3GPP TR 38.876 V0.6.0 (2023-10)

Technical Report

3rd Generation Partnership Project;

Technical Specification Group Radio Access Network;

NR;

Study on Air-to-ground network for NR

(Release 18)

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Keywords

Radio, LTE

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# Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

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# 1 Scope

The present document covers the RF, RRM and co-existence aspects of the work item “Air-to-ground network for NR” [2]

The objectives for the study are the following:

- Study and evaluate adjacent channel co-existence for ATG scenarios.

- Study and specify RF core requirements for ATG network and the ATG UE such that ATG deployment are well supported.

- Study and specify RRM requirement supporting ATG network deployment and ATG UE mobility

# 2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non‑specific.

- For a specific reference, subsequent revisions do not apply.

- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] RP-230279, Air-to-ground network for NR, CMCC

[3] ERC Recommendation 74-01: "Unwanted emissions in the spurious domain".

[4] 3GPP TS 38.101-1: “NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone”.

[5] 3GPP TS 38.104: “NR; Base Station (BS) radio transmission and reception”.

[6] R4-2308745, Discussion on ATG UE RF Tx requirements, Ericsson

[7] 3GPP TS 38.101-5: “NR; User Equipment (UE) radio transmission and reception; Part 5: Satellite access Radio Frequency (RF) and performance requirements”.

[8] ITU-R M.2059-0: “Operational and technical characteristics and protection criteria of radio altimeters utilizing the band 4 200-4 400 MHz”.

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[x] <doctype> <#>[ ([up to and including]{yyyy[-mm]|V<a[.b[.c]]>}[onwards])]: "<Title>".

# 3 Definitions, symbols and abbreviations

## 3.1 Definitions

For the purposes of the present document, the terms and definitions given in 3GPP TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in 3GPP TR 21.905 [1].

**ATG UE:** a UE mounted on an aircraft

**TAB connector:** *transceiver array boundary* connector

**TRP (total radiated power):** the total power radiated by the antenna

NOTE: The *total radiated power* is the power radiating in all direction for two orthogonal polarizations.

**RX beam peak direction**: direction where the maximum total component of RSRP and thus best total component of EIS is found

**TX beam peak direction:** direction where the maximum total component of EIRP is found

## 3.2 Symbols

For the purposes of the present document, the following symbols apply:

*Symbol format (EW)*

<symbol> <Explanation>

## 3.3 Abbreviations

For the purposes of the present document, the abbreviations given in 3GPP TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in 3GPP TR 21.905 [1].

AA Antenna Array

ATG Air To Ground

EIRP Effective Isotropic Radiated Power

RDN Radio Distribution Network

TAB Transceiver Array Boundary

TN Terrestrial Network

TRP Total Radiated Power

# 4 Background

Air-to-ground (ATG) network refers to in-flight connectivity technique, using ground-based cell towers that send signals up to an aircraft’s antenna(s) of onboard ATG terminal. As a plane travels into different sections of airspace, the onboard ATG terminal automatically connects to the cell with strongest received signal power, just as a mobile phone does on the ground. In this network, a direct radio link will be established between BS on the ground and CPE type of UE mounted in the aircraft.

From the trials and commercial operation [https://inflight.telekom.net/ean/] of adapted LTE ATG solutions, some characteristics are considered for ATG network deployment scenarios.

**- Extremely large inter-site distance (ISD) and large coverage range:** In order to control the network deployment cost and considering the limited number of flights, large ISD is preferred, e.g., about 100km to 200km. At the same time, when the plane is above the sea, the distance between the plane and the nearest base station could be more than 200km and even up to 300km. Therefore, ATG network should be able to provide up to 300km cell coverage range.

**- Utilizing non-disjoint frequency for deploying both ATG and terrestrial networks, i.e. same operating band but ATG network and TN use adjacent carriers:** Operators are interested to adopt the same frequency for deploying both ATG and terrestrial networks to save frequency resource cost, while interference between ATG and terrestrial networks becomes non-negligible and should be addressed.

**- Much powerful on-board ATG terminal capacity:** On-board ATG terminal can be much powerful than normal terrestrial UE, e.g., with higher EIRP via much larger transmission power and/or much larger on-board antenna gain.

# 5 ATG bands

ATG will operate within existing NR operating bands and does not need new bands. Depending on the operator’s request so far, the following NR bands are intended for ATG deployment in Rel-18. Other new band request for ATG deployment is not precluded in future.

**Table 5-1: ATG operating bands**

|  |  |  |  |
| --- | --- | --- | --- |
| **NR operating band** | **Uplink (UL) *operating band* BS receive / UE transmit**  **FUL\_low  – FUL\_high** | **Downlink (DL) *operating band* BS transmit / UE receive**  **FDL\_low – FDL\_high** | **Duplex Mode** |
| n1 | 1920 MHz – 1980 MHz | 2110 MHz – 2170 MHz | FDD |
| n3 | 1710 MHz – 1785 MHz | 1805 MHz – 1880 MHz | FDD |
| n34 | 2010 MHz – 2025 MHz | 2010 MHz – 2025 MHz | TDD |
| n39 | 1880 MHz – 1920 MHz | 1880 MHz – 1920 MHz | TDD |
| n41 | 2496 MHz – 2690 MHz | 2496 MHz – 2690 MHz | TDD |
| n78 | 3300 MHz – 3800 MHz | 3300 MHz – 3800 MHz | TDD |
| n79 | 4400 MHz – 5000 MHz | 4400 MHz – 5000 MHz | TDD |

# 6 Co-existence study

6.1 Co-existence simulation scenario

Table 6.1-1 summarizes the initial simulation scenarios for ATG coexistence study considering non co-location scenario as the baseline. Assume non-co-located for simulation cases 1, 4, 5, 6, 7, 8, 9, 12, 13, 14. For simulation cases 2, 3, 10, 11, if evidence is brought forward that the ACLR/ACS requirements to cover co-location are substantially different to the requirements for the non-co-location, then discuss further how to cover both cases.

**Table 6.1-1: Simulation scenarios for ATG coexistence study**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **No.** | **Combination** | **Aggressor** | | **Victim** | | **Simulation frequency** | **Notes** | **Study Phase** |
| **deployment scenario**  **UL/DL** | **CBW**  **duplex mode** | **deployment scenario**  **UL/DL** | **CBW**  **duplex mode** |
| 1 | TN with ATG | ATG DL | 100MHz  TDD | TN rural DL | 100MHz  /TDD | 4 GHz |  | Phase 1 |
| 2 | TN with ATG | ATG UL | 100MHz  TDD | TN rural UL | 100MHz  TDD | 4 GHz |  | Phase 1 |
| 3 | TN with ATG | TN rural DL | 100MHz  TDD | ATG DL | 100MHz  TDD | 4 GHz |  | Phase 1 |
| 4 | TN with ATG | TN rural UL | 100MHz  TDD | ATG UL | 100MHz  TDD | 4 GHz |  | Phase 1 |
| 5 | TN with ATG | ATG DL | 100MHz  TDD | TN rural UL | 100MHz  /TDD | 4 GHz |  | Phase 2 |
| 6 | TN with ATG | ATG UL | 100MHz  TDD | TN rural DL | 100MHz  TDD | 4 GHz |  | Phase 2 |
| 7 | TN with ATG | TN rural DL | 100MHz  TDD | ATG UL | 100MHz  TDD | 4 GHz |  | Phase 2 |
| 8 | TN with ATG | TN rural UL | 100MHz  TDD | ATG DL | 100MHz  TDD | 4 GHz |  | Phase 2 |
| 9 | TN with ATG | ATG DL | 20MHz FDD | TN rural DL | 20MHz FDD | 2 GHz |  | Phase 1 |
| 10 | TN with ATG | ATG UL | 20MHz FDD | TN rural UL | 20MHz FDD | 2 GHz |  | Phase 1 |
| 11 | TN with ATG | TN rural DL | 20MHz FDD | ATG DL | 20MHz FDD | 2 GHz |  | Phase 1 |
| 12 | TN with ATG | TN rural UL | 20MHz FDD | ATG UL | 20MHz FDD | 2 GHz |  | Phase 1 |
| 13 | TN with ATG | ATG UL | 20MHz FDD | TN rural DL | 20MHz TDD | 2 GHz | n1/n39 | Phase 2 |
| 14 | TN with ATG | TN rural DL | 20MHz TDD | ATG UL | 20MHz FDD | 2 GHz | n39/n1 | Phase 2 |
| NOTE 1: ACLR/ACS requirement for ATG BS and ATG UE are derived based on the synchronized scenario in Phase 1.  NOTE 2: the non-synchronized coexistence scenarios listed in phase 2 are mainly used to identify the isolation distance between ATG BS and the the legacy TN BSs. And it’s agreed to reuse 45dB ACLR and 46dB ACS for both TN and ATG BS for non-synchronized scenarios to derive isolated distance.  NOTE 3: For scenario 11, if simulator doesn’t support additional ring of TN network, i.e. additional 18 site and 54 cells, it’s allowed to double the aggregate interference power from the 57 TN cells to simplify the platform modification, i.e. interference +3dB.  NOTE 4: For scenario 6, 8 and 13 which is CLI between ATG UE and TN UE, it’s not expected to have further coexistence simulation evaluation in Phase 2 due to low interference level. | | | | | | | | |

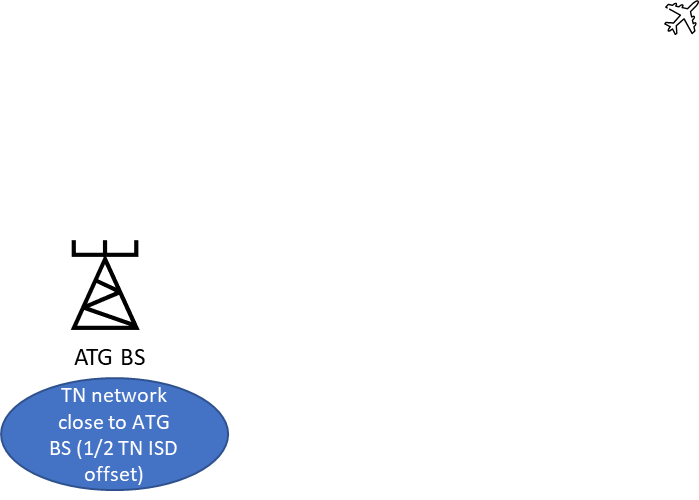
## 6.2 Co-existence simulation assumption

### 6.2.1 Network layout model

#### 6.2.1.1 Co-existence between ATG and NR terrestrial network

Co-existence modelling is based on positioning a single ATG BS/sector and a TN cluster. Two options exist for the positioning of the TN cluster relative to the ATG BS.

For simulation cases 1, 4, 5, 7, 8, 9, 12, 14 the worst-case network layout for simulation is one in which the TN cluster is placed at the same location as the ATG BS. The ATG BS are offset from the TN BS with as depicted in figure 6.2.1.1-2.



**Figure 6.2.1.1-1 Network layout with TN network located close to ATG BS**



Figure 6.2.1.1-2 Offset of ATG BS compared to TN BS grid when the TN cluster is located close to the ATG BS

For the remaining simulation cases, if the ATG UE has an omnidirectional radiation pattern then the worst-case network layout for simulation is one in which the TN is placed directly below the aircraft. If the UE has a directional radiation pattern, then in these cases companies should assess which of the network layout options (TN placed close to ATG BS or TN placed underneath the aircraft) is worst case and apply the worst-case option.



**Figure 6.2.1.1-3 Network layout with TN network located directly underneath the aircraft**

6.2.1.2 TN Network Layout

A rural hexagonal grid layout is assumed for TN network clusters with the parameters of table 6.2.1.1.

**Table 6.2.1.2-1: Simulation scenarios for TN network layout**

|  |  |  |
| --- | --- | --- |
| **Parameters** | | **Values** |
| Network layout | | For synchronized case:  For scenario 11: hexagonal grid, 37 macro sites, 3 sectors per site with wrap around  For other scenarios: hexagonal grid, 19 macro sites, 3 sectors per site with wrap around |
| For non-synchronized case: no wrap around in TN |
| Inter-site distance | | 3.5 km (4GHz)  7.5 km (2GHz) |
| BS antenna height | | 30 m |
| UE location | Outdoor/indoor | Outdoor only |
| Indoor UE ratio | 0% |
| LOS/NLOS | LOS and NLOS, see subclause 6.2.5 |
| UE antenna height | 1.5m |
| UE distribution (horizontal) | | Uniform |
| Minimum BS - UE distance (2D) | | 35 m |

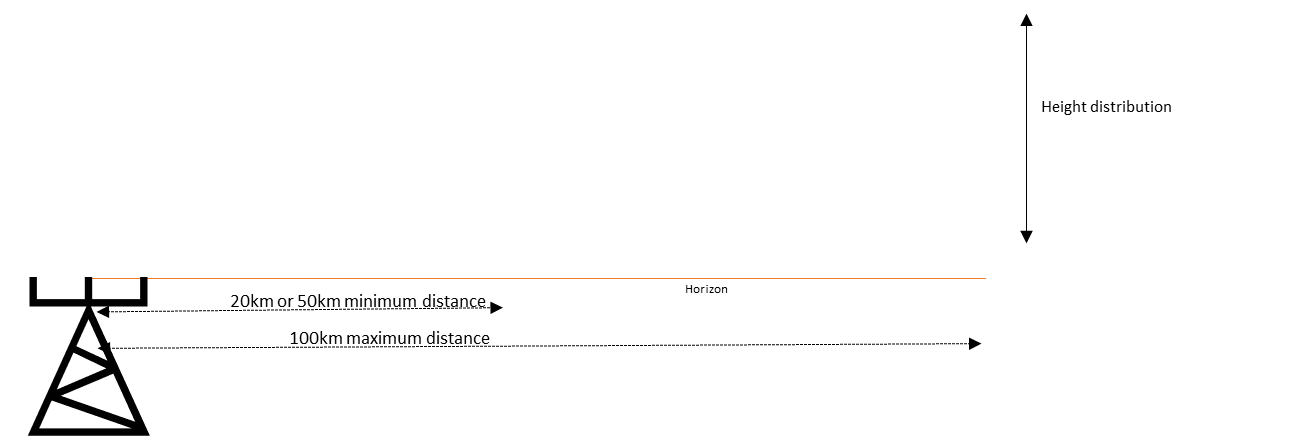
6.2.1.3 ATG Network Layout

A single ATG BS with a single cell is assumed for the ATG network. The aircraft are assumed to fly in a straight line from the minimum distance to the maximum horizontal distance from the ATG BS in the horizontal boresight of the ATG sector. The minimum and maximum horizontal distance of the ATG UE from the ATG BS are as depicted in table 6.2.1.3-1 and depend on the assumption of sub-arrays or not for the antenna model

In the vertical domain, ATG UEs are distributed in height between 3000m and 10000m

**Table 6.2.1.2-1: Simulation scenarios for ATG coexistence study**

|  |  |  |
| --- | --- | --- |
| **Parameters** | **No sub-arrays** | **Sub-arrays** |
| Minimum ATG BS-UE horizontal distance | 20km | 50km |
| Maximum ATG BS-UE horizontal distance | 100km | 100km |



**Figure 6.2.1.3-1 ATG BS layout (In horizontal boresight direction of ATG antenna)**

For Scenarios 2, 3, 10, 11, in addition to simulations in the above assumptions some extra simulations were carried out in which the ATG UE is assumed to be around 300km from the ATG BS. The TN network is also located at 300km, and the ATG UE is assumed to be positioned within a straight line from the ATG BS and within the TN ground network area.

