RF exposure compliance assessment

Massive MIMO Adaptive Antenna Products – AEUD/E

FCC ID: 2AD8UAEUDAEUE01

Author	Kamil Bechta
Owner	Christophe Grangeat
Organization	MN 5G&SC Arch
Approver	Mohsin Zia
Document Type	Preliminary test report
Document ID	LPITPN2I4Q5L-1109616211-625
Document location	https://teams.microsoft.com/_#/files/General?threadId=19:199516ad8ed84ef78ed31c6252c0534d@thread.skype&ctx=channel&context=Products-RF-exposure-assessment%252FAEUD-E

Change History

Version	Status	Date	Author	Owner	Reviewed by	Reviewed date	Approver	Approval date	Description of changes
1.0	Preliminary	29-08-2019	K. Bechta	C. Grangeat	C. Grangeat	29-08-2019	Mohsin Zia		Initial model calculation
1.1	Preliminary	29-08-2019	K. Bechta	C. Grangeat	C. Grangeat	29-08-2019	Mohsin Zia	29-08-2019	Report approved; Document ID added
1.2	Preliminary	29-08-2019	K. Bechta	C. Grangeat	C. Grangeat	29-08-2019	Mohsin Zia	29-08-2019	Peak EIRP value removed
1.3	Preliminary	06-09-2019	K. Bechta	C. Grangeat	C. Grangeat	29-08-2019	Mohsin Zia	29-08-2019	Product name modified; Document ID updated

NOKIA

Contents

List of Tables

NOKIA

List of Figures

1 General content

This test report is addressing human exposure to radiofrequency electromagnetic fields (RF-EMF) transmitted by the following massive MIMO Adaptive Antenna (MAA) Product (see §2.2):

Nokia AirScale MAA 2x2T2R 256AE n257 4W AEUD/E

FCC ID: 2AD8UAEUDAEUE01

It provides the RF exposure compliance boundaries for these products regarding both general population and occupational exposure. Outside of these compliance boundaries, human exposure to RF-EMF is below the limits defined by the US Federal Communications Commission (FCC), Canada Safety Code 6, Australia ARPANSA and European regulations (see §2.1 and 3).

2 References

2.1 Applicable RF exposure standards and regulations

[1] EU 1999/519/EC, “Council Recommendation on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz)”, July 1999

[2] EU 2013/35/EU, “Directive of the European Parliament and of the Council on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (20th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) and repealing Directive 2004/40/EC”, June 2013

[3] EN 50385:2017, “Product standard to demonstrate the compliance of base station equipment with radiofrequency electromagnetic field exposure limits (110 MHz - 100 GHz), when placed on the market”, July 2017

[4] IEC/EN 62232:2017, “Determination of RF field strength, power density and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure”, September 2017.

[5] AS/NZS 2772.2, "Radiofrequency fields Part 2: Principles and methods of measurement and computation-3 kHz to 300 GHz", 2016

[6] ARPANSA “Maximum Exposure Levels to Radiofrequency Fields — 3 kHz to 300 GHz”, Radiation Protection Series Publication No. 3, 2016

[7] Canada Safety Code 6, “Limits of Human Exposure to Radiofrequency Electromagnetic Energy in the Frequency Range from 3 kHz to 300 GHz”, June 2015

[8] Canada RSS-102, “Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands)”, Issue 5, March 2015,

[9] US FCC 47CFR 1.1310 “Radiofrequency radiation exposure limits”, August 1997.

[10] US FCC OET Bulletin 65, “Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields and its supplements”, edition 97-01, August 1997.

2.2 Product and assessment method

[11] Nokia, “Massive MIMO Adaptive Antenna Product Description”.

[12] Nokia, “AEUD AirScale MAA 2x2T2R 256AE n257 4W A101 474611A, Antenna Performance Test Report”, 22-08-2019.

[13] Microwave Vision Group (MVG), “EMF Visual User Manual”, SEWB/EMF-VISUAL-UM.1/v2019.1.

[14] Z. Altman, B. Begasse, C. Dale, A. Karwowski, J. Wiart, M. Wong and L. Gattoufi, “Efficient models for base station antennas for human exposure assessment”, IEEE Trans. Electromagnetic Compatibility, Nov 2002, vol.44, pp. 588-592.

[15] P. Baracca, A. Weber, T. Wild and C. Grangeat, “A Statistical Approach for RF Exposure Compliance Boundary Assessment in Massive MIMO Systems”, WSA 2018, https://arxiv.org/abs/1801.08351.

[16] IEC TR62669:2019, “Case studies supporting the implementation of IEC 62232”.

3 RF exposure limits

The applicable RF exposure limits are defined by [1] and [2] to in Europe and ICNIRP countries, by [5] in Australia and New Zealand, by [7] in Canada and by [9] in the US and related countries such as Bolivia, Estonia, Mexico and Panama. The applicable power density limits are recalled in Table 1 for the frequency range applicable to the equipment under test.

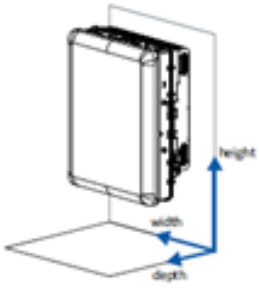
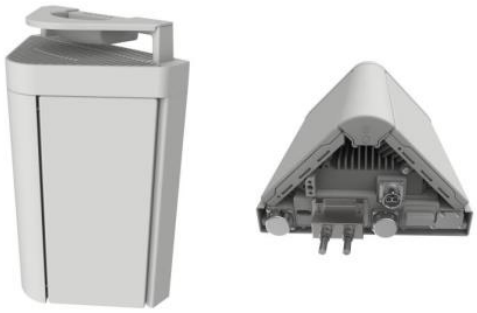
Table 1 – Applicable RF exposure levels in n257 band expressed in power density

Region of application	General Population/Uncontrolled Exposures	Occupational/Controlled Exposures
EU/ICNIRP, Australia/NZ, Canada, US/related	10 W/m²	50 W/m²

4 Description of the equipment under test (EUT)

The main technical characteristics of AEUD/E product are reproduced in Table 2 and Table 4.

