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Technical Report

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Study on Air-to-ground network for NR

(Release 18)

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# Foreword

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

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x the first digit:

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y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

# 1 Scope

The present document covers the RF 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”.

…

[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].

*Definition format (Normal)*

***<defined term>:*** *<definition>.*

**example:** text used to clarify abstract rules by applying them literally.

## 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].

*Abbreviation format (EW)*

<ACRONYM> <Explanation>

# 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 and band properties to be identified. Depending on the operator’s request, the following NR bands are intended for ATG deployment:

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 baselin. 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 | 3.5 GHz |  | Phase 1 |
| 2 | TN with ATG | ATG UL | 100MHz  TDD | TN rural UL | 100MHz  TDD | 3.5GHz |  | Phase 1 |
| 3 | TN with ATG | TN rural DL | 100MHz  TDD | ATG DL | 100MHz  TDD | 3.5GHz |  | Phase 1 |
| 4 | TN with ATG | TN rural UL | 100MHz  TDD | ATG UL | 100MHz  TDD | 3.5GHz |  | Phase 1 |
| 5 | TN with ATG | ATG DL | 100MHz  TDD | TN rural UL | 100MHz  /TDD | 3.5GHz |  | FFS |
| 6 | TN with ATG | ATG UL | 100MHz  TDD | TN rural DL | 100MHz  TDD | 3.5GHz |  | FFS |
| 7 | TN with ATG | TN rural DL | 100MHz  TDD | ATG UL | 100MHz  TDD | 3.5GHz |  | FFS |
| 8 | TN with ATG | TN rural UL | 100MHz  TDD | ATG DL | 100MHz  TDD | 3.5GHz |  | FFS |
| 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 | FFS |
| 14 | TN with ATG | TN rural DL | 20MHz TDD | ATG UL | 20MHz FDD | 2 GHz | n39/n1 | FFS |

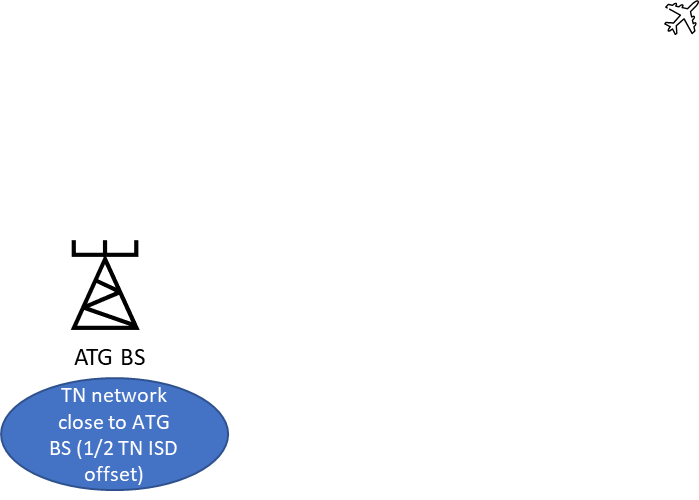
## 6.2 Co-existence simulation assumption

### 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 ATG coexistence study**

|  |  |  |
| --- | --- | --- |
| **Parameters** | | **Values** |
| Network layout | | 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 |
| Inter-site distance | | 7.5 km (4GHz)  3.5 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 |

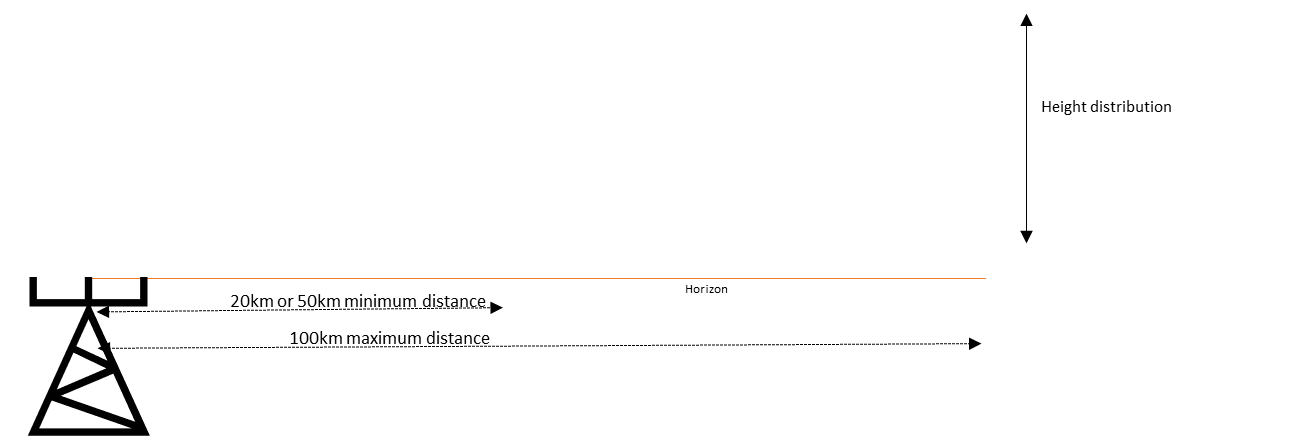
6.2.1.3 ATG Network Layout

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.