For Scenario 2,3,10,11, it is agreed to conclude simulation results based on that ATG UEs flying over a TN cluster while ATG BS is 100km away as shown below.

- Optional: ATG BS is 300km away.

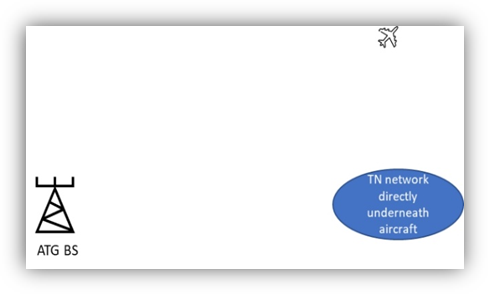


Figure 6.2.1.3-2 ATG BS layout (Case 2,3, 10 and 11)

**Issue 1-3-2: location relationship between ATG UE and TN network for non-synchronized scenario to conclude isolation distance**

**FFS and conclude in May meeting to simulate the worst case.**

- ATG UE and TN cluster are on the same side of ATG BS, i.e. ATG BS actually point at TN cluster to consider the worst case.

- Minimum distance between ATG BS and ATG UE is 20/50km

- There is no additional restriction between ATG BS and ATG UE. Companies are welcome to provide their results for worst case with detailed deployment illustration.

- Following show one example for simulation

- if isolation distance between TN cluster and ATG BS is larger than 20/50km, ATG UE is always on top of TN cluster

- if isolation distance between TN cluster and ATG BS is less than 20/50km, ATG UE is dropped 20/50km distant from ATG BS

- The isolation distance is the distance from the ATG BS to the nearest TN BS. The ATG BS sector and nearest TN BS sector should be pointing towards one another in azimuth. The diagram below is illustrative and does not capture this.





6.2.2 System parameters

6.2.2.1 ATG parameters

The system parameters for ATG BS for co-existence study are assumed as below.

**Table 6.2.2.1-1: system parameters for ATG BS**

|  |  |
| --- | --- |
| ATG BS altitude | 30m |
| Carrier frequency | 2GHz, 4GHz |
| Frequency reuse factor | 1 |
| Duplex mode | FDD@2GHz, TDD@4GHz |
| Channel bandwidth | 20MHz@2GHz, 100MHz@4GHz |
| Subcarrier spacing (SCS) | 15k@2GHz, 30k@4GHz |
| Number of cells | one cell |
| UE distribution | Single ATG UE per ATG cell  Horizontal: Random between minimum and maximum distance in the straight line within range described in section 6.2.1.3  Vertical: Based on ATG UE uniform distribution among 3 to 10km |
| Indoor UE percentage | 0% |
| Number of DL active UEs per cell (NOTE 2) | one UE |
| Number of UL active UEs per cell  (NOTE 2) | one UE |
| DL scheduled bandwidth per UE | Full bandwidth |
| UL scheduled bandwidth per UE | Full bandwidth |
| UL target SNR (NOTE 3) | 15dB |
| Traffic model | Full buffer |
| ATG BS maximum output power | 46dBm sum of two polarizations for 2GHz  53dBm sum of two polarizations for 4GHz |
| ATG BS noise figure | 5dB |
| Handover margin | Not needed |
| NOTE 1: ATG BS is assumed to serve UEs in the rural environment.  NOTE 2: Same as the number of BS beam(s).  NOTE 3: Target SNR for simulation is based on CL values and only compensates pathloss in the simulation assumptions. | |

6.2.2.2 ATG UE parameters

The system parameters for ATG UE are assumed as below.

**Table 6.2.2.2-1: system parameters for ATG UE**

|  |  |
| --- | --- |
| ATG UE altitude | Vertical: Distributed between 3km and 10km |
| Carrier frequency | 2GHz, 4GHz |
| ATG UE max TX power in dBm | 40dBm TRP for 2GHz  43dBm EIRP for 4GHz |
| ATG UE min TX power in dBm | -33dBm for 100MHz  -40dBm for 20MHz |
| ATG UE noise figure | 9dB |

6.2.2.3 TN BS and UE parameters

The system parameters for TN BS and TN UE are assumed as below.

**Table 6.2.2.3-1: system parameters for TN BS and UE**

|  |  |  |
| --- | --- | --- |
| **Parameters** | **Rural** | **Rural** |
| Carrier frequency | 2GHz | 4GHz |
| Channel bandwidth | 20MHz | 100MHz |
| Scheduled channel bandwidth per UE (DL) | 1 | 1 |
| Scheduled channel bandwidth per UE (UL) | 1 | 1 |
| The number of active UE (DL) (NOTE 1) | 1 | 1 |
| The number of active UE (UL) (NOTE 1) | 1 | 1 |
| Traffic model | full buffer | full buffer |
| DL power control | No | No |
| UL power control | Yes | Yes |
| UL target SNR (NOTE 3) | 15dB | 15dB |
| TN BS-UE min distance in meters | 35m | 35m |
| TN BS max TX power in dBm (NOTE 2) | 46dBm | 53dBm |
| TN UE max TX power in dBm | 23dBm | 23dBm |
| TN UE min TX power in dBm | -40dBm | -40dBm |
| TN BS Noise figure in dB | 5dB | 5dB |
| TN UE Noise figure in dB | 9dB | 9dB |
| Handover margin | 3dB | 3dB |
| NOTE 1: Same as the number of BS beam(s).  NOTE 2: TN BS max TX power is defined as the sum over both polarizations.  NOTE 3: Target SNR for simulation is based on CL values and only compensates pathloss in the simulation assumptions. | | |

### 6.2.3 Antenna and beamforming pattern modelling

#### 6.2.3.1 ATG BS antenna model

For ATG BS antenna modelling, the following two options for antenna modelling could be used for ATG coexistence study.

**Option 1: non sub-array model**

Table 6.2.3.1-1: AAS antenna parameters for non sub-array model

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | | ATG | | |
| Base Station Antenna Characteristics | | | | |
| Antenna pattern | | TR 38.921 | | |
| Element gain (dBi) | | 7.1 | | |
| Horizontal/vertical 3 dB beam width of single element (degree) | | 90º for H  54º for V | | |
| Horizontal/vertical front‑to‑back ratio (dB) | | 30 for both H/V | | |
| Antenna polarization | | Linear ±45º | | |
| Antenna array configuration (Row × Column) | | 8 × 8 elements | | |
| Number of supported polarizations, *P* | | 2 | | |
| Horizontal/Vertical radiating element spacing | | 0.5 of wavelength for H, 0.9 of wavelength for V | | |
| Array Ohmic loss (dB) | | 2 | | |
| Conducted power (before Ohmic loss) per antenna element (dBm) (Note 1) | | 25 for 2GHz  32 for 4GHz | | |
| Base station maximum coverage angle in the horizontal plane (degrees) | | 120 | | |
| Base station vertical coverage range (degrees) (Note 2) | | 25 | | |
| Mechanical uptilt (degrees) | | 14 | | |
| Note 1: The conducted power per element assumes 8x8x2 elements (i.e. power per H/V polarized element).  Note 2: The vertical coverage range includes the mechanical downtilt. | | | | |

**Option 2: sub-array model**

Table 6.2.3.1-2: AAS antenna parameters for sub-array model

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | | Macro urban | |
| Element gain (dBi) | | 6.4 | |
| Horizontal/vertical 3 dB beam width of single element (degree) | | 90º for H 65º for V | |
| Horizontal/vertical front‑to‑back ratio (dB) | | 30 for both H/V | |
| Antenna polarization | | Linear ±45º | |
| Antenna sub-array configuration (Row × Column) | | 4 × 8 elements | |
| Horizontal/Vertical radiating sub-array spacing | | 0.5 of wavelength for H, 2.1 of wavelength for V | |
| Number of element rows in sub-array | | 3 | |
| Vertical element separation in sub-array () | | 0.7 of wavelength of V | |
| Array Ohmic loss (dB) | | 2 | |
| Conducted power (before Ohmic loss) per sub-array (dBm) (Note 1) | | 28 for 2GHz  35 for 4GHz | |
| Base station horizontal coverage range (degrees) | | +/-60 | |
| Base station vertical coverage range (degrees) (Note 2) | | 10 | |
| Mechanical up-tilt (degrees) | | 6.5 | |
| Note 1: The conducted power per sub-array assumes 4x8x2 sub-arrays (i.e. power per H/V polarized sub-array).  Note 2: The vertical coverage range includes the mechanical downtilt. | | | |

#### 6.2.3.2 ATG UE antenna model

For 2GHz, assume omni-directional antenna, assume [40dBm] UE output power for calibration (as worst case for simulation purposes).

For 4GHz, assume that UE is equipped with directional antenna, assume a UE EIRP of [43dBm] for calibration (as worst case for simulation purposes)

- Use following as the starting point for calibration.

Table 6.2.3.2-1: antenna parameters for phase antenna array

|  |  |
| --- | --- |
| Horizontal/vertical 3 dB beam width of single element (degree) | 90º for H  90º for V |
| Element gain (dBi) | 5 dBi |
| Horizontal/vertical front‑to‑back ratio (dB) | 30dBc |
| Antenna polarization | Linear ±90º |
| Antenna array configuration (Row × Column x Polarization) | (8x2x2) or  (16x1x2) |
| Horizontal/Vertical radiating element spacing | 0.5 of wavelength for H, 0.5 of wavelength for V |
| UE antenna orientation | Single UE panel deployed on the abdomen of the airplane facing downwards and with the longest dimension of the array aligned with the direction of the flight route. The flight route is pointed at the BS. |

#### 6.2.3.3 TN BS antenna model

For TN BS antenna modelling, the following two options for antenna modelling could be used for ATG coexistence study.

**Option 1: non sub-array model**

Table 6.2.3.3-1: Antenna parameters for non sub-array model

|  |  |
| --- | --- |
|  | TN |
| Base Station Antenna Characteristics | |
| Antenna pattern | TR 38.921 |
| Element gain (dBi) | 7.1 |
| Horizontal/vertical 3 dB beam width of single element (degree) | 90º for H  54º for V |
| Horizontal/vertical front‑to‑back ratio (dB) | 30 for both H/V |
| Antenna polarization | Linear ±45º |
| Antenna array configuration (Row × Column) | 8 × 8 elements AAS  Optional: 8 x 1 elements non AAS |
| Number of supported polarizations, *P* | 2 |
| Horizontal/Vertical radiating element spacing | 0.5 of wavelength for H, 0.9 of wavelength for V |
| Array Ohmic loss (dB) | 2 |
| Conducted power (before Ohmic loss) per antenna element (dBm) (Note 1) | 25 for 2GHz  32 for 4GHz |
| Base station maximum coverage angle in the horizontal plane (degrees) | 120 |
| Base station vertical coverage range (degrees) (Note 2) | 25 |
| Mechanical down (degrees) | 3 |
| Note 1: The conducted power per element assumes 8x8x2 elements (i.e. power per H/V polarized element).  Note 2: The vertical coverage range includes the mechanical downtilt. | |

**Option 2: sub-array model**

Table 6.2.3.3-2: Antenna parameters for sub-array model

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | | Macro urban | |
| Element gain (dBi) | | 6.4 | |
| Horizontal/vertical 3 dB beam width of single element (degree) | | 90º for H 65º for V | |
| Horizontal/vertical front‑to‑back ratio (dB) | | 30 for both H/V | |
| Antenna polarization | | Linear ±45º | |
| Antenna sub-array configuration (Row × Column) | | 4 × 8 elements AAS  Optional: 4x1 elements non-AAS | |
| Horizontal/Vertical radiating sub-array spacing | | 0.5 of wavelength for H, 2.1 of wavelength for V | |
| Number of element rows in sub-array | | 3 | |
| Vertical element separation in sub-array () | | 0.7 of wavelength of V | |
| Array Ohmic loss (dB) | | 2 | |
| Conducted power (before Ohmic loss) per sub-array (dBm) (Note 1) | | 28 for 2GHz  35 for 4GHz | |
| Base station horizontal coverage range (degrees) | | +/-60 | |
| Base station vertical coverage range (degrees) (Note 2) | | 10 | |
| Mechanical downtilt (degrees) | | 3 | |
| Note 1: The conducted power per sub-array assumes 4x8x2 sub-arrays (i.e. power per H/V polarized sub-array).  Note 2: The vertical coverage range includes the mechanical downtilt. | | | |

#### 6.2.3.4 TN UE antenna model

The following assumption for TN UE antenna is shown as below.

Table 6.2.3.4-1: TN handheld UE antenna charateristic

|  |  |
| --- | --- |
| Characteristics | Handheld |
| Antenna type and configuration | (1, 1, 2) with omni-directional antenna element |
| Polarisation | Linear: +/-45°X-pol |
| Tx/Rx Antenna gain | 0 dBi per element |
| the number of Tx and Rx | 1T2R |

### 6.2.4 ACLR and ACS modelling

For DL it seems reasonable from the perspective of simulating worst case scenarios that we assume BS ACLR is modelled as flat in space, and the UE ACS can be modelled flat in space.

If this assumption is for DL, then the similar assumption could be made for the UL.

Therefore, it is assumed that both ACLR ( or the adjacent channel interference) and ACS are flat in both space and frequency. The ACIR model can be express as:



(Assuming ACLR, ACS and ACIR to be linear).

The ACLR/ACS requirements for TN are defined as below.

Table 6.2.4-1: ACLR/ACS requirements for TN

|  |  |  |
| --- | --- | --- |
| **NR TN system** | | |
| BS | ACLR | 45 dB |
| ACS | 46 dB |
| UE | ACLR | 30dB (ACLR1)  43dB (ACLR2) |
| ACS | 33 |

### 6.2.5 Propagation model

#### 6.2.5.1 Propagation model between TN UE and ATG UE

Referring to section 6.6 in TR 38.811, the propagation model between TN UE and ATG UE can be simplified and summarized as below.

**LOS probability**

Line-Of-Sight (LOS) probability depends on UE environment and elevation angle, and is obtained from Table 6.2.5.1-1. Reference elevation angles are considered from 10° to 90° with a 10° step. For an ATG UE-to-ATG BS, the LOS probability is taken from the nearest reference elevation angle.

Table 6.2.5.1-1 LOS probability

|  |  |
| --- | --- |
| Elevation | Suburban and Rural scenarios |
| 10° | 78.2% |
| 20° | 86.9% |
| 30° | 91.9% |
| 40° | 92.9% |
| 50° | 93.5% |
| 60° | 94.0% |
| 70° | 94.9% |
| 80° | 95.2% |
| 90° | 99.8% |

**Path loss and Shadow fading**

The signal path between ATG UE and ATG BS undergoes several stages of propagation and attenuation. The path loss (PL) is composed of components as follows:

, (6.2.5.1-1)

where is the total path loss in dB,

 is the basic path loss in dB,

This section specifies the basic path loss model () which accounts for the signal's free space propagation, clutter loss, and shadow fading.