Table 2 – AEUD/E product general technical characteristics

Product name	Nokia AirScale MAA 2x2T2R 256AE n257 4W AEUD/E	
Model number	474611A & 474690A	
Rated max output power per antenna module	0.32 W (25 dBm) per TRx; 0.64 W (28 dBm) total	
Number of TXRX	2 * 2TX2RX	
Beamforming	Yes	
SW supported techno.	TDD NR	
Band / Frequency range	26.5 – 29.5 GHz (3GPP Band n257)	
Nb of antenna elements	8 (horizontal) x 8 (vertical) x 2 (polarizations) x 2 (panels)	
Gain	23 dBi	
Horizontal half-power beamwidth	15° (boresight)	
Vertical half-power beamwidth	15° (boresight)	
Total average EIRP per antenna module	51 dBm	
Beam steering range per antenna module	± 45° (horizontal @ 3dB); ±45° (vertical @ 3dB)	
Dimensions 	Main Unit (AEUD): Height: 364 mm Depth: 169 mm Width: 283 mm w/o handle	
Technology duty cycle factor	75 %	
Transmitted power tolerance	1.5 dB	

Nokia AirScale MAA 2x2T2R 256AE n257 4W AEUD/E can be deployed as Main Unit only (AEUD) with ±90° azimuth coverage or as Main Unit (AEUD) plus Extension Unit (AEUE) with ±180° azimuth coverage. Figure 1 illustrates AEUD/E antenna modules (AM) configuration in horizontal

plane. Coordinate system for horizontal plane from Figure 1 is used as reference in the remaining part of the report.

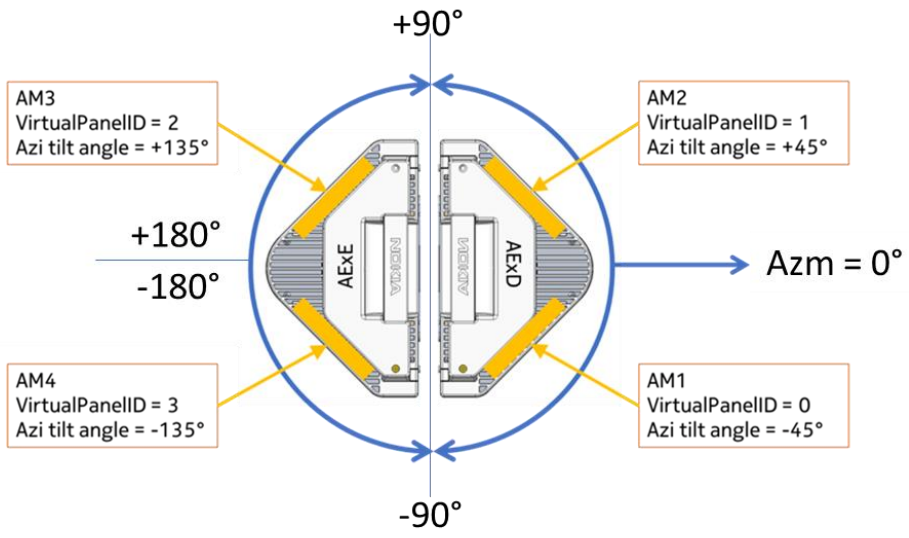


Figure 1. AEUD/E antenna modules configuration

Table 3 – Measured AEUD antenna gain characteristics for various beam steering directions (from [12])

Azimuth (at AM1/AM2 respectively)	Elevation	Gain (dBi)	Note
		28 GHz	
-45°/+45°	0°	**22.9** / 22.8	Max boresight gain per AM

In order to provide a conservative assessment on the frequency range, we performed the calculation at 28 GHz using the maximum gain over all similar steering directions (value in bold in Table 3). The compliance boundary is defined by the half-pipe shape perimeter for Main Unit only (AEUD) and by the full pipe shape perimeter for Main Unit (AEUD) plus Extension Unit (AEUE), as displayed in Figure 2. The distance Rp is the radius of the half-pipe and full pipe, whereas Da,u and Da,d are taken from the nearest point of the antenna. For convenience, the distances Duc and Ddc (respectively) taken from antenna center are also provided, as well as distance to the back Db.

