, FR1)** | **Case 413 (InF-SH, FR1)** | **Case 414 (InF-SH, FR1)** | **Case 415 (InF-SH, FR1)** |  | | | | |
| Reference Signal Transmission Bandwidth | 5MHz | 20MHz | 5MHz | 20MHz | 100MHz |  | | | | |
| Reference Signal Physical Structure and Resource Allocation (RE pattern) (reference to figure in contribution) | DL-PRS (Comb-6, 6 symbols), PosSRS (Comb-2, 2 symbols) | | | | |  | | | | |
| Reference signal  (type of sequence, number of ports, …) | Gold/ZC, single port | | | | |  | | | | |
| Number of symbols used per occasion | 48 in DL and 2 in UL | | | | |  | | | | |
| Description of positioning technique / applied positioning algorithm (e.g. Least square, Taylor series, etc) | Multi-RTT  PSO | | | | |  | | | | |

### B.6.11.2 NR RedCap UE positioning accuracy evaluation results

Table B.6.11.2-1 provides summary of evaluation results for horizontal positioning error in UMi.

Table B.6.11.2-2 provides summary of evaluation results for horizontal positioning error in UMa.

Table B.6.11.2-3 provides summary of evaluation results for horizontal positioning error in IOO.

Table B.6.11.2-4 provides summary of evaluation results for horizontal positioning error in InF-SH.

Table B.6.11.2-1: Positioning in UMi (Case 1) - horizontal location error results

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Cases |  | 50% | 67% | 80% | 90% |
| Case 101, UMi, FR1, DL-TDOA with 5MHz | All UEs | 8.9 | 12 | 15 | 19 |
| Case 102, UMi, FR1, DL-TDOA with 20MHz | All UEs | 3.9 | 5.1 | 6.5 | 8.3 |
| Case 103, UMi, FR1, DL-TDOA with 100MHz | All UEs | 1.0 | 1.4 | 1.9 | 2.7 |
| Case 104, UMi, FR1, UL-TDOA with 5MHz | All UEs | 10 | 14 | 17 | 22 |
| Case 105, UMi, FR1, UL-TDOA with 20MHz | All UEs | 4.2 | 5.5 | 6.9 | 8.5 |
| Case 106, UMi, FR1, UL-TDOA with 100MHz | All UEs | 1.1 | 1.6 | 2.2 | 3.0 |
| Case 107, UMi, FR1, Multi-RTT with 5MHz | All UEs | 8.5 | 11 | 14 | 17 |
| Case 108, UMi, FR1, Multi-RTT with 20MHz | All UEs | 3.1 | 3.9 | 4.8 | 5.8 |
| Case 109, UMi, FR1, Multi-RTT with 100MHz | All UEs | 0.9 | 1.1 | 1.4 | 1.9 |

Table B.6.11.2-2: Positioning in UMa (Case 2) - horizontal location error results

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Cases |  | 50% | 67% | 80% | 90% |
| Case 201, UMa, FR1, DL-TDOA with 5MHz | All UEs | 18 | 25 | 34 | 45 |
| Case 202, UMa, FR1, DL-TDOA with 20MHz | All UEs | 6.7 | 9.7 | 13 | 20 |
| Case 205, UMa, FR1, DL-TDOA with 100MHz | All UEs | 1.8 | 3.6 | 8.4 | 15 |
| Case 206, UMa, FR1, UL-TDOA with 5MHz | All UEs | 34 | 48 | 79 | 178 |
| Case 207, UMa, FR1, UL-TDOA with 20MHz | All UEs | 12 | 20 | 52 | 180 |
| Case 208, UMa, FR1, UL-TDOA with 5MHz and FH | All UEs | 2.2 | 5.0 | 10 | 24 |
| Case 209, UMa, FR1, UL-TDOA with 20MHz and FH | All UEs | 3.2 | 9.3 | 20 | 86 |
| Case 210, UMa, FR1, UL-TDOA with 100MHz | All UEs | 6.1 | 17 | 62 | 185 |