The free space path loss (FSPL) in dB for a separation distance *d* (between ATG UE and ATG BS) in meter and frequency in GHz is given by

 (6.6-2)

is clutter loss, and  is shadow fading loss represented by a random number generated by the normal distribution, i.e.,  ~. When the UE is in LOS condition, clutter loss is negligible and should be set to 0 dB in the basic path loss model.

Table 6.2.5.1-2: Shadow fading and clutter loss for suburban and rural scenarios

|  |  |  |  |
| --- | --- | --- | --- |
| Elevation | 2GHz 3.5GHz | | |
| LOS | NLOS | |
| (dB) | (dB) | (dB) |
| 10° | 1.79 | 8.93 | 19.52 |
| 20° | 1.14 | 9.08 | 18.17 |
| 30° | 1.14 | 8.78 | 18.42 |
| 40° | 0.92 | 10.25 | 18.28 |
| 50° | 1.42 | 10.56 | 18.63 |
| 60° | 1.56 | 10.74 | 17.68 |
| 70° | 0.85 | 10.17 | 16.50 |
| 80° | 0.72 | 11.52 | 16.30 |
| 90° | 0.72 | 11.52 | 16.30 |

#### 6.2.5.2 Propagation model between TN BS and TN UE

Referring to section 7.4 in TR 38.901, the propagation model between TN BS and TN UE can be summarized as below, which is same as RMa scenario.

**Pathloss:**

The pathloss models are summarized in Table 6.2.5.2-1 and the distance definitions are indicated in Figure 6.2.5.2-1 and Figure 6.2.5.2-2. Note that the distribution of the shadow fading is log-normal, and its standard deviation for each scenario is given in Table 6.2.5.2-1.

|  |  |
| --- | --- |
|  |  |
| Figure 6.2.5.2-1: Definition of *d2D* and *d3D*  for outdoor UTs | Figure 6.2.5.2-2: Definition of *d2D-out*, *d2D-in*  and *d3D-out*, *d3D-in* for indoor UTs. |

Note that

 (7.4-1)

Table 6.2.5.2-1: Pathloss models

| Scenario | LOS/NLOS | Pathloss [dB], *fc* is in GHz and *d* is in meters, see note 6 | Shadow  fading  std [dB] | Applicability range,  antenna height  default values |
| --- | --- | --- | --- | --- |
| RMa | LOS | , see note 5 |  | h = avg. building height  W = avg. street width  The applicability ranges: |
| NLOS | for |  |
| Note 1: Breakpoint distance *d*'BP = 4 *h*'BS *h*'UT *f*c/*c*, where *f*c is the centre frequency in Hz, *c* = 3.0×108 m/s is the propagation velocity in free space, and *h*'BS and *h*'UT are the effective antenna heights at the BS and the UT, respectively. The effective antenna heights *h*'BS and *h*'UT are computed as follows: *h*'BS = *h*BS – *h*E, *h*'UT = *h*UT – *h*E, where *h*BS and *h*UT are the actual antenna heights, and hE is the effective environment height. For UMi *h*E = 1.0m. For UMa *h*E=1m with a probability equal to 1/(1+C(*d*2D, *h*UT)) and chosen from a discrete uniform distribution uniform(12,15,…,(*h*UT-1.5)) otherwise. With C(*d*2D, *h*UT) given by  ,  where  .  Note that *h*E depends on *d*2D and *h*UT and thus needs to be independently determined for every link between BS sites and UTs. A BS site may be a single BS or multiple co-located BSs.  Note 2: The applicable frequency range of the PL formula in this table is 0.5 < *fc* < *f*H GHz, where *f*H = 30 GHz for RMa and *f*H = 100 GHz for all the other scenarios. It is noted that RMa pathloss model for >7 GHz is validated based on a single measurement campaign conducted at 24 GHz.  Note 3: UMa NLOS pathloss is from TR36.873 with simplified format and PLUMa-LOS = Pathloss of UMa LOS outdoor scenario.  Note 4: PLUMi-LOS = Pathloss of UMi-Street Canyon LOS outdoor scenario.  Note 5: Break point distance *dBP* = 2π *hBS* *hUT* *fc*/*c*, where *fc* is the centre frequency in Hz, *c* = 3.0 × 108 m/s is the propagation velocity in free space, and *hBS* and *hUT* are the antenna heights at the BS and the UT, respectively.  Note 6: *fc* denotes the center frequency normalized by 1GHz, all distance related values are normalized by 1m, unless it is stated otherwise. | | | | |

**LOS probability**

The Line-Of-Sight (LOS) probabilities are given in Table 6.2.5.2-2.

Table 6.2.5.2-2 LOS probability

|  |  |
| --- | --- |
| Scenario | LOS probability (distance is in meters) |
| RMa |  |
|  | |

**O2I building penetration loss**

The pathloss incorporating O2I building penetration loss is modelled as in the following:

 (6.2.5.2-2)

where  is the basic outdoor path loss given in Clause 6.2.5.2, where  is replaced by  .  is the building penetration loss through the external wall,  is the inside loss dependent on the depth into the building, and σ*P* is the standard deviation for the penetration loss.

 is characterized as:

 (6.2.5.2-3)

 is an additional loss is added to the external wall loss to account for non-perpendicular incidence; , is the penetration loss of material *i*, example values of which can be found in Table 7.4.3-1;  is proportion of *i*-th materials, where ; and *N* is the number of materials.

Table 6.2.5.2-3: Material penetration losses

|  |  |
| --- | --- |
| Material | Penetration loss [dB] |
| Standard multi-pane glass |  |
| IRR glass |  |
| Concrete |  |
| Wood |  |
| Note: f is in GHz | |

Table 6.2.5.2-4 gives ,  and σ*P* for two O2I penetration loss models. The O2I penetration is UT-specifically generated, and is added to the SF realization in the log domain.

Table 6.2.5.2-4: O2I building penetration loss model

|  |  |  |  |
| --- | --- | --- | --- |
|  | Path loss through external wall:  in [dB] | Indoor loss:  in [dB] | Standard deviation:  σ*P* in [dB] |
| **Low-loss model** |  | 0.5 | 4.4 |
| **High-loss model** |  | 0.5 | 6.5 |

 is minimum of two independently generated uniformly distributed variables between 0 and 25 m for UMa and UMi-Street Canyon, and between 0 and 10 m for RMa.  shall be UT-specifically generated.

Both low-loss and high-loss models are applicable to UMa and UMi-Street Canyon.

**Only the low-loss model is applicable to RMa.**

#### 6.2.5.3 Propagation model between ATG BS and TN BS

The propagation model between ATG BS and TN BS is same as the LOS propagation model between TN UE and ATG UE in clause 6.2.5.1 (shadow fading and clutter loss are assumed to be zero, since the ATG BS and TN BS are at 30m above the clutter).

#### 6.2.5.4 Propagation model between ATG BS and TN UE

The propagation model between ATG BS and TN UE is same as the propagation model between TN BS and TN UE in clause 6.2.5.2

#### 6.2.5.5 Propagation model between TN BS and ATG UE

The propagation model between TN BS and ATG UE is same as the LOS propagation model between TN UE and ATG UE in clause 6.2.5.1 (shadow fading and clutter loss are assumed to be zero, since the ATG BS and TN BS are at 30m and above the clutter).

#### 6.2.5.6 Propagation model between ATG BS and ATG UE

The propagation model between ATG BS and ATG UE is same as the LOS propagation model between TN UE and ATG UE in clause 6.2.5.1 (shadow fading and clutter loss are assumed to be zero, since the ATG BS and TN BS are at 30m and above the clutter).

### 6.2.6 Transmission power control model

#### 6.2.6.1 TN UL TPC

For uplink scenario, TPC model specified in Section 9.1 TR 36.942 is applied for TN with following parameters.



where:

- Pmax = 23dBm,

- Rmin = -40dBm,

- CLx-ile and γ are set as following:

- CLx-ile = 88 + 10\*log10 (200/X) + 11 – Y, where X is UL transmission BW (MHz) and Y is the BS noise figure

- γ = 1 For uplink scenario.

#### 6.2.6.2 TN DL TPC

For downlink scenario, no power control scheme is applied.

#### 6.2.6.3 ATG UL TPC

For uplink scenario, TPC model specified in Section 9.1 TR 36.942 is applied for TN with following parameters.



where:

- Pmax is ATG UE maximum output power (TRP) dBm,

- Rmin is ATG UE minimum output power (TRP) dBm,

- CLx-ile and γ are set as following:

- CLx-ile = 10\*log10(Pmax) – (SNRtarget + (-174+F+10\*log(B)) )

- SNRtarget is the targeted UL SNR (dB).

- F is BS noise figure (dB).

- B is UL transmission BW (Hz)

- γ = 1 for uplink scenario.

The specific parameters are assumed as below in table 6.2.6.3.

Table 6.2.6.3-1 LOS probability

|  |  |  |
| --- | --- | --- |
| UE UL power control parameters | 2GHz | 4GHz |
| Target SNR | 15dB | 15dB |
| Pmax (TRP) | 40dBm | 23dBm for per polarization |
| BW | 20MHz | 100MHz |
| Rmin | -27dBm | -20dBm |
| NF for ATG BS | 5dB | 5dB |
| CLx\_ile | 121dB | 97 |

#### 6.2.6.4 ATG DL TPC

For downlink scenario, no power control scheme is applied.

### 6.2.7 Received power model

The received power in downlink and uplink scenarios is defined as below:

RX\_PWR = TX\_PWR – Path loss + G\_TX + G\_RX

where:

- RX\_PWR is the received power

- TX\_PWR is the transmitted power

- G\_TX is the transmitter antenna gain (directional array gain)

- G\_RX is the receiver antenna gain (directional array gain).

### 6.2.8 Performance metric

For NR, the average throughput loss and 5%-ile throughput loss should be less than 5%.

For ATG, the average throughput loss and 5%-ile throughput loss should be less than 5%.

For synchronized scenario, when TN network as victim, the average throughput loss should be calculated in each of the TN cells. Results should be presented for the average throughput loss in the worst case TN cell, and an average of the average throughput losses in all of the TN cells in the cluster may also be presented. The details could be found as following:

* 5% and average in the whole network (When TN UL as victim, 5% and average are 5% and average of the whole TN UL. When ATG as victim, 5% and average are the 5% and average among all drops.)
* 5% and average of users within the cell with largest throughput loss for the case of TN DL victim

For non-synchronized scenario, compared with ATG UE-to-TN UE CLI, ATG BS-to-TN BS CLI is the dominate interference. So we only consider ATG BS-to-TN BS CLI simulation and detailed performance metric is as below:

* When TN gNB as victim, only focus on the TN sector with worst throughput loss, 5% and mean among all drops
* When ATG gNB as victim, 5% and mean among all drops.

### 6.2.9 Link level performance for NR ATG coexistence

The throughput of a modem with link adaptation can be approximated by an attenuated and truncated form of the Shannon bound. (The Shannon bound represents the maximum theoretical throughput than can be achieved over an AWGN channel for a given SNIR). The following equations approximate the throughput over a channel with a given SNIR, when using link adaptation:



Where:

- S(SNIR) Shannon bound, S(SNIR) =log2(1+SNIR) bps/Hz

- α Attenuation factor, representing implementation losses

- SNIRMIN Minimum SNIR of the code set, dB

- SNIRMAX Maximum SNIR of the code set, dB

The parameters α, SNIRMIN and SNIRMAX can be chosen to represent different modem implementations and link conditions. The parameters proposed in Table 4.2.7-1 represent a baseline case, which assumes:

- 1:1 antenna configuration

- AWGN channel model

- Link Adaptation (see Table 4.2.7-1 for details of the highest and lowest rate codes)

- No HARQ

Table 6.2.9-1: Parameters describing baseline Link Level performance for 5G NR

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | DL | UL | Notes |
| α, attenuation | 0.6 | 0.4 | Represents implementation losses |
| SNIRMIN, dB | -10 | -10 | Based on QPSK, 1/8 rate (DL) & 1/5 rate (UL) |
| SNIRMAX, dB | 30 | 22 | Based on 256QAM 0.93(DL) & 64QAM 0.93 (UL) |

Note that the parameters proposed in Table 4.2.7-1 are targeted for eMBB coexistence scenario.

## 6.3 Co-existence simulation methodology

Adopt following simulation steps.

- Step 1: Generate aggressor and victim networks.

- One ATG site with one sector is dropped referring to clause 6.2.1.3

- Deployment of terrestrial network (19 cells with wraparound) refers to Table 6.2.1.2-1

- The relationship between TN and ATG can refer to clause 6.2.1.1

- Step2: UE associations

- TN UE are generated randomly inside the TN network, make sure enough TN UEs are associated to each TN sectors based on coupling loss.

- Deployment of ATG UE refers to clause 6.2.1.3.

- Step 3: Once association is done, round robin scheduling is used. BF weights are adjusted to point to the LOS direction between BS/ATG BS-UE. This is done for both victim and aggressor networks.

- Step 4: Throughput is computed in the victim systems without considering ACI as below:

,

where: is the inter-cell interference.

- Step 5: Throughput is computed considering ACI as below:

,

where: is the adjacent channel interference.

- Step 6: RF parameters are determined based on the degradation cause by ACI as below:

6.4 Co-existence simulation results

### **6.4.1 Synchronized Scenarios**

#### **6.4.1.1 Scenario 1: 4GHz ATG DL interfering TN DL**

This scenario captures the co-existence results after evaluation from all possible options. Here ATG DL with both AAS subarray and non-subarray model is interfering TN DL deployed in rural macro environment.