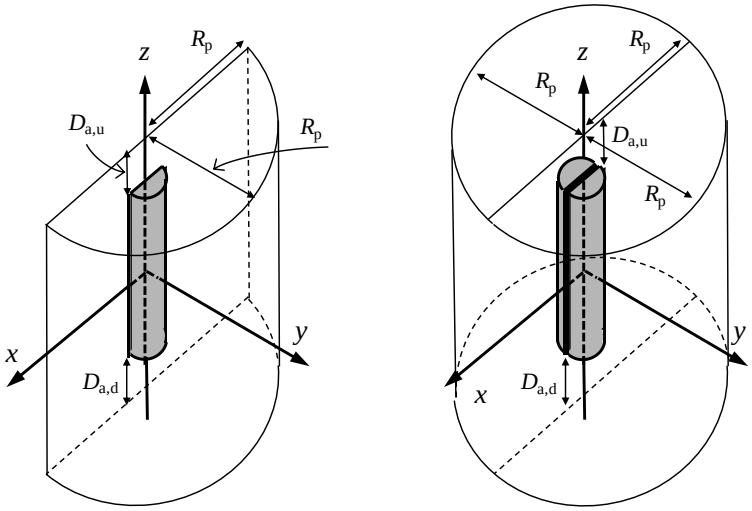


Figure 2 – Shape of the compliance boundary used for the RF exposure compliance assessment

5 RF exposure assessment method

RF exposure assessment is performed using the synthetic model computation method defined in B.4.4.1 of IEC 62232:2017 [4]. Calculations are performed with the "EMF Visual" software release 4.0 (see [13] and [14]).

The validation of the model is performed in the configuration with the beam in front of Antenna Module (boresight direction). The validation results are provided in Table 4.

Table 4 – Validation of the antenna model at 28 GHz

	Product (from [12])	EMF Visual Model	Deviation
Gain	22.9 dBi	22.9 dBi	0.0 dB
Horizontal half-power beamwidth	>12.0°	12.5°	0.5°
Vertical half-power beamwidth	>12.0°	12.5°	0.5°

For each configuration, the directivity pattern is derived from the simulation model and the antenna gain is adjusted to match exactly the measured values for accurate scaling.

The RF compliance distances are provided for the time-averaged maximum transmitted power of 0.68 W per AM and, for information, the time-averaged actual maximum transmitted power of 0.17 W per AM taking a 95th percentile approach as defined in [4], [15] and [16]. These values include a technology duty cycle factor of 75 % (see Table 2) for time averaging and a power

tolerance of 1.5 dB due to electronic component dispersion and operational environmental conditions (temperature).

6 RF exposure computation results

The computed power density 2D distributions are displayed in Figure 3 to Figure 16 for RF exposure limits defined in [1], [2] for EU/ICNIRP countries, [5] Australia/NZ, [7] Canada and [9] for US/related countries.

6.1 Configuration with Main Unit (AEUD) only

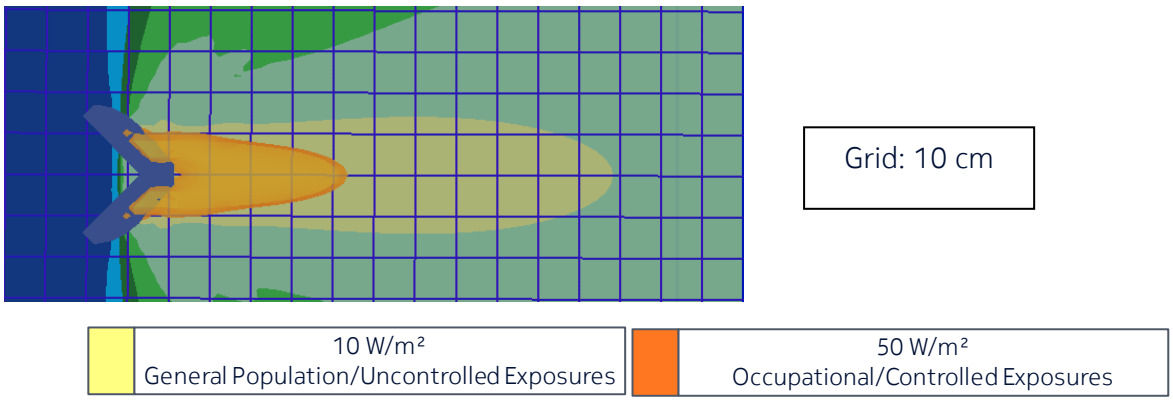


Figure 3 – Top view of AEUD power density for the time-averaged maximum transmitted power of 0.68 W per AM and the beams oriented in azimuth = 0° & elevation = 0°

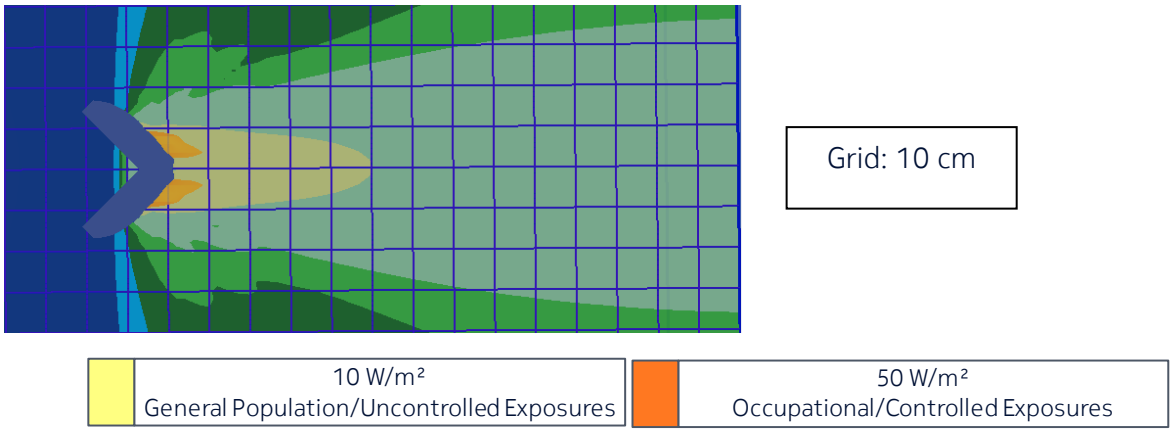


Figure 4 – Top view of AEUD power density for the time-averaged actual maximum transmitted power of 0.17 W per AM and the beams oriented in azimuth = 0° & elevation = 0°

