**3GPP TSG-RAN4 Meeting #100-E**

**Electronic Meeting, 16th - 27th August 2021**

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| *CR-Form-v12.1* | | | | | | | | |
| **CHANGE REQUEST** | | | | | | | | |
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|  | **38.820** | **CR** | **0003** | **rev** |  | **Current version:** | **16.1.0** |  |
|  | | | | | | | | |
| *For* [***HE******LP***](http://www.3gpp.org/3G_Specs/CRs.htm#_blank)*on using this form: comprehensive instructions can be found at* [*http://www.3gpp.org/Change-Requests*](http://www.3gpp.org/Change-Requests)*.* | | | | | | | | |
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| ***Proposed change affects:*** | UICC apps |  | ME |  | Radio Access Network | **X** | Core Network |  |

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| ***Title:*** | CR to TR 38.820: Addition of array antenna model extension in subclause 7.2 | | | | | | | | | |
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| ***Source to WG:*** | Ericsson | | | | | | | | | |
| ***Source to TSG:*** | R4 | | | | | | | | | |
|  |  | | | | | | | | | |
| ***Work item code:*** | NR\_newRAT-Core | | | | |  | ***Date:*** | | | 2021-08-16 |
|  |  | | | |  | |  | | |  |
| ***Category:*** | **F** |  | | | | | ***Release:*** | | | Rel-16 |
|  | *Use one of the following categories:* ***F*** *(correction)* ***A*** *(mirror corresponding to a change in an earlier release)* ***B*** *(addition of feature),* ***C*** *(functional modification of feature)* ***D*** *(editorial modification)*  Detailed explanations of the above categories can be found in 3GPP [TR 21.900](http://www.3gpp.org/ftp/Specs/html-info/21900.htm). | | | | | | | | *Use one of the following releases: Rel-8 (Release 8) Rel-9 (Release 9) Rel-10 (Release 10) Rel-11 (Release 11) … Rel-15 (Release 15) Rel-16 (Release 16) Rel-17 (Release 17) Rel-18 (Release 18)* | |
|  |  | | | | | | | | | |
| ***Reason for change:*** | | At last RAN4 meeting an extension of the antenna array model originally defined in TR 37.842 to support sub-arrays was agreed. The extension of the model and corresponding relevant model parameters was communicated to ITU-R WP 5D and CEPT in an LS (R4-2108080). The antenna model developed for AAS BS is also used for NR BS. This CR was created to document the updated model and corresponding parameters in proper TR in RAN4. The model update will not affect RAN4 coexistene work, but will better reflect AAS base station implementations. The new information is essential for coming work in RAN4 where new features related to AAS BS is continuously developed. Since RAN4 have communicated this information to groups outside 3GPP it is essential to document the background technical information in relevant RAN4 technical reports. Corresponding CR(s) for TR 37.842, TR 38.820 and TR 38.921 is also provided. | | | | | | | | |
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| ***Summary of change:*** | | A new subclause (7.2.5) is added for the antenna model extension. The model extension is required to study antenna geometries documented in subclause 7.2.3. The parameter sets relevant for the frequency range 7 to 24 GHz is still under discusison and would require more disucssions.  In rev 1, additional technical background relevant for 1710 to 4990 MHz is added as reference in Table 7.2.5-2. At the end of the subclause a statement is added saying that parameters for 7 to 24 GHz is FFS. | | | | | | | | |
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| ***Consequences if not approved:*** | | If not approved, the technical background information in technical reports would not capture relevant information relevant for modelling AAS base stations correctly. | | | | | | | | |
|  | |  | | | | | | | | |
| ***Clauses affected:*** | | Subclause 7.2 | | | | | | | | |
|  | |  | | | | | | | | |
|  | | **Y** | **N** |  | | | |  | | |
| ***Other specs*** | |  |  | Other core specifications | | | | TS/TR ... CR ... | | |
| ***affected:*** | |  |  | Test specifications | | | | TS/TR ... CR ... | | |
| ***(show related CRs)*** | |  |  | O&M Specifications | | | | TS/TR ... CR ... | | |
|  | |  | | | | | | | | |
| ***Other comments:*** | |  | | | | | | | | |
|  | |  | | | | | | | | |
| ***This CR's revision history:*** | |  | | | | | | | | |

# 7 NR BS

## 7.1 General

For the purposes of this SI, the RF technology analyses of the NR BS operation in 7 – 24 GHz frequency range are limited to the single-band operation, only.