Table 6.4.1.1-1: Throughput Loss (%) at ATG BS ACLR 45 dB for Scenario 1 – 4 GHz ATG DL interfering TN DL

|  |  |  |  |
| --- | --- | --- | --- |
| **Company** | **ATG/ TN BS antenna model** | **Performance Metric** | **Throughput Loss (%) at ATG BS ACLR 45 dB** |
| Ericsson | Non-Subarray | 5% in the whole network | 0.102 |
| Average of all users in the whole network | 0.010 |
| 5% of users within the cell with largest throughput loss for the case of TN DL victim | 2.465 |
| Average of all users within the cell with largest throughput loss for the case of TN DL victim | 0.268 |
| Subarray | 5% in the whole network | 0.038 |
| Average of all users in the whole network | 0.009 |
| 5% of users within the cell with largest throughput loss for the case of TN DL victim | 0.905 |
| Average of all users within the cell with largest throughput loss for the case of TN DL victim | 0.241 |
| ZTE | Non-Subarray | 5% in the whole network | 0.083 |
| Average of all users in the whole network | 0.013 |
| 5% of users within the cell with largest throughput loss for the case of TN DL victim | 2.388 |
| Average of all users within the cell with largest throughput loss for the case of TN DL victim | 0.175 |
| Subarray | 5% in the whole network | - |
| Average of all users in the whole network | - |
| 5% of users within the cell with largest throughput loss for the case of TN DL victim | - |
| Average of all users within the cell with largest throughput loss for the case of TN DL victim | - |
| CMCC | Non-Subarray | 5% in the whole network | - |
| Average of all users in the whole network | 0.016 |
| 5% of users within the cell with largest throughput loss for the case of TN DL victim | 3.455 |
| Average of all users within the cell with largest throughput loss for the case of TN DL victim | 0.761 |
| Subarray | 5% in the whole network | - |
| Average of all users in the whole network | - |
| 5% of users within the cell with largest throughput loss for the case of TN DL victim | - |
| Average of all users within the cell with largest throughput loss for the case of TN DL victim | - |
| Qualcomm | Non-Subarray | 5% in the whole network | 0.355 |
| Average of all users in the whole network | 0.080 |
| 5% of users within the cell with largest throughput loss for the case of TN DL victim | 0.524 |
| Average of all users within the cell with largest throughput loss for the case of TN DL victim | 0.149 |
| Subarray | 5% in the whole network | - |
| Average of all users in the whole network | - |
| 5% of users within the cell with largest throughput loss for the case of TN DL victim | - |
| Average of all users within the cell with largest throughput loss for the case of TN DL victim | - |
| Huawei | Non-Subarray | 5% in the whole network | 0 |
| Average of all users in the whole network | 0 |
| 5% of users within the cell with largest throughput loss for the case of TN DL victim | - |
| Average of all users within the cell with largest throughput loss for the case of TN DL victim | - |
| Subarray | 5% in the whole network | - |
| Average of all users in the whole network | - |
| 5% of users within the cell with largest throughput loss for the case of TN DL victim | - |
| Average of all users within the cell with largest throughput loss for the case of TN DL victim | - |
| CATT | Non-Subarray | 5% in the whole network | 0.096 |
| Average of all users in the whole network | 0.019 |
| 5% of users within the cell with largest throughput loss for the case of TN DL victim | - |
| Average of all users within the cell with largest throughput loss for the case of TN DL victim | - |
| Subarray | 5% in the whole network | - |
| Average of all users in the whole network | - |
| 5% of users within the cell with largest throughput loss for the case of TN DL victim | - |
| Average of all users within the cell with largest throughput loss for the case of TN DL victim | - |

##### **6.4.1.1.1 Non-Subarray model**

Figure 6.4.1.1-1: Simulation results for Throughput Loss - 5% of users in the whole network

Figure 6.4.1.1-2: Simulation results for Throughput Loss – Average of all users in the whole network

Figure 6.4.1.1-3: Simulation results for Throughput Loss – 5% of users within cell of largest throughput loss of victim network

Figure 6.4.1.1-4: Simulation results for Throughput Loss – Average of all users within cell of largest throughput loss of victim network

##### **6.4.1.1.2 Subarray model**

Figure 6.4.1.1-5: Simulation results for Throughput Loss - 5% of users in the whole network

Figure 6.4.1.1-6: Simulation results for Throughput Loss – Average of all users in the whole network

Figure 6.4.1.1-7: Simulation results for Throughput Loss – 5% of users within cell of largest throughput loss of victim network

Figure 6.4.1.1-4: Simulation results for Throughput Loss – Average of all users within cell of largest throughput loss of victim network

#### **6.4.1.2 Scenario 2: 4GHz ATG UL interfering TN UL**

This scenario captures the co-existence results after evaluation from all possible options. Here ATG UL with both AAS subarray and non-subarray model is interfering TN UL deployed in rural macro environment.

**Table 6.4.1.2-1: Simulation results for Scenario 2 – 4 GHz ATG UL interfering TN UL**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Company** | **ATG/ TN BS antenna model** | **Performance Metric** | **Throughput Loss (%) at ATG UE ACLR 30 dB** | |
| **Maximum distance between ATG BS and ATG UE** | |
| **100 km** | **300 km** |
| Ericsson | Non-Subarray | 5% in the whole network | 0 | 0 |
| Average of all users in the whole network | 0 | 0 |
| 5% of users within the cell with largest throughput loss for the case of TN UL victim | 0.05 | 0.05 |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim | 0 | 0 |
| Subarray | 5% in the whole network | 0 | 0 |
| Average of all users in the whole network | 0 | 0 |
| 5% of users within the cell with largest throughput loss for the case of TN UL victim | 0.03 | 0.03 |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim | 0.01 | 0.01 |
| ZTE | Non-Subarray | 5% in the whole network | 0 | - |
| Average of all users in the whole network | 0 | - |
| 5% of users within the cell with largest throughput loss for the case of TN UL victim | - | - |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim | - | - |
| Subarray | 5% in the whole network | - | - |
| Average of all users in the whole network | - | - |
| 5% of users within the cell with largest throughput loss for the case of TN UL victim | - | - |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim | - | - |
| CMCC | Non-Subarray | 5% in the whole network | 0 | - |
| Average of all users in the whole network | 0 | - |
| 5% of users within the cell with largest throughput loss for the case of TN UL victim | 0.03 | - |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim | 0.01 | - |
| Subarray | 5% in the whole network | - | - |
| Average of all users in the whole network | - | - |
| 5% of users within the cell with largest throughput loss for the case of TN UL victim | - | - |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim | - | - |
| Qualcomm | Non-Subarray | 5% in the whole network | 0 | - |
| Average of all users in the whole network | 0 | - |
| 5% of users within the cell with largest throughput loss for the case of TN UL victim | 0 | - |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim | 0 | - |
| Subarray | 5% in the whole network | - | - |
| Average of all users in the whole network | - | - |
| 5% of users within the cell with largest throughput loss for the case of TN UL victim | - | - |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim | - | - |
| Huawei | Non-Subarray | 5% in the whole network | 0 | - |
| Average of all users in the whole network | 0 | - |
| 5% of users within the cell with largest throughput loss for the case of TN UL victim | 0 | - |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim | 0 | - |
| Subarray | 5% in the whole network | - | - |
| Average of all users in the whole network | - | - |
| 5% of users within the cell with largest throughput loss for the case of TN UL victim | - | - |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim | - | - |
| CATT | Non-Subarray | 5% in the whole network | 0 | - |
| Average of all users in the whole network | 0 | - |
| 5% of users within the cell with largest throughput loss for the case of TN UL victim | - | - |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim | - | - |
| Subarray | 5% in the whole network | - | - |
| Average of all users in the whole network | - | - |
| 5% of users within the cell with largest throughput loss for the case of TN UL victim | - | - |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim | - | - |

##### **6.4.1.2.1 Non-Subarray model**

###### **Maximum distance between ATG BS and ATG UE is 100 km**

Figure 6.4.1.2-1: Simulation results for Throughput Loss - 5% of users in the whole network

Figure 6.4.1.2-2: Simulation results for Throughput Loss – Average of all users in the whole network

Figure 6.4.1.2-3: Simulation results for Throughput Loss – 5% of users within cell of largest throughput loss of victim network

Figure 6.4.1.2-4: Simulation results for Throughput Loss – Average of all users within cell of largest throughput loss of victim network

###### **Maximum distance between ATG BS and ATG UE is 300 km**

Figure 6.4.1.2-5: Simulation results for Throughput Loss - 5% of users in the whole network

Figure 6.4.1.2-6: Simulation results for Throughput Loss – Average of all users in the whole network

Figure 6.4.1.2-7: Simulation results for Throughput Loss – 5% of users within cell of largest throughput loss of victim network

Figure 6.4.1.2-8: Simulation results for Throughput Loss – Average of all users within cell of largest throughput loss of victim network

##### **6.4.1.2.2 Subarray model**

###### **Maximum distance between ATG BS and ATG UE is 100 km**

Figure 6.4.1.2-9: Simulation results for Throughput Loss - 5% of users in the whole network

Figure 6.4.1.2-10: Simulation results for Throughput Loss – Average of all users in the whole network

Figure 6.4.1.2-11: Simulation results for Throughput Loss – 5% of users within cell of largest throughput loss of victim network

Figure 6.4.1.2-12: Simulation results for Throughput Loss – Average of all users within cell of largest throughput loss of victim network

###### **Maximum distance between ATG BS and ATG UE is 300 km**

Figure 6.4.1.2-13: Simulation results for Throughput Loss - 5% of users in the whole network

Figure 6.4.1.2-14: Simulation results for Throughput Loss – Average of all users in the whole network

Figure 6.4.1.2-15: Simulation results for Throughput Loss – 5% of users within cell of largest throughput loss of victim network

Figure 6.4.1.2-16: Simulation results for Throughput Loss – Average of all users within cell of largest throughput loss of victim network

#### **6.4.1.3 Scenario 3: 4GHz TN DL interfering ATG DL**

This scenario captures the co-existence results after evaluation from all possible options. TN DL with both AAS subarray and non-subarray model is interfering ATG DL deployed in rural macro environment.

**Table 6.4.1.3-1: Simulation results for Scenario 3 – 4GHz TN DL interfering ATG DL**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Company** | **ATG/ TN BS antenna model** | **Performance Metric** | **Throughput Loss (%) at ATG UE ACS 33 dB** | |
| **Maximum distance between ATG BS and ATG UE** | |
| **100 km** | **300 km** |
| Ericsson | Non-Subarray | 5% in the whole network | 3.60 | 7.02 |
| Average of all users in the whole network | 1.35 | 2.22 |
| Subarray | 5% in the whole network | 6.35 | 11.93 |
| Average of all users in the whole network | 1.97 | 3.21 |
| ZTE | Non-Subarray | 5% in the whole network | 0.90 | - |
| Average of all users in the whole network | 0.24 | - |
| Subarray | 5% in the whole network | - | - |
| Average of all users in the whole network | - | - |
| CMCC | Non-Subarray | 5% in the whole network | 2.39 | - |
| Average of all users in the whole network | 0.47 | - |
| Subarray | 5% in the whole network | - | - |
| Average of all users in the whole network | - | - |
| Qualcomm | Non-Subarray | 5% in the whole network | 1.75 | - |
| Average of all users in the whole network | 0.55 | - |
| Subarray | 5% in the whole network | - | - |
| Average of all users in the whole network | - | - |
| Huawei | Non-Subarray | 5% in the whole network | 0.18 | - |
| Average of all users in the whole network | 0.23 | - |
| Subarray | 5% in the whole network | - | - |
| Average of all users in the whole network | - | - |
| CATT | Non-Subarray | 5% in the whole network | 2.04 | - |
| Average of all users in the whole network | 0.62 | - |
| Subarray | 5% in the whole network | - | - |
| Average of all users in the whole network | - | - |

##### **6.4.1.3.1 Non-Subarray model**

###### **Maximum distance between ATG BS and ATG UE is 100 km**

Figure 6.4.1.3-1: Simulation results for Throughput Loss - 5% of users in the whole network

Figure 6.4.1.3-2: Simulation results for Throughput Loss – Average of all users in the whole network

###### **Maximum distance between ATG BS and ATG UE is 300 km**

Figure 6.4.1.3-3: Simulation results for Throughput Loss - 5% of users in the whole network

Figure 6.4.1.3-4: Simulation results for Throughput Loss – Average of all users in the whole network

##### **6.4.1.3.2 Subarray model**

###### **Maximum distance between ATG BS and ATG UE is 100 km**

Figure 6.4.1.3-5: Simulation results for Throughput Loss - 5% of users in the whole network

Figure 6.4.1.3-6: Simulation results for Throughput Loss – Average of all users in the whole network

###### **Maximum distance between ATG BS and ATG UE is 300 km**

Figure 6.4.1.3-7: Simulation results for Throughput Loss - 5% of users in the whole network

Figure 6.4.1.3-8: Simulation results for Throughput Loss – Average of all users in the whole network

#### **6.4.1.4 Scenario 4: 4GHz TN UL interfering ATG UL**

This scenario captures the co-existence results after evaluation from all possible options. Here TN UL with both AAS subarray and non-subarray model is interfering ATG UL deployed in rural macro environment.

**Table 6.4.1.4-1: Simulation results for Scenario 4 – 4GHz TN UL interfering ATG UL**

|  |  |  |  |
| --- | --- | --- | --- |
| **Company** | **ATG/ TN BS antenna model** | **Performance Metric** | **Throughput loss (%) at ATG BS ACS 46 dB** |
| Ericsson | Non-Subarray | 5% in the whole network | 1.08 |
| Average of all users in the whole network | 0.34 |
| Subarray | 5% in the whole network | 0.91 |
| Average of all users in the whole network | 0.49 |
| ZTE | Non-Subarray | 5% in the whole network | 0.44 |
| Average of all users in the whole network | 0.13 |
| Subarray | 5% in the whole network | - |
| Average of all users in the whole network | - |
| CMCC | Non-Subarray | 5% in the whole network | 0.93 |
| Average of all users in the whole network | 0.15 |
| Subarray | 5% in the whole network | - |
| Average of all users in the whole network | - |
| Qualcomm | Non-Subarray | 5% in the whole network | 0 |
| Average of all users in the whole network | 0 |
| Subarray | 5% in the whole network | - |
| Average of all users in the whole network | - |
| Huawei | Non-Subarray | 5% in the whole network | 0.22 |
| Average of all users in the whole network | 0 |
| Subarray | 5% in the whole network | - |
| Average of all users in the whole network | - |
| CATT | Non-Subarray | 5% in the whole network | 0.27 |
| Average of all users in the whole network | 0.05 |
| Subarray | 5% in the whole network | - |
| Average of all users in the whole network | - |

##### **6.4.1.4.1 Non-Subarray model**

Figure 6.4.1.4-1: Simulation results for Throughput Loss - 5% of users in the whole network

Figure 6.4.1.4-2: Simulation results for Throughput Loss – Average of all users in the whole network

##### **6.4.1.4.2 Subarray model**

Figure 6.4.1.4-3: Simulation results for Throughput Loss - 5% of users in the whole network

Figure 6.4.1.4-4: Simulation results for Throughput Loss – Average of all users in the whole network

#### **6.4.1.5 Scenario 9: 2GHz ATG DL interfering TN DL**

This scenario captures the co-existence results after evaluation from all possible options. Here ATG DL with both AAS subarray and non-subarray model is interfering TN DL deployed in rural macro environment.