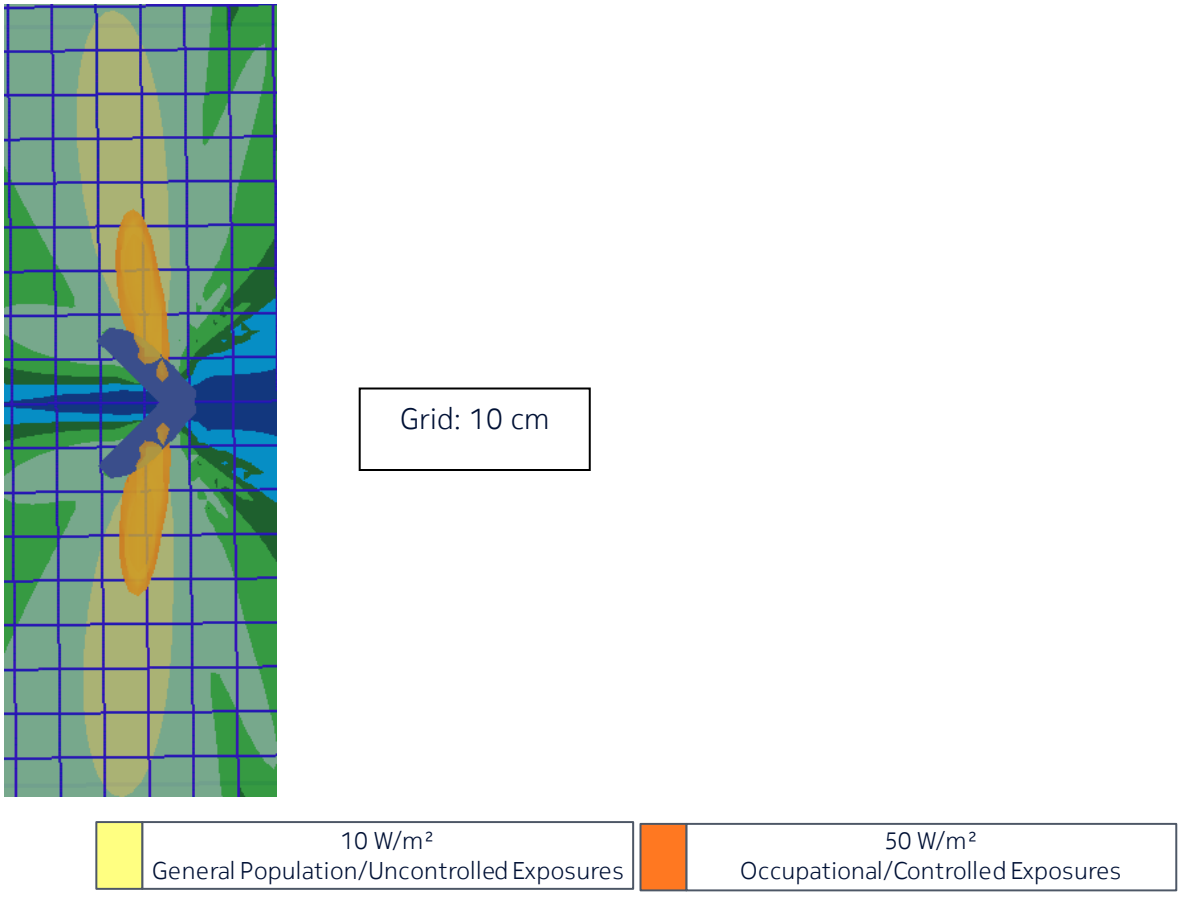


Figure 5 – Top view of AEUD power density for the time-averaged maximum transmitted power of 0.68 W per AM and the beams oriented in azimuth = +/-90° & elevation = 0°