Table B.6.11.2-3: Positioning in IOO (Case 3) - horizontal location error results

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Cases |  | 50% | 67% | 80% | 90% |
| Case 301, IOO, FR1, DL-TDOA with 5MHz | (Optional) All UEs | 5.7 | 8.1 | 12 | 17 |
| Convex UEs | 4.0 | 5.4 | 7.1 | 10 |
| Case 302, IOO, FR1, DL-TDOA with 20MHz | (Optional) All UEs | 2.8 | 4.1 | 6.0 | 9.5 |
| Convex UEs | 1.9 | 2.6 | 3.3 | 4.5 |
| Case 303, IOO, FR1, DL-TDOA with 5MHz and FH | (Optional) All UEs | 0.5 | 0.8 | 1.3 | 2.2 |
| Convex UEs | 0.3 | 0.4 | 0.6 | 0.8 |
| Case 304, IOO, FR1, DL-TDOA with 20MHz and FH | (Optional) All UEs | 0.5 | 0.8 | 1.3 | 2.1 |
| Convex UEs | 0.3 | 0.4 | 0.6 | 0.8 |
| Case 305, IOO, FR1, DL-TDOA with 100MHz | (Optional) All UEs | 0.5 | 0.8 | 1.2 | 2.2 |
| Convex UEs | 0.3 | 0.4 | 0.6 | 0.8 |
| Case 306, IOO, FR1, UL-TDOA with 5MHz | (Optional) All UEs | 5.9 | 8.4 | 12 | 18 |
| Convex UEs | 4.2 | 5.8 | 7.5 | 11 |
| Case 307, IOO, FR1, UL-TDOA with 20MHz | (Optional) All UEs | 2.9 | 4.1 | 5.8 | 8.8 |
| Convex UEs | 2.0 | 2.5 | 3.3 | 4.6 |
| Case 308, IOO, FR1, UL-TDOA with 5MHz and FH | (Optional) All UEs | 0.5 | 0.8 | 1.3 | 2.1 |
| Convex UEs | 0.3 | 0.4 | 0.6 | 0.9 |
| Case 309, IOO, FR1, UL-TDOA with 20MHz and FH | (Optional) All UEs | 0.5 | 0.8 | 1.3 | 2.1 |
| Convex UEs | 0.3 | 0.4 | 0.6 | 0.9 |
| Case 310, IOO, FR1, UL-TDOA with 100MHz | (Optional) All UEs | 0.5 | 0.8 | 1.3 | 2.2 |
| Convex UEs | 0.3 | 0.4 | 0.6 | 0.9 |
| Case 311, IOO, FR1, Multi-RTT with 5MHz | (Optional) All UEs | 5.6 | 7.4 | 9.5 | 13 |
| Convex UEs | 5.6 | 7.9 | 9.9 | 14 |
| Case 312, IOO, FR1, Multi-RTT with 20MHz | (Optional) All UEs | 2.4 | 3.2 | 4.2 | 5.7 |
| Convex UEs | 2.1 | 3.0 | 4.1 | 5.6 |
| Case 313, IOO, FR1, Multi-RTT with 5MHz and FH | (Optional) All UEs | 0.3 | 0.5 | 0.7 | 1.2 |
| Convex UEs | 0.2 | 0.4 | 0.5 | 0.8 |
| Case 314, IOO, FR1, Multi-RTT with 20MHz and FH | (Optional) All UEs | 0.3 | 0.5 | 0.7 | 1.1 |
| Convex UEs | 0.2 | 0.4 | 0.5 | 0.8 |
| Case 315, IOO, FR1, Multi-RTT with 100MHz | (Optional) All UEs | 0.3 | 0.5 | 0.7 | 1.3 |
| Convex UEs | 0.2 | 0.4 | 0.5 | 0.8 |