**Table 6.4.1.5-1: Simulation results for Scenario 9 – 2GHz ATG DL interfering TN DL**

|  |  |  |  |
| --- | --- | --- | --- |
| **Company** | **ATG/ TN BS antenna model** | **Performance Metric** | **Throughput loss (%) at ATG BS ACLR 45 dB** |
| Ericsson | Non-Subarray | 5% in the whole network | 0.16 |
| Average of all users in the whole network | 0.03 |
| 5% of users within the cell with largest throughput loss for the case of TN DL victim | 5.38 |
| Average of all users within the cell with largest throughput loss for the case of TN DL victim | 0.76 |
| Subarray | 5% in the whole network | 0.02 |
| Average of all users in the whole network | 0.03 |
| 5% of users within the cell with largest throughput loss for the case of TN DL victim | 1.51 |
| Average of all users within the cell with largest throughput loss for the case of TN DL victim | 0.74 |
| ZTE | Non-Subarray | 5% in the whole network | 0.06 |
| Average of all users in the whole network | 0.01 |
| 5% of users within the cell with largest throughput loss for the case of TN DL victim | 1.04 |
| Average of all users within the cell with largest throughput loss for the case of TN DL victim | 0.16 |
| Subarray | 5% in the whole network | - |
| Average of all users in the whole network | - |
| 5% of users within the cell with largest throughput loss for the case of TN DL victim | - |
| Average of all users within the cell with largest throughput loss for the case of TN DL victim | - |
| CMCC | Non-Subarray | 5% in the whole network | 0 |
| Average of all users in the whole network | 0.01 |
| 5% of users within the cell with largest throughput loss for the case of TN DL victim | 1.67 |
| Average of all users within the cell with largest throughput loss for the case of TN DL victim | 0.63 |
| Subarray | 5% in the whole network | - |
| Average of all users in the whole network | - |
| 5% of users within the cell with largest throughput loss for the case of TN DL victim | - |
| Average of all users within the cell with largest throughput loss for the case of TN DL victim | - |
| Qualcomm | Non-Subarray | 5% in the whole network | 0 |
| Average of all users in the whole network | 0 |
| 5% of users within the cell with largest throughput loss for the case of TN DL victim | 0 |
| Average of all users within the cell with largest throughput loss for the case of TN DL victim | 0 |
| Subarray | 5% in the whole network | - |
| Average of all users in the whole network | - |
| 5% of users within the cell with largest throughput loss for the case of TN DL victim | - |
| Average of all users within the cell with largest throughput loss for the case of TN DL victim | - |
| Huawei | Non-Subarray | 5% in the whole network | 0.22 |
| Average of all users in the whole network | 0.01 |
| 5% of users within the cell with largest throughput loss for the case of TN DL victim | - |
| Average of all users within the cell with largest throughput loss for the case of TN DL victim | - |
| Subarray | 5% in the whole network | - |
| Average of all users in the whole network | - |
| 5% of users within the cell with largest throughput loss for the case of TN DL victim | - |
| Average of all users within the cell with largest throughput loss for the case of TN DL victim | - |
| CATT | Non-Subarray | 5% in the whole network | 0.22 |
| Average of all users in the whole network | 0.02 |
| 5% of users within the cell with largest throughput loss for the case of TN DL victim | - |
| Average of all users within the cell with largest throughput loss for the case of TN DL victim | - |
| Subarray | 5% in the whole network | - |
| Average of all users in the whole network | - |
| 5% of users within the cell with largest throughput loss for the case of TN DL victim | - |
| Average of all users within the cell with largest throughput loss for the case of TN DL victim | - |

##### **6.4.1.5.1 Non-Subarray model**

Figure 6.4.1.5-1: Simulation results for Throughput Loss - 5% of users in the whole network

Figure 6.4.1.5-2: Simulation results for Throughput Loss – Average of all users in the whole network

Figure 6.4.1.5-3: Simulation results for Throughput Loss – 5% of users within cell of largest throughput loss of victim network

Figure 6.4.1.5-4: Simulation results for Throughput Loss – Average of all users within cell of largest throughput loss of victim network

##### **6.4.1.5.2 Subarray model**

Figure 6.4.1.5-5: Simulation results for Throughput Loss - 5% of users in the whole network

Figure 6.4.1.5-6: Simulation results for Throughput Loss – Average of all users in the whole network

Figure 6.4.1.5-7: Simulation results for Throughput Loss – 5% of users within cell of largest throughput loss of victim network

Figure 6.4.1.5-8: Simulation results for Throughput Loss – Average of all users within cell of largest throughput loss of victim network

#### **6.4.1.6 Scenario 10: 2GHz ATG UL interfering TN UL**

This scenario captures the co-existence results after evaluation from all possible options. Here ATG UL with both AAS subarray and non-subarray model is interfering TN UL deployed in rural macro environment.

**Table 6.4.1.6-1: Simulation results for Scenario 10 – 2GHz ATG UL interfering TN UL**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Company** | **ATG/ TN BS antenna model** | **Performance Metric** | **Throughput loss (%) at ATG UE ACLR 30 dB** | |
| **Maximum distance between ATG BS and ATG UE** | |
| **100 km** | **300 km** |
| Ericsson | Non-Subarray | 5% in the whole network | 0.02 | 0.32 |
| Average of all users in the whole network | 0.04 | 0.20 |
| 5% of users within the cell with largest throughput loss for the case of TN UL victim | 1.00 | 4.38 |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim | 0.07 | 0.37 |
| Subarray | 5% in the whole network | 0.13 | 0.42 |
| Average of all users in the whole network | 0.02 | 0.14 |
| 5% of users within the cell with largest throughput loss for the case of TN UL victim | 0.79 | 3.84 |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim | 0.04 | 0.28 |
| ZTE | Non-Subarray | 5% in the whole network | 0.01 | - |
| Average of all users in the whole network | 0.003 | - |
| 5% of users within the cell with largest throughput loss for the case of TN UL victim | - | - |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim | - | - |
| Subarray | 5% in the whole network | - | - |
| Average of all users in the whole network | - | - |
| 5% of users within the cell with largest throughput loss for the case of TN UL victim | - | - |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim | - | - |
| CMCC | Non-Subarray | 5% in the whole network | 0.07 | - |
| Average of all users in the whole network | 0.07 | - |
| 5% of users within the cell with largest throughput loss for the case of TN UL victim | 10.95 | - |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim | 1.60 | - |
| Subarray | 5% in the whole network | - | - |
| Average of all users in the whole network | - | - |
| 5% of users within the cell with largest throughput loss for the case of TN UL victim | - | - |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim | - | - |
| Qualcomm | Non-Subarray | 5% in the whole network | 0.004 | - |
| Average of all users in the whole network | 0.001 | - |
| 5% of users within the cell with largest throughput loss for the case of TN UL victim | 0.005 | - |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim | 0.003 | - |
| Subarray | 5% in the whole network | - | - |
| Average of all users in the whole network | - | - |
| 5% of users within the cell with largest throughput loss for the case of TN UL victim | - | - |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim | - | - |
| Huawei | Non-Subarray | 5% in the whole network | 0 | - |
| Average of all users in the whole network | 0.02 | - |
| 5% of users within the cell with largest throughput loss for the case of TN UL victim | 0.03 | - |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim | 0.003 | - |
| Subarray | 5% in the whole network | - | - |
| Average of all users in the whole network | - | - |
| 5% of users within the cell with largest throughput loss for the case of TN UL victim | - | - |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim | - | - |
| CATT | Non-Subarray | 5% in the whole network | 0 | - |
| Average of all users in the whole network | 0 | - |
| 5% of users within the cell with largest throughput loss for the case of TN UL victim | - | - |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim | - | - |
| Subarray | 5% in the whole network | - | - |
| Average of all users in the whole network | - | - |
| 5% of users within the cell with largest throughput loss for the case of TN UL victim | - | - |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim | - | - |

##### **6.4.1.6.1 Non-Subarray model**

###### **Maximum distance between ATG BS and ATG UE is 100 km**

Figure 6.4.1.6-1: Simulation results for Throughput Loss - 5% of users in the whole network

Figure 6.4.1.6-2: Simulation results for Throughput Loss – Average of all users in the whole network

Figure 6.4.1.6-3: Simulation results for Throughput Loss – 5% of users within cell of largest throughput loss of victim network

Figure 6.4.1.6-4: Simulation results for Throughput Loss – Average of all users within cell of largest throughput loss of victim network

###### **Maximum distance between ATG BS and ATG UE is 300 km**

Figure 6.4.1.6-5: Simulation results for Throughput Loss - 5% of users in the whole network

Figure 6.4.1.6-6: Simulation results for Throughput Loss – Average of all users in the whole network

Figure 6.4.1.6-7: Simulation results for Throughput Loss – 5% of users within cell of largest throughput loss of victim network

Figure 6.4.1.6-8: Simulation results for Throughput Loss – Average of all users within cell of largest throughput loss of victim network

##### **6.4.1.6.2 Subarray model**

###### **Maximum distance between ATG BS and ATG UE is 100 km**

Figure 6.4.1.6-9: Simulation results for Throughput Loss - 5% of users in the whole network

Figure 6.4.1.6-10: Simulation results for Throughput Loss – Average of all users in the whole network

Figure 6.4.1.6-11: Simulation results for Throughput Loss – 5% of users within cell of largest throughput loss of victim network

Figure 6.4.1.6-12: Simulation results for Throughput Loss – Average of all users within cell of largest throughput loss of victim network

###### **Maximum distance between ATG BS and ATG UE is 300 km**

Figure 6.4.1.6-13: Simulation results for Throughput Loss - 5% of users in the whole network

Figure 6.4.1.6-14: Simulation results for Throughput Loss – Average of all users in the whole network

Figure 6.4.1.6-15: Simulation results for Throughput Loss – 5% of users within cell of largest throughput loss of victim network

Figure 6.4.1.6-16: Simulation results for Throughput Loss – Average of all users within cell of largest throughput loss of victim network

#### **6.4.1.7 Scenario 11: 2GHz TN DL interfering ATG DL**

This scenario captures the co-existence results after evaluation from all possible options. Here TN DL with both AAS subarray and non-subarray model is interfering ATG DL deployed in rural macro environment.

**Table 6.4.1.7-1: Simulation results for Scenario 11 – 2GHz TN DL interfering ATG DL**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Company** | **ATG/ TN BS antenna model** | **Performance Metric** | **Throughput Loss (%) at ATG UE ACS 33 dB** | |
| **Maximum distance between ATG BS and ATG UE** | |
| **100 km** | **300 km** |
| Ericsson | Non-Subarray | 5% in the whole network | 3.62 | 7.85 |
| Average of all users in the whole network | 2.45 | 3.92 |
| Subarray | 5% in the whole network | 3.45 | 8.21 |
| Average of all users in the whole network | 2.59 | 4.08 |
| ZTE | Non-Subarray | 5% in the whole network | 1.45 | - |
| Average of all users in the whole network | 0.75 | - |
| Subarray | 5% in the whole network | - | - |
| Average of all users in the whole network | - | - |
| CMCC | Non-Subarray | 5% in the whole network | 13.52 | - |
| Average of all users in the whole network | 3.23 | - |
| Subarray | 5% in the whole network | - | - |
| Average of all users in the whole network | - | - |
| Qualcomm | Non-Subarray | 5% in the whole network | 2.07 | - |
| Average of all users in the whole network | 0.90 | - |
| Subarray | 5% in the whole network | - | - |
| Average of all users in the whole network | - | - |
| Huawei | Non-Subarray | 5% in the whole network | 1.36 | - |
| Average of all users in the whole network | 1.03 | - |
| Subarray | 5% in the whole network | - | - |
| Average of all users in the whole network | - | - |
| CATT | Non-Subarray | 5% in the whole network | 5.32 | - |
| Average of all users in the whole network | 0.86 | - |
| Subarray | 5% in the whole network | - | - |
| Average of all users in the whole network | - | - |

##### **6.4.1.7.1 Non-Subarray model**

###### **Maximum distance between ATG BS and ATG UE is 100 km**

Figure 6.4.1.7-1: Simulation results for Throughput Loss - 5% of users in the whole network

Figure 6.4.1.7-2: Simulation results for Throughput Loss – Average of all users in the whole network

###### **Maximum distance between ATG BS and ATG UE is 300 km**

Figure 6.4.1.7-3: Simulation results for Throughput Loss - 5% of users in the whole network

Figure 6.4.1.7-4: Simulation results for Throughput Loss – Average of all users in the whole network

##### **6.4.1.7.2 Subarray model**

###### **Maximum distance between ATG BS and ATG UE is 100 km**

Figure 6.4.1.7-5: Simulation results for Throughput Loss - 5% of users in the whole network

Figure 6.4.1.7-6: Simulation results for Throughput Loss – Average of all users in the whole network

###### **Maximum distance between ATG BS and ATG UE is 300 km**

Figure 6.4.1.7-7: Simulation results for Throughput Loss - 5% of users in the whole network

Figure 6.4.1.7-8: Simulation results for Throughput Loss – Average of all users in the whole network

#### **6.4.1.8 Scenario 12: 2GHz TN UL interfering ATG UL**

This scenario captures the co-existence results after evaluation from all possible options. Here TN UL with both AAS subarray and non-subarray model is interfering ATG UL deployed in rural macro environment.

**Table 6.4.1.8-1: Simulation results for Scenario 12 – 2GHz TN UL interfering ATG UL**

|  |  |  |  |
| --- | --- | --- | --- |
| **Company** | **ATG/ TN BS antenna model** | **Performance Metric** | **Throughput Loss (%) at ATG BS ACS 46 dB** |
| Ericsson | Non-Subarray | 5% in the whole network | 2.01 |
| Average of all users in the whole network | 0.55 |
| Subarray | 5% in the whole network | 3.23 |
| Average of all users in the whole network | 0.68 |
| ZTE | Non-Subarray | 5% in the whole network | 2.20 |
| Average of all users in the whole network | 0.63 |
| Subarray | 5% in the whole network | - |
| Average of all users in the whole network | - |
| CMCC | Non-Subarray | 5% in the whole network | 3.18 |
| Average of all users in the whole network | 0.88 |
| Subarray | 5% in the whole network | - |
| Average of all users in the whole network | - |
| Qualcomm | Non-Subarray | 5% in the whole network | 0.02 |
| Average of all users in the whole network | 0.01 |
| Subarray | 5% in the whole network | - |
| Average of all users in the whole network | - |
| Huawei | Non-Subarray | 5% in the whole network | 1.70 |
| Average of all users in the whole network | 0.001 |
| Subarray | 5% in the whole network | - |
| Average of all users in the whole network | - |
| CATT | Non-Subarray | 5% in the whole network | 1.32 |
| Average of all users in the whole network | 0.05 |
| Subarray | 5% in the whole network | - |
| Average of all users in the whole network | - |

##### **6.4.1.8.1 Non-Subarray model**

Figure 6.4.1.8-1: Simulation results for Throughput Loss - 5% of users in the whole network

Figure 6.4.1.8-2: Simulation results for Throughput Loss – Average of all users in the whole network

##### **6.4.1.8.2 Subarray model**

Figure 6.4.1.8-3: Simulation results for Throughput Loss - 5% of users in the whole network

Figure 6.4.1.8-4: Simulation results for Throughput Loss – Average of all users in the whole network

6.4.2 Non-synchronized Scenarios

6.4.2.1 Scenario 5: 4GHz ATG DL interfering TN UL

This scenario captures the co-existence results after evaluation from all possible options. Here ATG DL with both AAS subarray and non-subarray model is interfering TN UL deployed in rural macro environment. Plots will be included once the results are captured in the excel sheet from the interested companies.