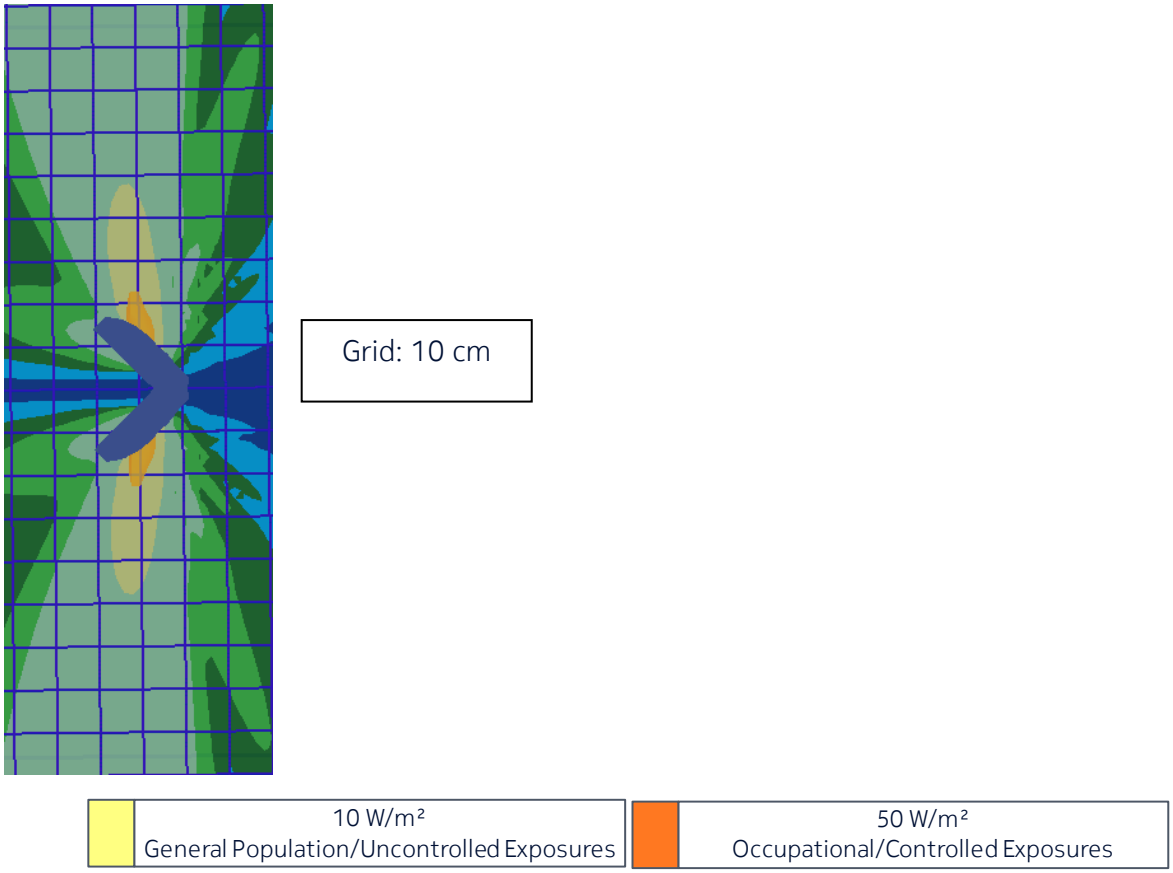


Figure 6 – Top view of AEUD power density for the time-averaged actual maximum transmitted power of 0.17 W per AM and the beams oriented in azimuth = +/-90° & elevation = 0°

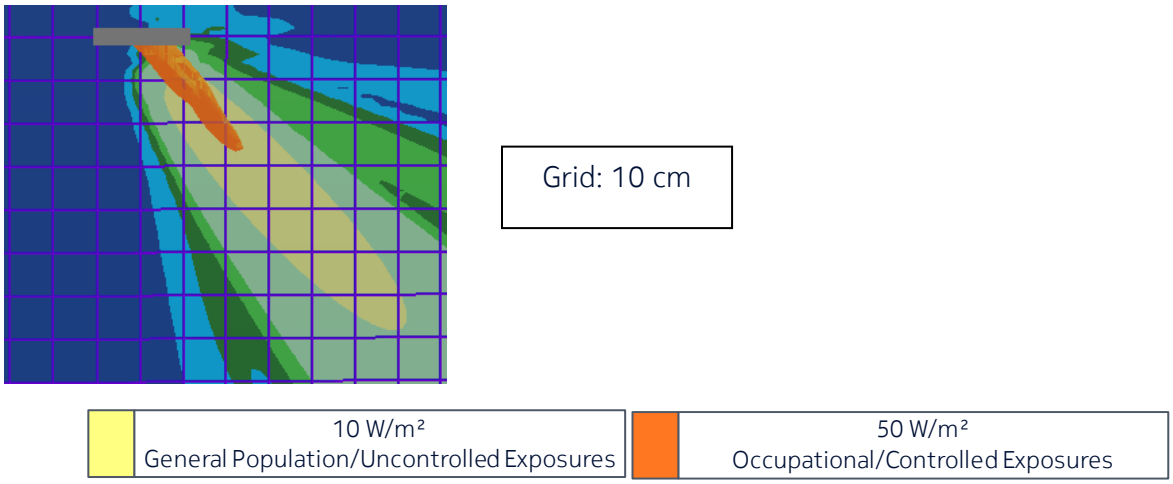


Figure 7 – Side view of AEUD power density for the time-averaged maximum transmitted power of 0.68 W per AM and the beams oriented in azimuth = 0° & elevation = -45°

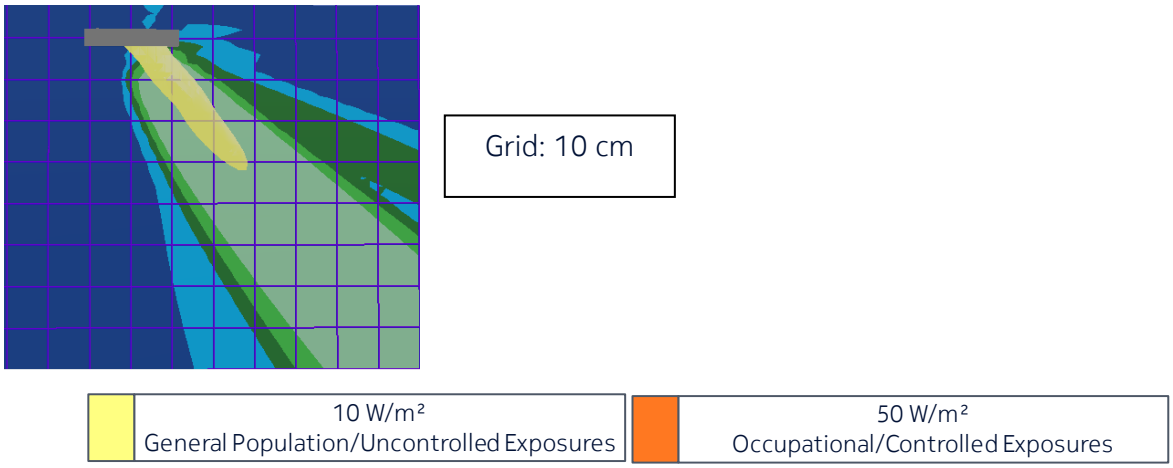


Figure 8 – Side view of AEUD power density for the time-averaged actual maximum transmitted power of 0.17 W per AM and the beams oriented in azimuth = 0° & elevation =-45°