## 7.2 BS architecture and requirements classification

### 7.2.1 Reference architecture

For NR BS two different architectures have been defined. The architectures different with respect to defined requirement anchor points and requirement applicability. A base station can into three main components:

- Transceiver Unit Array (TRXUA)

- RF Distribution Network (RDN)

- Antenna Array (AA)

In figure 7.2.1-1, the architecture for requirement set category H is visualized, where requirements are defined at TAB and RIB.



Figure 7.2.1-1: BS architecture relevant for requirement set category H

In figure 7.2.1-2, the architecture for requirement set category O is visualized, where all requirements are defined as OTA requirements at RIB.



Figure 7.2.1-2: BS architecture relevant for requirement set category O

The Release 15 NR basestation specifications include 3 types of basestation:

- The conducted basestation (*BS type 1-C*) type refers to a non-AAS BS architecture. The basestation does not include an antenna. The antenna is built separately and is likely to correspond to a passive sector antenna for a macro basestation. For micro and indoor basestations the antenna may have a wider coverage angle. All RAN4 requirements for conducted basestations are specified at each individual antenna connector. *BS type 1-C* is applicable to FR1 only.

- The hybrid basestation type (*BS type 1-H*) is an AAS basestation that has connectors or other means for conducted testing of individual transceivers. An AAS basestation has an integrated antenna. *BS type 1-H* basestations comply with two far field OTA requirements as well as conducted requirements. Unlike *BS type 1-C*, some conducted requirements are specified as a sum across multiple connectors. *BS type 1-H* is applicable for FR1 only.

- The OTA basestation is an AAS basestation type (*BS type 1-O* for FR1, *BS type 2-O* for FR2) that has only a radiated interface. All requirements are specified OTA, as either directional, TRP or co-location type requirements. The OTA BS type is applicable for both release 15 frequency ranges.

### 7.2.2 Requirement sets

The NR RF core specification defines multiple requirement sets. The requirement set support is different for FR1 and FR2. In table 7.2.2-1, the requirement set defined in NR are listed. Together, the requirement set category and frequency range defines the NR BS type.

Table 7.2.2-1: Requirement set categories for NR BS

|  |  |  |
| --- | --- | --- |
| Requirement set category | Applicability | Description |
| C – conducted | Antenna connector(s) for non-AAS architecture or TAB connector(s) for AAS BS architecture; applicable to FR1 only | All requirements are defined at the RF connector. This is the traditional approach used e.g. for E-UTRA in TS 36.104 [24] or for MSR in TS 37.104 [25]. |
| H – hybrid | TAB connector(s) or RIB depending on requirement; applicable to FR1 only | All requirements defined for requirement category C is applicable. However, emission requirements are scaled to capture the whole AAS system and TX IMD is extended.  In addition, two OTA requirements are defined for output power and sensitivity. This category is referred to as *hybrid*, since both conducted, and OTA requirements are included. This requirement set category was introduced in TS 37.105 [10] for AAS BS. |
| O – OTA, radiated | RIB; applicable to FR1 and FR2 | All requirements are defined as OTA requirements at the RIB. This requirement set category was introduced in TS 37.105 [10] for AAS BS. |

It is clear that xFR-O requirements will be needed for the 7 – 24 GHz frequency range. Type xFR-C BS (or non-AAS) will clearly be limited by lower antenna gain (compared to the beam forming architectures) and the larger path loss in this frequency range will result in smaller cell sizes than for FR1. However, at this stage, xFR-C and xFR-H requirements cannot be ruled out for BS operating within frequency sub-range 1 and sub-range 2.

Comparing the xFR-H and xFR-O AAS BS types, the principle differences from a testing perspective are that for 1-H, there is no need for out of band OTA testing facilities or for TRP testing. TRP emissions and conducted emissions limits could be set to be the same. In addition to this, most other TX requirements (i.e. signal quality and power dynamics) have the same value whether tested conducted or OTA.