**Table 6.4.2.1-1: Simulation results for Scenario 5 – 4GHz ATG DL interfering TN UL**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Company** | **ATG/ TN BS antenna model** | **Performance Metric** | **Isolation distance (km) for 5% throughput loss** | | |
| **Angle between ATG BS boresight and nearest TN BS boresight in azimuth** | | |
| **0°** | **30°** | **60°** |
| [Company 1] | Non-subarray | 5% of users within the cell with largest throughput loss for the case of TN UL victim |  |  |  |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim |  |  |  |
| Subarray | 5% of users within the cell with largest throughput loss for the case of TN UL victim |  |  |  |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim |  |  |  |
| [Company 2] | Non-Subarray | 5% of users within the cell with largest throughput loss for the case of TN UL victim |  |  |  |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim |  |  |  |
| Subarray | 5% of users within the cell with largest throughput loss for the case of TN UL victim |  |  |  |
| Average of all users within the cell with largest throughput loss for the case of TN UL victim |  |  |  |

6.4.2.2 Scenario 6: 4GHz ATG UL interfering TN DL

6.4.2.3 Scenario 7: 4GHz TN DL interfering ATG UL

This scenario captures the co-existence results after evaluation from all possible options. Here TN DL with both AAS subarray and non-subarray model is interfering ATG UL deployed in rural macro environment. Plots will be included once the results are captured in the excel sheet from the interested companies.

**Table 6.4.2.3-1: Simulation results for Scenario 7 – 4GHz TN DL interfering ATG UL**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Company** | **ATG/ TN BS antenna model** | **Performance Metric** | **Isolation distance (km) for 5% throughput loss** | | |
| **Angle between ATG BS boresight and nearest TN BS boresight in azimuth** | | |
| **0°** | **30°** | **60°** |
| [Company 1] | Non-Subarray | 5% in the whole network |  |  |  |
| Average of all users in the whole network |  |  |  |
| Subarray | 5% in the whole network |  |  |  |
| Average of all users in the whole network |  |  |  |
| [Company 2] | Non-Subarray | 5% in the whole network |  |  |  |
| Average of all users in the whole network |  |  |  |
| Subarray | 5% in the whole network |  |  |  |
| Average of all users in the whole network |  |  |  |

6.4.2.4 Scenario 8: 4GHz TN UL interfering ATG DL

6.4.2.5 Scenario 13: 2GHz ATG UL interfering TN DL

6.4.2.6 Scenario 14: 2GHz TN DL interfering ATG UL

This scenario captures the co-existence results after evaluation from all possible options. Here TN DL with both AAS subarray and non-subarray model is interfering ATG UL deployed in rural macro environment. Plots will be included once the results are captured in the excel sheet from the interested companies.

**Table 6.4.2.6-1: Simulation results for Scenario 13 – 2GHz TN DL interfering ATG UL**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Company** | **ATG/ TN BS antenna model** | **Performance Metric** | **Isolation distance (km) for 5% throughput loss** | | |
| **Angle between ATG BS boresight and nearest TN BS boresight in azimuth** | | |
| **0°** | **30°** | **60°** |
| [Company 1] | Non-Subarray | 5% in the whole network |  |  |  |
| Average of all users in the whole network |  |  |  |
| Subarray | 5% in the whole network |  |  |  |
| Average of all users in the whole network |  |  |  |
| [Company 2] | Non-Subarray | 5% in the whole network |  |  |  |
| Average of all users in the whole network |  |  |  |
| Subarray | 5% in the whole network |  |  |  |
| Average of all users in the whole network |  |  |  |

6.5 Summary of co-existence study

### **6.5.1 Synchronized Scenarios**

This sub-clause captures the summary of the co-existence studies for the synchronized scenarios.

Considering the following ACLR and ACS of TN BS and UE in Table 6.5.1-1, the suggested ACLR and ACS of ATG BS and UE for all scenarios are given in Table 6.5.1-2. It should be noted that the derived values are limited by the nature of assumptions and methodologies adopted in the co-existence studies.

Table 6.5.1-1: ACLR and ACS of TN

|  |  |  |
| --- | --- | --- |
| TN | | Values |
| BS | ACLR | 45 dB |
| ACS | 46 dB |
| UE | ACLR | 30 dB |
| ACS | 33 dB |

**Table 6.5.1-2: Co-existence results suggested ACLR and ACS of ATG system**

|  |  |  |
| --- | --- | --- |
| **ATG** | | **Values** |
| BS | ACLR | 45 dB |
| ACS | 46 dB |
| UE | ACLR | 30 dB |
| ACS | 33 dB |
| NOTE 1: Higher interference maybe caused by aircraft at lower altitudes in the applicable range. | | |



# 7 RF requirements

## 7.1 ATG UE specific

### 7.1.1 ATG UE power class and requirement type

Since the required power level for ATG might be varying in different aircraft types and also in different frequency ranges, it’s quite difficult to focus on one specific power class for ATG UE from 3GPP perspective, therefore 3GPP agreed to introduce the new capability for ATG UE to indicate the rated maximum output power at maximum modulation order and full PRB configurations and its capability report granularity as 1dB. The range of its power limit are defined as following:

- The lower limit of conductive MOP or TRP of ATG UE is 23 dBm

- The upper limit of conductive MOP or TRP of ATG UE is 40 dBm

In addition, considering the implementation freedom for ATG UE(e.g. for 2 GHz, to use omni antenna for ATG UE and for 4 GHz, to use antenna array for ATG UE), therefore 3GPP RAN4 agreed to introduce two ATG UE types to distinguish the antenna types for ATG UE.

### 7.1.2 Tx requirements

#### 7.1.2.1 Frequency error

The doppler frequency for ATG UE can be determined by,

Where,

- fD is Doppler frequency, f\_c is the carrier frequency, which is set as 5GHz for n79.

- v is the speed of the aircraft which is 1200km/h.

- is the elevation angle between UE and gNB.

Since the potential maximum cell range is up to 200-300km [2] and the normal commercial airplane altitude is 10km, the elevation angle is only about 2~3 degrees when UE doing initial access at cell edge. Then the maximum DL doppler frequency is approaching 5.5kHz and the UL doppler frequency compared to the configured UL central frequency is approaching 5.5kHz if without any compensation which may cause not negligible impact for link performance and access successful rate. ATG UE needs to perform frequency compensation. The frequency accuracy requirement will be written assuming Doppler frequency pre-compensation.

The ATG BS location information could be broadcasted for UE to do frequency compensation if necessary. [UE shall rely on the ATG BS location broadcasted by the IE *EphemerisInfo* in NTN SIB 19 in 38.331 if pre-compensation is based on SIB19]. Where, Ephemeris may be expressed in format of position and velocity state vector.

7.1.2.2 MOP requirements

For ATG UE, the maximum output power is declared at maximum modulation order and full PRB configurations within the channel bandwidth of NR carrier unless otherwise stated. The period of measurement shall be at least one sub frame (1ms).

ATG UE implementations/antenna patterns might be varying for different operating bands. The output power from the UE may depend on the aircraft type and exact deployment scenario. Currently, there is a lack of knowledge in 3GPP of the appropriate output power for an ATG UE considering all design, regulatory constraints and potential avionics device protection. For this reason, it is agreed that ATG UE is allowed to declare the output power and signal it to the network. The lower limit of conductive MOP or TRP declared by ATG UE is 23dBm. The upper limit of conductive MOP or TRP declared by ATG UE is 40dBm. The capability report granularity is 1dB.

7.1.2.3 MPR/AMPR requirements

ATG UE is allowed to declare the output power at supported maximum modulation order and full PRB configurations. Thus, MPR/AMPR requirements are not needed as ATG UE can declare a lower power whenever power back-off is needed. Additionally, when ATG UE indicate the maximum output power under the specific conditions (the supported maximum modulation order, full PRB configurations, SEM/spurious emission requirements, regulation requirements and so on), the necessary power back-off should be considered. In total, the power back-off has been included in the declared maximum output power, so there is no need to specify MPR/AMPR requirements for ATG UE.

#### 7.1.2.4 Configured transmitted power

The UE is allowed to set its configured maximum output power PCMAX,f,c for carrier f of serving cell c in each slot. The configured maximum output power PCMAX,f,c is set within the following bounds:

PCMAX\_L,f,c ≤ PCMAX,f,c ≤ PCMAX\_H,f,c with

PCMAX\_L,f,c = MIN {PEMAX,c, [*PMaxOutputPower*]}

PCMAX\_H,f,c = PEMAX,c

where

PEMAX,c is the value given by [either the *p-Max* IE or the field *additionalPmax* of the *NR-NS-PmaxList IE]*, whichever is applicable according to TS 38.331[7];

[*PMaxOutputPower*] is the maximum UE output power at maximum modulation order and full PRB configurations which is indicated by ATG UE;

#### 7.1.2.5 Minimum output power

The calculation and results for minimum output power are listed below.

Table 7.1.2.5-1 the calculation for minimum output power requirements

|  |  |  |
| --- | --- | --- |
| Parameters | Omni-directional antenna | phased array antenna |
| center frequency GHz | 2 | 4 |
| Distance meter | 3000 | 3000 |
| Pathloss dB | 108.063 | 114.0836 |
| ATG BS antenna gain | 21 | 21 |
| ATG UE antenna gain | 0 | 11 |
| Thermal noise power density dBm/MHz | -114 | -114 |
| ATG BS Noise figure dB | 5 | 5 |
| Minimum output power dBm/MHz | -21.937 | -26.9164 |
| Minimum output power dBm/5MHz | -14.9473 | -19.92669996 |

The minimum output power requirements are specified below.

Table 7.1.2.5-2 the calculation for minimum output power requirements

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Channel bandwidth | (MHz) | 5,10,15,20 | 25,30,35,40,45,50 | 60,70,80,90,100 |
| REF\_SCS | (kHz) | 15 | | 30 |
| Minimum output power | (dBm) | X | X+10log10 (BWChannel /20) | X+10log10 (BWChannel /20) |
| Measurement bandwidth | (MHz) | MBW=REF\_SCS\*(12\*NRB+1)/1000 | | |
| NOTE 1: The minimum output power value is rounded to the nearest number down to one decimal point.  NOTE 2: X = -15 for the ATG UE with omni-direction antenna. X = -19 for the ATG UE with phased array antenna. | | | | |

7.1.2.6 Transmit OFF power

The current requirements for Transmit OFF power specified in clause 6.3.2 of TS 38.101-1 are applicable to ATG UE, i.e. -50dBm.

7.1.2.7 Transmit ON/OFF time mask

The current requirements for Transmit ON/OFF time mask specified in clause 6.3.3 of TS 38.101-1 are applicable to ATG UE.

7.1.2.8 Power control

The current requirements for power control specified in clause 6.3.4 of TS 38.101-1 are applicable to ATG UE.

7.1.2.9 Transmit signal quality

Transmit signal quality include frequency error and transmit modulation quality.

For frequency error, frequency pre-compensation is assumed for ATG UE. The existing requirement defined for NTN UE in TS 38.101-5 [7] will be reused as baseline.

Regarding modulation scheme, QPSK/16QAM/64QAM will be supported as mandatory. For 256QAM, there are some challenges for ATG due to large propagation distance. While according to the evaluation for 2GHz and 4GHz in [6], the SNR above 25dB can still be seen in the considered scenarios for both UL and DL. UL 256QAM is supported for ATG UE as optional feature.

Figure 7.1.2.9-1

Figure 7.1.2.9-2

For transmit modulation quality, the following requirement for FR1 UE in 38.101-1 [4] will be reused for ATG UE.

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Unit** | **Average EVM Level** |
| QPSK | % | 17.5 |
| 16 QAM | % | 12.5 |
| 64 QAM | % | 8 |
| 256 QAM | % | 3.5 |

7.1.2.10 Occupied bandwidth

The Occupied bandwidth requirement in subclause 6.5.1 of 38.101-1 [4] is applicable for ATG UE operating in FR1.

7.1.2.11 SEM requirements

TBA

7.1.2.12 ACLR requirements

FR1 PC3 ACLR requirement in 38.101-1 is reused for ATG CPE.

7.1.2.13 Spurious emission

The general spurious emission requirement in subclause 6.5.3.1 of 38.101-1 [4] is applicable for ATG UE operating in FR1.

7.1.2.14 Spurious emissions for UE co-existence

Given the separation distance between ATG UE and TN UE is quite large, it is expected that the achievable MCL can be large enough to overcome the UE-UE interference. This requirement will not be specified for ATG UE.

7.1.2.15 Transmit intermodulation

TBA

### 7.1.3 Rx requirements

7.1.3.1 General

Unless otherwise stated the receiver characteristics are specified at the antenna connector(s) of the ATG UE. For CPE(s) with an integral antenna only, a reference antenna(s) with a gain of 0 dBi is assumed for each antenna port(s). CPE with an integral antenna(s) may be taken into account by converting these power levels into field strength requirements, assuming a 0 dBi gain antenna. For CPEs with more than one receiver antenna connector, identical interfering signals shall be applied to each receiver antenna port if more than one of these is used (diversity).

7.1.3.2 Diversity characteristics

The CPE for ATG is required to be equipped with a minimum of two Rx antenna ports in all the ATG operating bands in FR1.

7.1.3.3 REFSENS requirements

The reference sensitivity power level REFSENS is the minimum mean power applied to each one of the CPE antenna ports, at which the throughput shall meet or exceed the requirements for the specified reference measurement channel.

The same assumptions of NR FR1 handheld UE are used for NR ATG CEP in ATG operating bands in FR1. Therefore, the reference sensitivity of NR FR1 handheld UE could be reused for ATG UE.

The throughput shall be ≥ 95 % of the maximum throughput of the reference measurement channels as specified in Annexes A.2.2.2 and A.3.2 from TS 38.101-1 [4] (with one sided dynamic OCNG Pattern OP.1 FDD for the DL-signal as described in Annex A.5.1.1 from TS 38.101-1 [4]) with parameters specified in Table 7.1.3.2.2-1, Table 7.1.3.2.2-2 and Table 7.1.3.2.2-3

**Table 7.1.3.2.2-1: Two antenna port reference sensitivity QPSK REFSENS for FDD bands**

| **Operating band / SCS / Channel bandwidth** | | | | | |
| --- | --- | --- | --- | --- | --- |
| **Operating Band** | **SCS kHz** | **5**  **MHz (dBm)** | **10**  **MHz (dBm)** | **15**  **MHz (dBm)** | **20**  **MHz (dBm)** |
| n1 | 15 | -100.0 | -96.8 | -95.0 | -93.8 |
| 30 |  | -97.1 | -95.1 | -94.0 |
| 60 |  | -97.5 | -95.4 | -94.2 |

**Table 7.1.3.2.2-2: Two antenna port reference sensitivity QPSK REFSENS for TDD bands**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Operating band / SCS / Channel bandwidth / REFSENS** | | | | |
| **Operating band** | **SCS**  **kHz** | **Channel bandwidth (MHz)** | **REFSENS (dBm)** | **Duplex Mode** |
| n39 | 15 | 5, 10, 15, 20, 25, 30, 40 | -100 + 10log10(NRB/25) | TDD |
| 30 | 10, 15, 20, 25, 30, 40 | -97.1 + 10log10(NRB/24) |
| 60 | 10, 15, 20, 25, 30, 40 | -97.5 + 10log10(NRB/11) |
| n78 | 15 | 10, 15, 20, 25, 30, 40, 50 | -95.8 + 10log10(NRB/52) | TDD |
| 30 | 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100 | -96.1 + 10log10(NRB/24) |
| 60 | 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100 | -96.5 + 10log10(NRB/11) |
| n79 | 15 | 10, 20, 30, 40, 50 | -95.8 + 10log10(NRB/52) | TDD |
| 30 | 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 | -96.1 + 10log10(NRB/24) |
| 60 | 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 | -96.5 + 10log10(NRB/11) |

For UE(s) equipped with 4 Rx antenna ports, reference sensitivity for 2Rx antenna ports in Table 7.3.2-1a and in Table 7.3.2-1b shall be modified by the amount given in ΔRIB,4R in Table 7.3.2-2 for the applicable operating bands.