6.2 Configuration with Main Unit (AEUD) plus Extension Unit (AEUE)

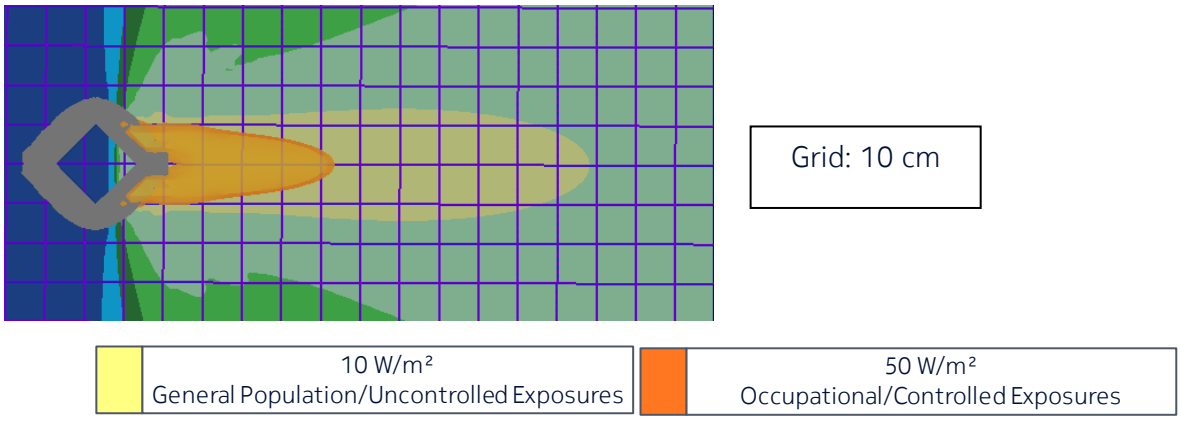
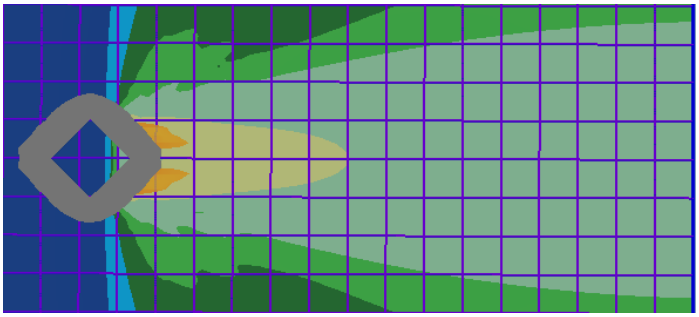


Figure 9 – Top view of AEUD+AEUE power density for the time-averaged maximum transmitted power of 0.68 W per AM and the beams oriented in azimuth = 0° & elevation = 0°

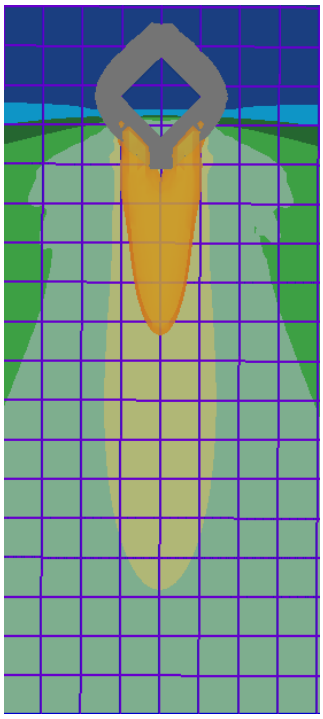


Grid: 10 cm

10 W/m²
General Population/Uncontrolled Exposures

50 W/m²
Occupational/Controlled Exposures

Figure 10 – Top view of AEUD+AEUE power density for the time-averaged actual maximum transmitted power of 0.17 W per AM and the beams oriented in azimuth = 0° & elevation = 0°



Grid: 10 cm

10 W/m²
General Population/Uncontrolled Exposures

50 W/m²
Occupational/Controlled Exposures

Figure 11 – Top view of AEUD+AEUE power density for the time-averaged maximum transmitted power of 0.68 W per AM and the beams oriented in azimuth = +90° & elevation = 0°