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) (Note 2) | 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)  (Note 4) | 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) (Note 2) | 2 |
| Conducted power (before Ohmic loss) per antenna element (dBm) (Note 3) | 25 |
| Base station maximum coverage angle in the horizontal plane (degrees) | 120 |
| Base station vertical coverage range (degrees) (Note 1) | 25 |
| Mechanical uptilt (degrees) | 14 |

**Option 2: sub-array model**

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

|  |  |
| --- | --- |
| Parameter | Macro urban |
| Element gain (dBi) (Note 2) | 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)  (Note 4) | 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) (Note 2) | 2 |
| Conducted power (before Ohmic loss) per sub-array (dBm) (Note 3) | 28 |
| Base station horizontal coverage range (degrees) | +/-60 |
| Base station vertical coverage range (degrees) (Note 1) | 10 |
| Mechanical up-tilt (degrees) | 6.5 |

#### 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)  (Note 4) | (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) (Note 2) | 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)  (Note 4) | 8 × 8 elements AAS  [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) (Note 2) | 2 |
| Conducted power (before Ohmic loss) per antenna element (dBm) (Note 3) | 25 |
| Base station maximum coverage angle in the horizontal plane (degrees) | 120 |
| Base station vertical coverage range (degrees) (Note 1) | 25 |
| Mechanical down (degrees) | 3 |

**Option 2: sub-array model**

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

|  |  |
| --- | --- |
| Parameter | Macro urban |
| Element gain (dBi) (Note 2) | 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)  (Note 4) | 4 × 8 elements AAS  [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) (Note 2) | 2 |
| Conducted power (before Ohmic loss) per sub-array (dBm) (Note 3) | 28 |
| Base station horizontal coverage range (degrees) | +/-60 |
| Base station vertical coverage range (degrees) (Note 1) | 10 |
| Mechanical downtilt (degrees) | 3 |

#### 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 the TN network, 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.

### 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

# 7 RF requirements

## 7.1 ATG CPE specific

### 7.1.1 ATG CPE power class and requirement type

### 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 [x] 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 is approaching 11kHz 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.

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

#### 7.1.2.5 Minimum output power

#### 7.1.2.6 Transmit OFF power

#### 7.1.2.7 Transmit ON/OFF time mask

#### 7.1.2.8 Power control

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 will be reused as baseline.

For transmit modulation quality, the following requirement for FR1 UE in 38.101-1 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

7.1.2.12 ACLR requirements

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

7.1.2.15 Transmit intermodulation

### 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 CPE. 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 CPE.

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

#### 7.1.3.6 In-band blocking requirements

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

#### 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 tree 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 CPE 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

**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 should be 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 type type1-C, 1-H, and clause 10.3 of TS 38.104[5] can be reused for ATG BS type 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 type type1-C, 1-H, and clause 10.4 of TS 38.104[5] can be reused for ATG BS type type1-O.

#### 7.2.3.3 ACS

#### 7.2.3.4 In-band blocking

#### 7.2.3.5 Receiver intermodulation

#### 7.2.3.6 Out of band blocking

#### 7.2.3.7 In-channel selectivity

# 8 RRM requirements

8.1 General

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 mechanism] | TBD |
| [Cell re-selection measurement requirements for inter-frequency measurement] | [TBD] |
| [Conditional handover] | [Conditional handover mechanism] | TBD |
| [Conditional handover requirements] | TBD |
| UE transmit timing | Initial transmit timing requirements Te | Involve UE pre-compensation timing error, GNSS error=40m is assumed |
| [Gradual timing adjustment] | TBD |
| Timing advance adjustment delay requirement | Introduce the mechanism of Koffset |
| [Measurement mechanism] | | TBD |
| NR intra-frequency measurements | | For ATG TDD deployment, ‘deriveSSB-IndexFromCell’ is not always applicable |
| [Scheduling restrictions of UE performing measurements] | | TBD |

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> (normative):  
<Normative annex title>

Annexes are only to be used where appropriate:

Annex B:  
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 revised to R4-2303640 |  |  | 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  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 | 0.1.0 | 0.2.0 |
| 04/2023 | RAN4#106 bis-e | R4-2304282 |  |  | R4-2306608 TP to TR 38.876: Update of assumptions for scenarios 2, 3, 10, 11, Ericsson  R4-2306610 TP for TR 38.876: General aspects, Apple  R4-2306611 TP for TR 38.876: Transmit signal quality, Apple  R4-2306612 TP on TR 38.876 for ATG UE Rx requirements, Qualcomm Incorporated  R4-2306613 TP to TR 38.876 on ATG UE Rx requirements, Ericsson  R4-2306614 TP for TR 38.876 to introduce ATG UE Tx requirements Huawei, HiSilicon  R4-2305895 TP for TR 38.876 to introduce ATG BS Rx requirements, CMCC  R4-2305896 TP for TR 38.876 on BS RF requirements, Huawei, Hisilicon  R4-2305897 TP for TR 38.876, On ATG BS class and BS type in clause 7.2.1, CATT  R4-2305898 TP for TR 38.876, On transmitter spurious emissions in clause 7.2.2.4 and transmitter intermodulation in clause 7.2.2.5, CATT  R4-2306345 TP to TR 38.876: RRM requirements for ATG network, CMCC | 0.2.0 | 0.3.0 |
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