**Table 7.3.2-2: Four antenna port reference sensitivity allowance ΔRIB,4R**

|  |  |
| --- | --- |
| **Operating band** | **ΔRIB,4R (dB)** |
| n1, n39 | -2.7 |
| n78, n79 | -2.2 |

**Table 7.1.3.2.2-3: Uplink configuration for reference sensitivity**

| **Operating band / SCS (kHz) / Channel bandwidth (MHz) / Duplex mode** | | | | | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Operating Band** | **SCS** | **5** | **10** | **15** | **20** | **25** | **30** | **35** | **40** | **45** | **50** | **60** | **70** | **80** | **90** | **100** | **Duplex Mode** |
| n1 | 15 | 25 | 501 | 751 | 1001 | 1281 | 1281 |  | 1281 | 1281 | 1281 |  |  |  |  |  | FDD |
| 30 |  | 24 | 361 | 501 | 641 | 641 |  | 641 | 641 | 641 |  |  |  |  |  |
| 60 |  | 101 | 18 | 24 | 301 | 301 |  | 301 | 301 | 301 |  |  |  |  |  |
| n39 | 15 | 25 | 50 | 75 | 100 | 128 | 160 |  | 216 |  |  |  |  |  |  |  | TDD |
| 30 |  | 24 | 36 | 50 | 64 | 75 |  | 100 |  |  |  |  |  |  |  |
| 60 |  | 10 | 18 | 24 | 30 | 36 |  | 50 |  |  |  |  |  |  |  |
| n78 | 15 |  | 50 | 75 | 100 | 128 | 160 |  | 216 |  | 270 |  |  |  |  |  | TDD |
| 30 |  | 24 | 36 | 50 | 64 | 75 |  | 100 |  | 128 | 162 | 180 | 216 | 243 | 270 |
| 60 |  | 10 | 18 | 24 | 30 | 36 |  | 50 |  | 64 | 75 | 90 | 100 | 120 | 135 |
| n79 | 15 |  | 50 |  | 100 |  | 160 |  | 216 |  | 270 |  |  |  |  |  | TDD |
| 30 |  | 24 |  | 50 |  | 75 |  | 100 |  | 128 | 162 | 180 | 216 | 243 | 270 |
| 60 |  | 10 |  | 24 |  | 36 |  | 50 |  | 64 | 75 | 90 | 100 | 120 | 135 |

#### 7.1.3.4 Maximum input level

#### 7.1.3.5 Adjacent channel selectivity

For ACS, the coexistence studies outcome shows that the legacy ACS values as for NR FR1 UE are appropriate, and therefore reused.

The legacy ACS test parameters in case 1 is applied for ATG UE. ACS requirements in case 2 shall be specified based on the maximum input level of xdBm.

#### 7.1.3.6 In-band blocking requirements

Blocking due to TN interference

Compared to terrestrial UE, ATG UEs are distant from base stations, experiencing LoS path loss from the TN BS that is not directly pointed at them. ATG UE at 2 GHz with omnidirectional antennas, may receive power from multiple TN BSs. Even at 4 GHz, an ATG UE pointing downwards may still receive Rx power from the ground TN BS.

To evaluate the TN’s blocking power, simulations are conducted based on Scenario 3 and 11 (TN aggressor DL to ATG DL) and analyze the CDF of the absolute Rx power received by the ATG UE from the TN. The simulation is based on the following deployment scenarios: the ATG BS is located 300 km away from the center of the TN cluster and the ATG UEs x-coordinate is uniformly distributed over the horizontal extent of the TN cluster. The TN BSs utilize non-co-located 8-column non-subarray antennas. A single 5 dBi gain element has been used at the ATG UE at 4 GHz while an isotropic radiator is used at 2 GHz.

At a CDF of 99.999%, the simulation shows that the Rx power for a uniform distribution of ATG UEs’ altitude between 3 km and 10 km is -52 dBm and -56 dBm for 2 GHz and 4 GHz, respectively. For a fixed 10 km case, the Rx power is quite similar. A 6 dB difference can be observed in the fixed 3 km case, which is an unlikely scenario. Strictly following the simulation suggests -52 dBm in-band blocking, but it is essential to note that this relies on a 99.999% CDF. Lowering CDF to 99.99% is expected to yield lower interference at least several dB lower.

Therefore, it is suggested to reuse the in-band blocking requirements in TS 38.101-1 for ATG UE.



Figure 7.1.3.6-1 Simulation results of ACI blocking for scenario 3.



Figure 7.1.3.6-2 Simulation results of ACI blocking for scenario 11.

Blocking due to interference from another ATG network

The co-existence simulations do not consider ATG-ATG co-existence. In the case of in-band blocking, the involvement of neighboring operators operating ATG could be significant. The most severe situation arises when co-located ATG BS direct their beams toward aircraft that are relatively close to each other and the BS. In such a case, the victim ATG UE could still be in the vicinity of the beam of the aggressor BS. Two scenarios are illustrated in 7.1.3.6-3, scenario 1 with two adjacent aircrafts separated vertically by 300 m and scenario 2 with a 9.26 km horizontal separation.

Graphical user interface, chart, line chart

Description automatically generated

Figure 7.1.3.6-3 Two scenarios when co-located BS pointing towards different aircraft that are relatively close.

Considering the FAA regulations mandating minimum aircraft separations of 300 m (1000 ft) vertically or 9.26 km (5 NM) horizontally in en-route airspace, one can estimate the angular separation. The victim aircraft could fall within the main lobe or the edge of the beam lobe towards the aggressor aircraft. Assuming 20 km distance from the ATG BS to the victim aircraft at a 10 km flight level, the angle separation is less than 1 deg in Scenario 1 and 15.4 deg in Scenario 2.

In Scenario 1, the victim UE falls into the main lobe of the aggressor beam. Determining the EIRP of the victim involves utilizing the ATG BS output power from simulation parameters and accounting for free space path loss. For an ATG UE operating at 2 GHz, the EIRP is calculated to be - 72 dBm, significantly lower than the blocking caused by TN interference. Furthermore, the 300 m vertical separation is an absolute minimum distance and is very unlikely to occur during normal cruising in the same direction.

Thus, it is not necessary to consider blocking from other ATG networks when assessing the in-band blocking requirement.

#### 7.1.3.7 Out-of-Band blocking requirements/ Spurious response

Referring to the ITU-R M.2059-0 [8], Tables 1 and 2 of ITU-R M.2059-0 provide technical characteristics for representative analogue and digital FMCW radio altimeters. In 3GPP, the ATG UE OOB specification is defined to ensure the telecommunication link and there may be other sources of interference and regulatory issues that need to be considered when designing ATG UE, i.e. avionic equipment.

Thus, the existing out-of-band blocking requirements and spurious response requirement (-44dBm) in TS 38.101-1 are used for ATG UE.

#### 7.1.3.8 Narrow band blocking requirements

It was agreed not to specify narrow band blocking requirements for ATG UE.

#### 7.1.3.9 Intermodulation characteristics

#### 7.1.3.10 Receiver Spurious emissions

As this is regulatory requirements and referring to the ERC Recommendation 74-01 Annex 3 [3], the spurious emissions limits specified in sub-clause of TS 38.101-1[4] would also be applicable to ATG UE.

## 7.2 ATG BS specific

For most of the requirements, it was generally agreed to aim to reuse the existing TN BS requirements for ATG BS wherever possible since the TN BS requirements would provide the same or better BS performance for an ATG BS deployment. The following section will capture the considerations of ATG BS RF requirements.

### 7.2.1 ATG BS class and BS type

This WI study focus on FR1 bands only. After some discussion, the three BS FR1 types are specified for ATG BS, i.e. ATG BS type type1-C, 1-H and 1-O are defined.

For the ATG BS class, the deployment scenarios were discussed. ATG BSs are supposed to be deployed on the ground to serve ATG UEs (CPE type of UE mounted in the aircraft) in the air. The flight altitude of ATG UE is supposed to turn on is assumed from 3~10km based on the regulatory input and coexistence study. The distance between aircraft and the nearest ATG BS in azimuth angle could be more than 200km and even up to 300km. So the scenario for ATG is different from existing scenarios for TN BS and scenario for HAPS. Separate BS classes for ATG need to be defined.

For ATG BS type type1-C, 1-H and 1-O, ATG BS class is defined as below:

ATG Base Stations are characterized by requirements derived from ATG scenarios with a ground BS to air UE with typical vertical altitude of around 10,000m and take-off/landing altitudes down to 3000m.

Generally most of the WA BS class requirements can be reused by ATG BS. Some exceptions were found in the WI study, for example TAE requirement. The detail requirements study and conclusion are captured in the corresponding sections.

### 7.2.2 Tx requirements

7.2.2.1 ATG Base station power

**Base station output power**

Considering the large coverage requirements of ATG system, only wide area BS is proper for ATG BS type 1-C, type 1-H and type 1-O. Similar to NR Wide area BS, there is no upper limit for the rated carrier output power, maximum output power should be left up to the declaration. The existing requirement defined in TS 38.104 [5] can be reused.

**RE power control dynamic range**

The RE power control dynamic range is the difference between the power of an RE and the average RE power for a BS at maximum output power for a specified reference condition.

The RE power control dynamic range was derived by considering the relation between RE power boosting/de-boosting and other RF requirements like UEM, ACLR and EVM. For ATG BS, since the same waveform as NR is used, the existing requirement defined in TS 38.104 [5] can be applicable.

**Total power dynamic range**

The BS total power dynamic range is the difference between the maximum and the minimum transmit power of an OFDM symbol for a specified reference condition. It can be calculated by 10log10 (NRB). The Total power dynamic range for ATG BS can reuse the requirement from TN BS in 3GPP TS 38.104 [5] for the same channel bandwidth.

7.2.2.2 Transmitted signal quality

**Frequency error**

Frequency error mainly depends on the timing and synchronization performance and PLL performance within transceiver chain. ATG system is expected to use the existing timing and synchronization network directly. Meanwhile, similar PLL performance of ATG BS as NR BS is also expected as they are operating at the same frequency range. With the above considerations, frequency error requirement of NR can be reused for ATG BS.

Considering the 0.05ppm BS frequency error, for 2100 MHz, it is 105 Hz. For ATG system, UE velocity can be reach up 900-1200km/h at cruising speed, it can be seen that the more serious frequency offset is caused by the Doppler effect. The 0.05 ppm frequency offset has little impact on the system performance.

**Time alignment error**

For a specific set of NR signals/transmitter configurations/transmission modes, the conducted Time Alignment Error (TAE) is defined as the largest allowed timing difference (i.e. error) between two different reference signals belonging to different antenna connectors (for 1-C type NR BS), or *TAB connectors* (for 1-H type NR BS).

TAE is only applicable for NR BS transmitting from multiple antennas via MIMO, CA, or combination of them.

However, in ATG system, BS transmits signals from the ground to the air. Generally, these are only the main path signals, and few multipath signals. Thus, it’s unnecessary to specify the MIMO TAE requirements for ATG BS. In addition, CA is not supported for ATG in Rel-18. As a result, no TAE requirements need to be developed for ATG BS.

**Modulation quality**

It is agreed to specify QPSK, 16QAM, 64QAM and 256QAM for ATG, for the supported modulation order is up to the vendor’s declaration.

For ATG BS, the EVM value of each carrier for different modulation schemes on PDSCH in TS 38.104 [5] shall be met.

7.2.2.3 Unwanted emission requirements

**Occupied bandwidth**

The occupied bandwidth is the width of a frequency band such that, below the lower and above the upper frequency limits, the mean powers emitted are each equal to a specified percentage /2 (=0.5%) of the total mean transmitted power. For ATG BS, it is agreed to reuse the same requirement defined in TS38.104 [5] which is following Recommendation ITU-R SM.328.

**Adjacent Channel Leakage Power Ratio (ACLR)**

Based on the coexistence simulation results, it is sufficient to reuse the legacy FR1 ACLR 45dBc requirement for ATG BS..

**Operating band unwanted emissions**

ATG BS can follow Wide Area BS, that the UEM level in the spurious domain is aligned with ITU-R recommendation SM.329.

#### 7.2.2.4 Transmitter spurious emissions

Since transmitter spurious emissions for TN BS should meet the requirements of ITU-R SM329, CEPT, and FCC etc., the spurious emission requirement defined in TS 38.104 [5] for TN BS is sufficient for ATG.

The same spurious emission requirement defined in TS 38.104 [5] for TN BS can be reused.

#### 7.2.2.5 Transmitter intermodulation

In the standard discussion, it's supposed that there’s no surrounding interfering BS with same bands existing for ATG BS. But some other scenarios were identified, for example, interfering signals from other bands or other asynchronous BS, also temporary interferers could occur close to the ATG BS. Therefore, it was agreed that it is important to verify that the ATG BS will still meet all emissions requirements, including regulatory requirements robustly.

It was agreed that the Tx IM requirement in TS 38.104 [5] can be reused to guarantee the performance of the ATG BS.

### 7.2.3 Rx requirements

7.2.3.1 Reference sensitivity level

For reference sensitivity level because it is expected that the BS technology will be the same and hence the noise factor the same. The existing requirements specified in clause 7.2 of TS 38.104[5] can be reused for ATG BS type1-C, 1-H, and clause 10.3 of TS 38.104[5] can be reused for ATG BS type1-O.

7.2.3.2 Dynamic range

For dynamic range because it is based on assumptions on the maximum interference level around the BS. Detailed investigation has not been made, but since the main difference between an ATG BS and TN BS is the tilt, it is not expected to be greater and may be expected sometimes to be similar to a TN BS. The existing requirements specified in clause 7.3 of TS 38.104[5] can be reused for ATG BS type1-C, 1-H, and clause 10.4 of TS 38.104[5] can be reused for ATG BS type1-O.

7.2.3.3 ACS

The co-existence simulations demonstrate that if 46dBc ACS is applied for BS in ATG scenarios then the cross operator interference is acceptable (<5% degradation) in all scenarios. It is desirable to apply the same ACS as TN BS to maximize compatibility with BS hardware platforms. Thus, based on the simulation results, the ATG adjacent channel selectivity (ACS) reuse the existing FR1 ACS (i.e. 46dBc) requirement applied for TN BS. The existing requirements specified in clause 7.4 of TS 38.104[5] can be reused for ATG BS type1-C, 1-H, and clause 10.5 of TS 38.104[5] can be reused for ATG BS type1-O.

7.2.3.4 In-band blocking

Since ATG BS is supposed to steer its beam up towards to provide the service for ATG UE in the air, the received power level of in-band blocking would be also lower than that for the legacy TN BS with beam steering down towards to provide the service on the ground. In addition, considering that it’s agreed to reuse the FR1 BS ACS requirement [46dBc] for ATG BS, therefore it is also reasonable to reuse the in-band blocking requirement for FR1 WA BS for ATG BS.