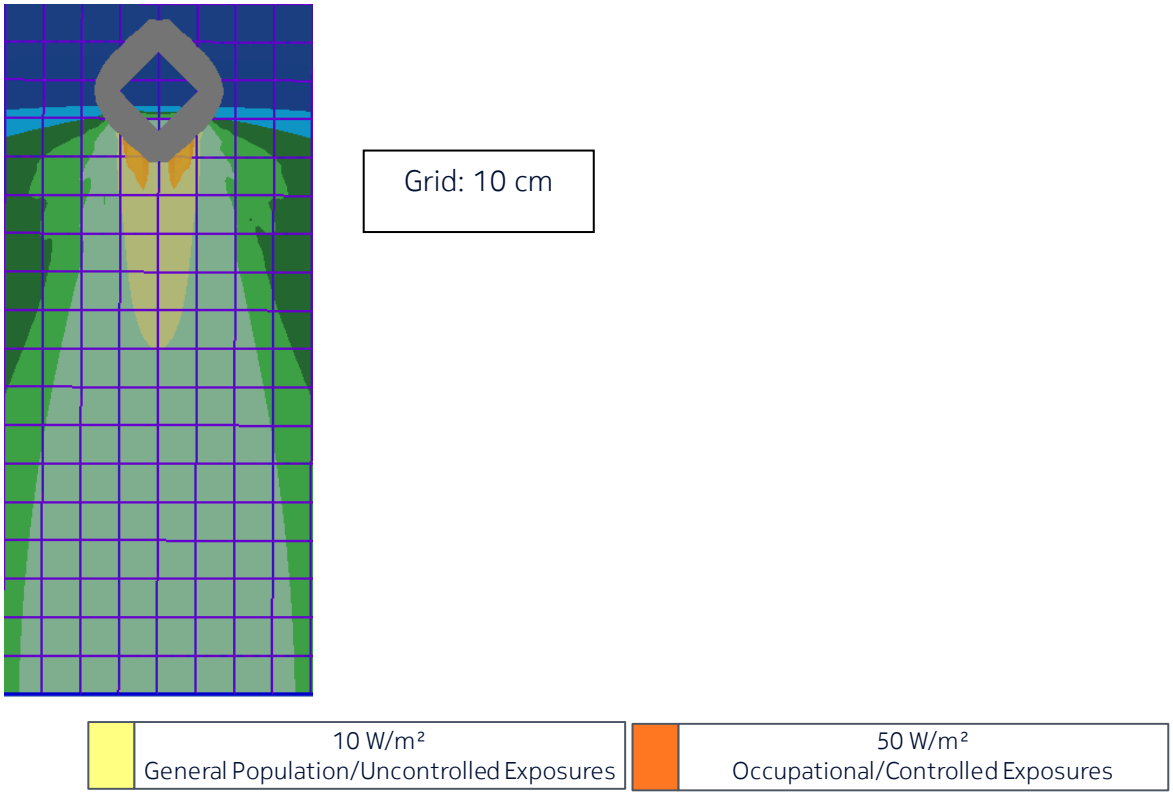


Figure 12 – Top view of AEUD+AEUE power density for the time-averaged actual maximum transmitted power of 0.17 W per AM and the beams oriented in azimuth = +90° & elevation = 0°

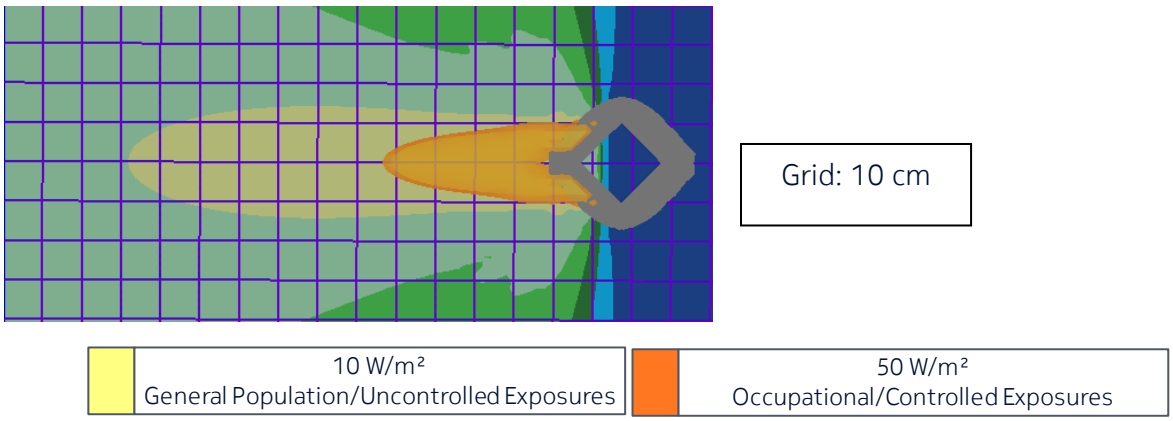


Figure 13 – Top view of AEUD+AEUE power density for the time-averaged maximum transmitted power of 0.68 W per AM and the beams oriented in azimuth = -180° & elevation = 0°

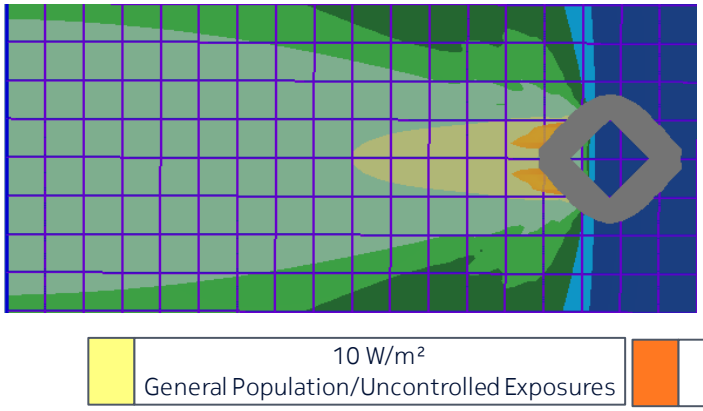


Figure 14 – Top view of AEUD+AEUE power density for the time-averaged actual maximum transmitted power of 0.17 W per AM and the beams oriented in azimuth = -180° & elevation = 0°