For the receiver, for FR1 a method to relate conducted and radiated requirements has been established. For FR2, there is no such methodology as there are no conducted requirements. For the 7 – 24 GHz range, depending on the frequency and the expected receiver types, the FR1 approach may be applicable, or further work may be needed to develop a new approach or in the worst case, no mapping between radiated and conducted requirements may be possible. (In the latter case, it may of course be possible to derive conducted and radiated requirements without relating them). Depending on the applicable new band, if introducing both conducted and radiated requirements a future WI may need to take such factors into account.

Demodulation requirements for up to 2RX map directly between conducted and OTA. OTA testing of >2RX demodulation requirements is not feasible for FR1 or FR2 and will not be feasible in 7 – 24 GHz range. An assessment of the link budget in applicable test chambers for the frequency in question is needed to ensure OTA testability feasibility of demodulation requirements at sufficiently high SINR at the BS receiver. BS demodulation requirements that are not OTA tested may still be specified as conducted only. Within these constraints, demodulation requirements are possibly for any BS type in 7 – 24 GHz range. Therefore, discussion of further details of the BS demodulation testing in 7 – 24 GHz range is deferred to the related future WI.

### 7.2.3 Antenna topologies

The antenna array (AA) consists of *M* x *N* x 2 antenna elements (AE) placed is a certain lattice, arranged in *M* rows and *N* columns of cross-polarized elements. The signals from the AA are mapped in the RDN creating different antenna topologies, as presented on examples in figure 7.2.3-1. The RDN mapping is creating sub-arrays, where the radiating characteristics of a sub-array is different to single antenna elements.



Figure 7.2.3-1: Example RDN mappings

Depending on intended coverage scenarios different types of RDN mappings are foreseen for the frequency range 7 – 24 GHz. For *BS type xFR-H* and *BS type xFR-O*, the OTA RF characteristics defined for requirement set category H and requirement set category O is declared by the base station manufacturer in terms of full array capability as well as sub‑array or element capability, see TS 38.141-2 [6], clause 4.6.

### 7.2.4 Array antenna model

In Table 7.2.4-1, the parameters used by the parameterized array antenna model are described. Based on AAS base station architecture in clause 7.2.1 (i.e. the BS type xFR-H and BS type xFR-O) and deployment scenarios envisioned for the 7 – 24 GHz range, different parameter sets are required to model an AAS base station.

**Table 7.2.4-1: Parameters of the parameterized array antenna model**

| **Parameter** | **Symbol** | **Unit** |
| --- | --- | --- |
| Front to back ratio | *Am* | dB |
| Side lobe suppression | *SLAv* | dB |
| Horizontal HPBW | *j3dB* | Degrees |
| Vertical HPBW | *q3dB* | Degrees |
| Array element peak gain | *GE,max* | dBi |
| Array element loss | *LE* | dB |
| Number of radiating elements rows and columns | *(M, N)* | Integer |
| Horizontal element separation | *dh* | m |
| Vertical element separation | *dv* | m |
| Electrical down-tilt angle | *qetilt* | Degrees |
| Electrical scan angle | *jescan* | Degrees |

The parameterized antenna model is built around array antenna model where the element factor, array factor and linear phase progressing is characterized as described by equations in Table 7.2.4-2.

**Table 7.2.4-2: Array antenna model details**

| **Description** | **Equation** | **Unit** |
| --- | --- | --- |
| Peak normalized element radiation pattern |  | dB |
| Peak gain normalized element radiation pattern |  | dBi |
| Element peak gain | , where the peak directivity *DE,max*is calculated from given values on *j3dB, q3dB, dh* and*dv* | dBi |
| Composite array radiation pattern | , where | dBi |

To conserve complexity the model is created so that the element is gain normalized, instead of the composite array pattern. As a consequence, parameters cannot be selected arbitrarily, since parameters are dependent on each other. The intension with the model is to model absolute gain patterns correctly without full pattern directivity normalization. To model absolute gain, parameters must be selected carefully, if not the model produces nonphysical and incorrect gain response.

When array antenna parameters are selected for the array antenna model it is preferable to consider physical aspects such as the gain/area relation and gain/beamwidth relations by checking following aspects in given order:

1. The considered deployment scenario and coexistence situation will give the appropriate coverage range requirement for the horizontal and vertical domain.

NOTE 1: For analysis of the NR deployment scenarios considered for the 7 – 24 GHz range, refer to clause 5.6.