7.2.3.5 Receiver intermodulation

Regarding the Rx intermodulation, although it is not likely to have the coexistence scenario in which ATG BS is subject to intermodulation interferers with the power levels defined in FR1 WA Rx intermodulation requirement, Rx intermodulation still dimension some aspects of receiver design (e.g. receiver linearity to minimize the interfering signal intermodulation fall into the wanted signal). Therefore, it’ s still useful to keep the receiver intermodulation requirements and it is agreed to reuse the Rx IM requirement for FR1 WA BS for ATG BS.

7.2.3.6 Out of band blocking

Since ATG BS is supposed to steer its beam up towards to provide the service for ATG UE in the air, the received OOBB power level would be also lower than that for the legacy TN BS with beam steering down towards to provide the service on the ground, then it’s sufficient to reuse the existing OOBB requirement defined for Wide Area BS in TS38.104.

7.2.3.7 In-channel selectivity

Since the IoT level of ATG BS is supposed to quite low compared with IoT level of the legacy TN BS. In addition, considering that noise figure for WA BS and FRC could be reused for ATG BS, then it’s sufficient to reuse the existing requirement for Wide Area BS defined in TS 38.104.

# 8 RRM requirements

8.1 General

In R18, the WI on ATG doesn’t consider FR2, CA/DC and inter-RAT measurement scenario, the corresponding requirements are not applicable for R18 ATG. In light of ATG characteristics (e.g. ISD assumption of [14]-200km, maximum UE speed of 1200km/h, maximum distance between UE and BS is greater than [200]km), some RRM requirements are different from legacy ground-based network requirements, as listed in table 8-1.

<Editor’s Note: In table 8-1, the RRM requirements with square brackets are still under discussion, which may be updated according to the latest agreements. >

**Table 8-1: RRM requirements for R18 ATG which are different from legacy ground-based network requirements**

|  |  |  |
| --- | --- | --- |
| Requirement | Item | Comments |
| Cell re-selection |  |  |
| Cell re-selection measurement requirements for intra-frequency measurement | Introduce scaling factor N for L3 measurements for ATG UEs with [antenna arrays]   * N = 3 for the case when network assistance on ATG cells reference locations is provided * N = 4 otherwise |
| Cell re-selection measurement requirements for inter-frequency measurement | Define two set of cell detection requirements for ATG   * Set 1: legacy R15 cell-reselection requirement * Set 2: R17 HST cell-reselection requirement |
| Conditional handover | Conditional handover mechanism | Introduce location-based CHO for ATG, reusing the procedure in R17 NTN for R18 ATG |
| UE transmit timing | Initial transmit timing requirements Te | Involve UE pre-compensation timing error, GNSS error=40m is assumed |
| Timing advance adjustment delay requirement | Introduce the mechanism of Koffset |
| Signalling characteristics | Radio link monitoring | Introduce the sharing factor for ATG UEs with [antenna arrays] |
| Link recovery procedures | Introduce the sharing factor for ATG UEs with [antenna arrays] |
| Measurement procedure and requirements | NR intra-frequency measurements | For ATG TDD deployment, ‘deriveSSB-IndexFromCell’ is not always applicable for NR intra-frequency measurement.  For intra-frequency measurements without gap, Introduce scaling factor N for L3 measurements for ATG UEs with [antenna arrays]   * N = 3 for the case when network assistance on ATG cells reference locations is provided * N = 4 otherwise   Introduce the sharing factor for ATG UEs with [antenna arrays] |
| Inter-frequency measurements without measurement gap | Introduce scaling factor N for L3 measurements for ATG UEs with [antenna arrays]   * N = 3 for the case when network assistance on ATG cells reference locations is provided * N = 4 otherwise   Introduce the sharing factor for ATG UEs with [antenna arrays] |
| CSI-RS based intra-frequency measurements | For ATG TDD deployment, ‘deriveSSB-IndexFromCell’ is not always applicable for CSI-RS based intra-frequency measurement.  For intra-frequency measurements without gap, Introduce scaling factor N for L3 measurements for ATG UEs with [antenna arrays]   * N = 3 for the case when network assistance on ATG cells reference locations is provided * N = 4 otherwise   Introduce the sharing factor for ATG UEs with [antenna arrays] |
| L1-RSRP/SINR measurements for Reporting | Introduce the sharing factor for ATG UEs with [antenna arrays] |
| Scheduling restrictions of UE performing measurements | Introduce additional scheduling restriction for ATG UEs with [antenna arrays] |

For other RRM requirements, no new ATG specific requirements will be defined in R18.

*<Other text to be added>*

# 9 Conclusion

<Text to be added>

# 10 Required changes to NR, E-UTRA, UTRA and MSR specifications

The required changes to the 3GPP specifications for the ATG are summarised in a Table 10-1.

Table 10-1: Overview of 3GPP specifications with required changes

|  |  |  |  |
| --- | --- | --- | --- |
| Affected existing specifications | | | |
| Spec No. | Subject of the CR | Comments | CR/TP (Tdoc) |
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# Annex A: Calibration results of ATG components

## A.1 Calibration assumptions

The calibration assumptions is the same as listed in clause 6.2 and 6.3.

## A.2 Calibration results at 2GHz and 4GHz

Following show explanation for two SINR tables in calibration excel file. These two new SINR tables are only for calibration purpose. Besides, they are not mandatory to submit.

* Table 2: SINR CDF with adjacent channel interference from synchronization intra-system. Here the SINR=S/(N+IICI +IACI).
  + For TN, IACI is from synchronized TN network using adjacent channel
  + For ATG, due to we only consider one ATG BS and UE, IACI and IICI are both 0
* Table 3: SINR CDF with adjacent channel interference from synchronization inter-system. Here the SINR=S/(N+IICI +IACI).
  + For TN, IACI is from synchronized ATG network using adjacent channel
  + For ATG, IACI is from synchronized TN network using adjacent channel and IICI is 0

The below linked sheet captures the data of calibration co-existence simulation study for all synchronized scenarios. More details on the assumptions can be found in the Cover page of the sheet.



# Annex B: Calibration results of TN components

## B.1 Calibration assumptions

The calibration assumptions is the same as listed in clause 6.2 and 6.3.

## B.2 Calibration results at 2GHz and 4GHz

Following show explanation for two SINR tables in calibration excel file. These two new SINR tables are only for calibration purpose. Besides, they are not mandatory to submit.

* Table 2: SINR CDF with adjacent channel interference from synchronization intra-system. Here the SINR=S/(N+IICI +IACI).
  + For TN, IACI is from synchronized TN network using adjacent channel
  + For ATG, due to we only consider one ATG BS and UE, IACI and IICI are both 0
* Table 3: SINR CDF with adjacent channel interference from synchronization inter-system. Here the SINR=S/(N+IICI +IACI).
  + For TN, IACI is from synchronized ATG network using adjacent channel
  + For ATG, IACI is from synchronized TN network using adjacent channel and IICI is 0

The below linked sheet captures the data of calibration co-existence simulation study for all synchronized scenarios. More details on the assumptions can be found in the Cover page of the sheet.



# Annex C: Co-existence scenarios simulation data

## C.1 Synchronized scenarios

The below linked sheet captures the data of co-existence simulation study for all synchronized scenarios. More details on the assumptions can be found in the Cover page of the sheet.



## C.2 Non-Synchronized scenarios

(To be added later)

# Annex D: Supplementary simulation results for co-existence synchronized scenarios

This section comprises the additional simulation results captured during the early discussions for extra robustness of the ATG system. The simulation parameters are changed to check the influence on the simulation results.

## D.1 Synchronized scenarios

### D.1.1 Impact of the number of TN BS columns

To protect the legacy deployments, it is important to highlight that 8-column AAS may not be satisfactory for all deployments in 2 GHz. With this consideration, this subsection points out the impact of the number of antenna columns in the TN BSs for 2 GHz carrier frequency. The results captured are for scenarios 9-12, where one and eight antenna columns at the TN are assumed using both sub-array and non-subarray configurations.

The linked excel sheet  provides detailed plots for the Scenarios 9-12.

Highlight:

The number of TN BS columns study adopts the acceptable ACLR/ ACS values for all the scenarios. The 8-column cases seem to be the worst ones. The simulations results show varied degradation in some cases, but the variations don’t make a large difference from the agreed requirements. Overall, the one and eight column antennas still follow the acceptable ACLR/ ACS requirements.

### D.1.2 Impact of ATG UE antenna type

This subsection points out the impact of the number of antenna array at the ATG UEs for 4 GHz frequency. The results captured are for scenarios 1-4, where 16x1 and 8x2 antenna array are compared.

The linked excel sheet provides detailed plots for the Scenarios 1-4.

Highlight:

The ATG UE antenna type study adopts the acceptable ACLR/ ACS values for all the scenarios The 16x1 and 8x2 antenna array options have minimal differences in Scenarios 1,2 and 4 for 4 GHz frequency. However, in Scenario 3, 16x1 antenna array seems to be the worst case for 5% throughput loss level. Though the differences are not that significant that would impact any of the acceptable ACLR/ ACS requirements as per the agreements.

Figure D.1.2-1: Simulation results for Throughput Loss - 5% of users in the whole network

### D.1.3 Impact of ATG-TN BS antennas collocation

This subsection points out the impact of the TN and ATG BS collocation to identify the worst cases. The collocated deployments are the ones in which the ATG BS is located inside the TN cluster and the horizontal distance between ATG BS and ATG UE is in the range of [20, 100] km. Similarly, the non-collocated deployments are the ones in which the ATG BS is located 300 km away from the center of the TN cluster and ATG UEs x-coordinate is uniformly distributed over the horizontal extent of the TN cluster.

The linked excel sheet  provides detailed plots for the Scenarios 2,3,10 and 11.

Highlight:

The ATG-TN BS collocation study adopts the acceptable ACLR/ ACS values with the non-collocated deployment option as the worst case for most of the scenarios. In scenarios where it is observed the other way round, the differences are not that significant that would impact any of the acceptable ACLR/ ACS requirements as per the agreements.

### D.1.4 Impact of ATG UE height distribution

This subsection points out the impact of the ATG UE height distribution. The results shown are for cases when ATG UEs are uniformly distributed between 3 and 10 km heights, all ATG UEs have a fixed height of 3 km and all ATG UEs have a fixed height of 10 km.

The linked excel sheet  provides detailed plots for the Scenarios 1-4 and 9-12.

Highlight:

The ATG height distribution studied adopts the acceptable ATG ACLR/ ACS requirements in most of the scenarios. However, in scenarios 3 and 11 (as shown below), 3 km is the worst case, and the ATG UE ACS level is way above the accepted level of 33 dB.

Figure D.1.4-1: Simulation results for Throughput Loss - 5% of users in the whole network

Figure D.1.4-2: Simulation results for Throughput Loss - 5% of users in the whole network

It is possible that ATG UE suffers degradation during take-off and landing i.e., at 3 km. A certain throughput loss higher than 5% maybe be acceptable, as far as the ATG network doesn’t break off when ATG UEs are at a height of 3 km.

## D.2 Non-Synchronized scenarios

(To be added later)

# Annex E: Change history

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |
| **Date** | **TSG #** | **TSG Doc.** | **CR** | **Rev** | **Subject/Comment** | **Old** | **New** |
| 08/2022 | RAN4#104-e | R4-2214912 |  |  | TR skeleton | N/A | 0.0.1 |
| 11/2022 | RAN4#105 | R4-2218030 |  |  | R4-2215335 TP for ATG TR 38.876 skeleton  R4-2217504 TP for TR 38.876 | 0.0.1 | 0.1.0 |
| 02/2023 | RAN4#106 | R4-2301861 |  |  | R4-2220826 TP for TR 38.876: frequency error  R4-2220539 TP for TR 38.876 to capture general assumptions  R4-2220540 TP for TR 38.876 to capture scenarios and network layout  R4-2220541 TP for TR 38.876 to capture system parameter assumption and antenna modelling | 0.1.0 | 0.2.0 |
| 04/2023 | RAN4#106bis | R4-2303640 |  |  | R4-2302096 TP for TR 38.876 to add some coexistence assumption and methodology  R4-2303641 TP for TR 38.876 to capture system parameter assumption  R4-2303642 TP to TR 38.876: Update of simulation assumptions  R4-2303643 TP for TR 38.876 to introduce ATG UE Tx requirements  R4-2303644 TP for TR 38.876 to introduce technical analysis for ATG UE Rx requirements.  R4-2303227 TP to TR 38.876: RRM requirements for ATG network  R4-2302905 TP for TR 38.876 on BS RF requirements | 0.2.0 | 0.3.0 |
| 05/2023 | RAN4#107 | R4-2309106 |  |  | R4-2310402 TP for TR 38.876 to add Annex, CMCC  R4-2310494 TP to TR 38.876: Skeleton for Co-existence simulation results, Ericsson  R4-2310404 TP for TS 38.876: Clause 6.1~6.3, ZTE Corporation  R4-2310405 TP for TR38.876:clause 7.1 and 7.1.1, ZTE Corporation  R4-2310406 TP for TR 38.876 to introduce ATG UE Tx requirements part 1, Huawei, HiSilicon  R4-2309169 TP for TR38.876 :clause 7.2.3.4~7.2.3.7, ZTE Corporation  R4-2309761 TP for TR 38.876 to introduce ATG BS Rx requirements, CMCC  R4-2310056 TP to TR 38.876 RRM requirements for ATG network, CMCC | 0.3.0 | 0.4.0 |
| 08/2023 | RAN4#108 | R4-2312291 |  |  | R4-2311266, TP to TR 38.876: Addition of Co-existence simulation results for Synchronized Scenarios, Ericsson  R4-2311458, TP for TR 38.876 on BS RF requirements, Huawei, HiSilicon  R4-2313501, TP for TR 38.876: General aspects, Apple  R4-2313502, TP for TR 38.876: ATG UE Tx requirement, Apple  R4-2314451, TP to TR 38.876: RRM requirements for ATG network, CMCC  R4-2314758, TP to TR 38.876: Extra results of co-existence synchronized scenarios in Annexure, Ericsson  R4-2314760, TP for TR 38.876 to introduce ATG UE Tx requirements part 1, Huawei, HiSilicon | 0.4.0 | 0.5.0 |
| 10/2023 | RAN4#108bis | R4-2315904 |  |  | R4-2317745, TP for TR 38.876 to introduce minimum output power requirements for ATG UE, Huawei, HiSilicon  R4-2317746 TP for TR 38.876 to introduce some consideration for OOBB requirements, Huawei, HiSilicon  R4-2315197, TP for ATG TR annex calibration part, CMCC  R4-2315443 TP for TR 38.876 Addition of Summary for synchronized scenarios simulation results, Ericsson  R4-2316518 TP to TR 38.876 In-band blocking, Ericsson  R4-2316719, TP on TR 38.876 for ATG UE Rx requirements – Part 1, Qualcomm Incorporated  R4-2317741, TP for TR 38876 - section 1 to section 6, CMCC | 0.5.0 | 0.6.0 |