Table B.6.11.2-4: Positioning in InF-SH (Case 4) - horizontal location error results

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Cases |  | 50% | 67% | 80% | 90% |
| Case 401, InF-SH, FR1, DL-TDOA with 5MHz | (Optional) All UEs | 5.9 | 9.2 | 13 | 20 |
| Convex UEs | 4.8 | 6.7 | 8.8 | 12 |
| Case 402, InF-SH, FR1, DL-TDOA with 20MHz | (Optional) All UEs | 0.7 | 1.1 | 1.8 | 3.4 |
| Convex UEs | 0.5 | 0.8 | 1.1 | 1.7 |
| Case 403, InF-SH, FR1, DL-TDOA with 5MHz and FH | (Optional) All UEs | 0.04 | 0.06 | 0.09 | 0.2 |
| Convex UEs | 0.03 | 0.04 | 0.06 | 0.1 |
| Case 404, InF-SH, FR1, DL-TDOA with 20MHz and FH | (Optional) All UEs | 0.04 | 0.06 | 0.1 | 0.2 |
| Convex UEs | 0.03 | 0.04 | 0.06 | 0.1 |
| Case 405, InF-SH, FR1, DL-TDOA with 100MHz | (Optional) All UEs | 0.04 | 0.06 | 0.1 | 0.2 |
| Convex UEs | 0.03 | 0.04 | 0.06 | 0.1 |
| Case 406, InF-SH, FR1, UL-TDOA with 5MHz | (Optional) All UEs | 7.9 | 12 | 17 | 25 |
| Convex UEs | 6.3 | 8.7 | 11 | 15 |
| Case 407, InF-SH, FR1, UL-TDOA with 20MHz | (Optional) All UEs | 0.8 | 1.2 | 2.0 | 3.4 |
| Convex UEs | 0.6 | 0.8 | 1.2 | 2.0 |
| Case 408, InF-SH, FR1, UL-TDOA with 5MHz and FH | (Optional) All UEs | 0.04 | 0.06 | 0.1 | 0.2 |
| Convex UEs | 0.03 | 0.04 | 0.06 | 0.1 |
| Case 409, InF-SH, FR1, UL-TDOA with 20MHz and FH | (Optional) All UEs | 0.04 | 0.06 | 0.1 | 0.2 |
| Convex UEs | 0.03 | 0.04 | 0.06 | 0.1 |
| Case 410, InF-SH, FR1, UL-TDOA with 100MHz | (Optional) All UEs | 0.04 | 0.06 | 0.1 | 0.2 |
| Convex UEs | 0.03 | 0.04 | 0.06 | 0.1 |
| Case 411, InF-SH, FR1, Multi-RTT with 5MHz | (Optional) All UEs | 5.5 | 8.0 | 11 | 16 |
| Convex UEs | 4.8 | 6.8 | 9.6 | 13 |
| Case 412, InF-SH, FR1, Multi-RTT with 20MHz | (Optional) All UEs | 0.4 | 0.6 | 0.9 | 1.5 |
| Convex UEs | 0.4 | 0.5 | 0.8 | 1.1 |
| Case 413, InF-SH, FR1, Multi-RTT with 5MHz and FH | (Optional) All UEs | 0.02 | 0.03 | 0.05 | 0.07 |
| Convex UEs | 0.02 | 0.03 | 0.04 | 0.06 |
| Case 414, InF-SH, FR1, Multi-RTT with 20MHz and FH | (Optional) All UEs | 0.02 | 0.04 | 0.05 | 0.08 |
| Convex UEs | 0.02 | 0.03 | 0.04 | 0.07 |
| Case 415, InF-SH, FR1, Multi-RTT with 100MHz | (Optional) All UEs | 0.02 | 0.04 | 0.05 | 0.08 |
| Convex UEs | 0.02 | 0.03 | 0.04 | 0.06 |
| Convex UEs | 0.003 | 0.004 | 0.008 | 0.2 |