2. From the coverage ranges and deployment scenario the required antenna gain can be determined, from which the array antenna geometry can be determined in terms of number of rows (*M*), the number of columns (*N*).

3. From the coverage ranges the array antenna steering capability can be determined in terms element separations (*dv*, *dh*).

NOTE 2: The element separations *dv* and *dh* is the distance between radiating elements in the array antenna. The RDN can be used to create sub-arrays to optimize coverage. When sub-arrays are modelled, parameters can be selected to model the sub-array as a radiating element, in this case *dv* and *dh* is the distance between sub-arrays in the antenna array.

4. From the given array lattice the element parameters can be considered with respect to the given area for a single element. The element peak gain (*GE,max*) and half power beamwidth product (*j3dB* and*q3dB*) depend on each other and must be selected together to maintain accurate model gain response. The element loss (*LE*) needs to be included when the element peak gain is determined. Select parameter values for beamwidth based on the following two parameters checks:

a. Check the peak element directivity (*DE,max*) with the unit area available for a single element in the array lattice, as described in Eq. 7.2.4-1.

b. Check the peak element directivity (*DE,max*) with the half-power beam width product (*j3dB* and*q3dB*), as described in Eq. 7.2.4-2.

5. The model gain is guaranteed by an element peak directivity normalization directivity (*DE,max*) described in Eq. 7.2.4-3. The peak element gain *GE,max* is calculated based on Eq. 7.2.4-4.

The peak element directivity (assuming no losses for a given antenna aperture area) can be expressed as:

(Eq. 7.2.4-1)

Also, the peak element directivity for a given wide symmetrical beam can be approximated by:

(Eq. 7.2.4-2)

, where *K* is a factor that depends on the element properties. For single elements with symmetrical large beamwidths, *K* = 52525 is appropriate, while for sub-arrays with narrower beamwidth characteristics, *K* = 32400 is more appropriate. Depending on the element characteristics the relation between element peak gain and the half power beam width product is different as described in [65].

To be exact it is recommended to select element parameters, where the peak element gain is determined by calculating the directivity from a given geometry including beam widths. The element directivity can be calculated based on the pattern described by Table 7.2.4-1 in dBi as:

(Eq. 7.2.4-3)

, where *Alin(q,j)* is defined in linear scale as:

(Eq. 7.2.4-4)

### 7.2.5 Array antenna model extension

In Table 7.2.5-1, the parameters used by the parameterized array antenna model supporting sub-array geometries are described.

**Table 7.2.5-1: Extended parameter definitions**

| **Level** | **Parameter** | **Symbol** | **Unit** |
| --- | --- | --- | --- |
| Element | Front to back ratio | *Am* | dB |
| Side lobe suppression | *SLAv* | dB |
| Horizontal half power beamwidth | *3dB* | Degrees |
| Vertical half power beamwidth | *3dB* | Degrees |
| Array element peak gain | *GE,max* | dBi |
| Sub-array | Number of element rows in sub-array | *Msub* | Integer |
| Vertical element separation | *dv,sub* | m |
| Electrical pre-set sub-array down-tilt angle | *subtilt* | Degrees |
| Array | Number of elements/sub-array rows | *M* | Integer |
| Number of elements columns | *N* | Integer |
| Horizontal element separation | *dh* | m |
| Vertical element/sub-array separation | *dv* | m |
| Electrical down-tilt angle | *etilt* | Degrees |
| Electrical scan angle | *escan* | Degrees |

The parameterized antenna model is built around array antenna model where the element factor, array factor and linear phase progressing is characterized as described by equations in Table 7.2.5-2.

**Table 7.2.5-2: Extended AAS model**

| **Description** | **Equation** |
| --- | --- |
| Peak normalized element radiation pattern |  |
| Peak gain normalized element radiation pattern |  |
| Sub-array excitation |  |
| Sub-array radiation pattern | , where |
| Array excitation |  |
| Composite array radiation pattern | , where |

For the frequency range 1710 to 4990 MHz parameters sets listed in Table 7.2.5-2 was collected for different deployment scenarios.

**Table 7.2.5-2: Parameter sets relevant for the frequency range 1710 to 4990 MHz**

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Macro Rural | Macro suburban | Macro urban |
| Element gain (dBi) (Note 2) | 6.4 | 6.4 | 6.4 |
| Horizontal/vertical 3 dB beam width of single element (degree) | 90º for H 65º for V | 90º for H 65º for V | 90º for H 65º for V |
| Horizontal/vertical front‑to‑back ratio (dB) | 30 for both H/V | 30 for both H/V | 30 for both H/V |
| Antenna polarization | Linear ±45º | Linear ±45º | Linear ±45º |
| Antenna sub-array configuration (Row × Column)  (Note 4) | 4 × 8 elements | 4 × 8 elements | 4 × 8 elements |
| Horizontal/Vertical radiating sub-array spacing | 0.5 of wavelength for H, 2.1 of wavelength for V | 0.5 of wavelength for H, 2.1 of wavelength for V | 0.5 of wavelength for H, 2.1 of wavelength for V |
| Number of element rows in sub-array | 3 | 3 | 3 |
| Vertical element separation in sub-array () | 0.7 of wavelength of V | 0.7 of wavelength of V | 0.7 of wavelength of V |
| Pre-set sub-array down-tilt (degrees) | 3 | 3 | 3 |
| Array Ohmic loss (dB) (Note 2) | 2 | 2 | 2 |
| Conducted power (before Ohmic loss) per sub-array (dBm) (Note 3) | 28 | 28 | 28 |
| Base station horizontal coverage range (degrees) | +/-60 | +/-60 | +/-60 |
| Base station vertical coverage range (degrees) (Note 1) | 90-100 | 90-100 | 90-100 |
| Mechanical down-tilt (degrees) | 3 | 6 | 6 |

Note 1: The vertical coverage range is given for the elevation angle θ, defined between 0° and 180°.

Note 2: The element gain includes the loss and is per polarization.

Note 3: The conducted power per sub-array assumes 4x8x2 sub-arrays (i.e., power per H/V polarized element).

Note 4: 4 × 8 means there are 4 vertical and 8 horizontal radiating sub-arrays.

Note 5: For the case of 3 elements per sub array, dv will be 2.1 wavelengths.

Parameters sets relevant base station intended for operation within the frequency range 7 to 24 GHz are not yet defined. Further discssuion is required to determine relevant parameter sets for relevant deployment scenarios.

## 7.3 BS classes

The BS to UE minimum coupling loss of each NR BS class as defined in TS 38.104 [5] is the same as that of UTRAN in TS 25.104 [60] or E-UTRA in TS 36.104 [24], while the BS to UE minimum distance of each NR BS class is calculated using the path-loss formula in TR 25.951 [61]:

Which is derived from the free-space path-loss formula as in TR 25.942 [22]:

Where:

- d is the BS to UE distance in meters,

- c is the speed of light in m/s,

- f is the carrier frequency in Hz.

For FR1 studies the carrier frequency was assumed to be 2 GHz. For FR2 it was decided to use the same definition of BS classes using the same set of minimum distances and minimum coupling losses as for FR1.

The considered base station classes are Wide Area Base Stations, Medium Range Base Stations and Local Area Base Stations. The associated deployment scenarios (as discussed in clause 5.6) for each class are exactly the same for BS with and without connectors.

For *BS type xFR-O*, BS classes are defined as indicated below:

- Wide Area Base Stations are characterised by requirements derived from Macro Cell scenarios with a BS to UE minimum distance along the ground equal to 35 m.

- Medium Range Base Stations are characterised by requirements derived from Micro Cell scenarios with a BS to UE minimum distance along the ground equal to 5 m.

- Local Area Base Stations are characterised by requirements derived from Pico Cell scenarios with a BS to UE minimum distance along the ground equal to 2 m.

For *BS type xFR-C* and *BS type xFR-H*, BS classes are defined as indicated below:

- Wide Area Base Stations are characterised by requirements derived from Macro Cell scenarios with a BS to UE minimum coupling loss equal to 70 dB.

- Medium Range Base Stations are characterised by requirements derived from Micro Cell scenarios with a BS to UE minimum coupling loss equals to 53 dB.

- Local Area Base Stations are characterised by requirements derived from Pico Cell scenarios with a BS to UE minimum coupling loss equal to 45 dB.

Considering the 7 - 24 GHz frequency range is between FR1 and FR2 in the frequency domain, it is logical to use the same set of minimum distances and minimum coupling losses for the BS classes within the 7 - 24 GHz frequency range.