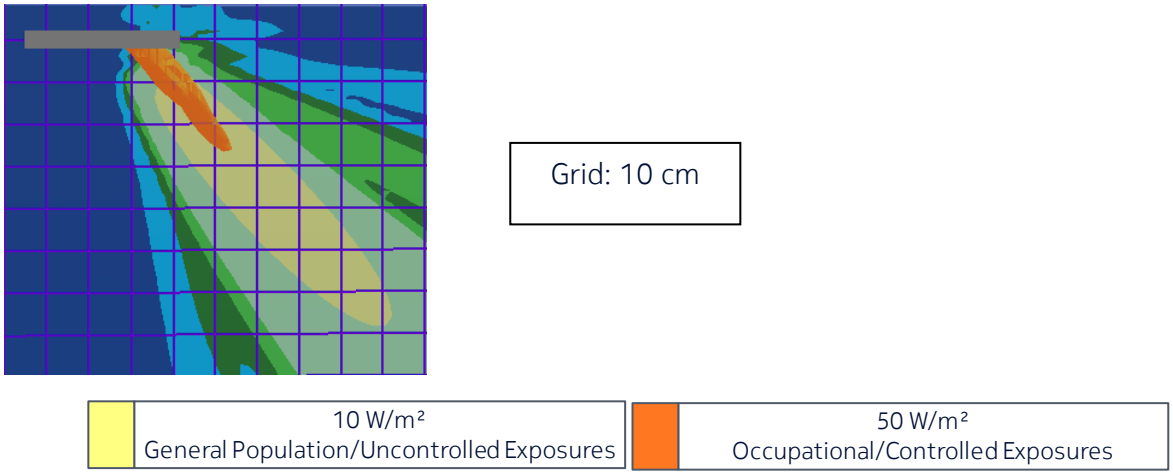


Figure 15 – Side view of AEUD+AEUE power density for the time-averaged maximum transmitted power of 0.68 W per AM and the beams oriented in azimuth = 0° & elevation=-30°

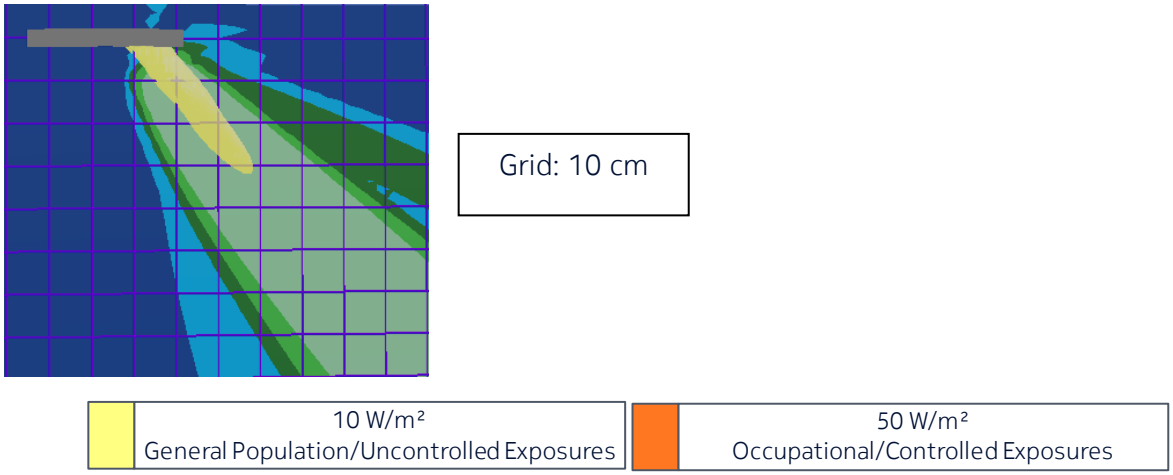


Figure 16 – Side view of AEUD+AEUE power density for the time-averaged actual maximum transmitted power of 0.17 W per AM and the beams oriented in azimuth = 0° & elevation =-30°

7 Conclusion and installation recommendations

The RF exposure compliance distances for the Nokia AirScale MAA 2x2T2R 256AE n257 4W AEUD/E product are summarized in Table 5 and Table 6 for EU/ICNIRP [1][2], Australia/NZ [5], Canada [7] and US/related [9] requirements.

Table 5 – AEUD RF exposure compliance distances based on the time-averaged maximum transmitted power of 0.68 W per AM (corresponding to 0.64 W per AM rated max transmitted power)

Region of application: EU/ICNIRP, Australia/NZ, Canada and US/related	General Population/Uncontrolled Exposures	Occupational/Controlled Exposures
RF-EMF power density exposure limits	10 W/m²	50 W/m²
Radius of the half-pipe (Rp)	1.3 m	0.6 m
Distance to the back (Db)	0.1 m	0.0 m
Distance below and above (Da,d and Da,u)	0.6 m	0.2 m
Distance below and above (Ddc and Duc)	0.7 m	0.3 m

Table 6 – AEUD+AEUE RF exposure compliance distances based on the time-averaged maximum transmitted power of 0.68 W per AM (corresponding to 0.64 W per AM rated max transmitted power)

Region of application: EU/ICNIRP, Australia/NZ, Canada and US/related	General Population/Uncontrolled Exposures	Occupational/Controlled Exposures
RF-EMF power density exposure limits	10 W/m²	50 W/m²
Radius of the full pipe (Rp)	1.3 m	0.6 m
Distance below and above (Da,d and Da,u)	0.6 m	0.2 m
Distance below and above (Ddc and Duc)	0.7 m	0.3 m

The RF exposure compliance distances based on the actual maximum transmitted power considering a 95th percentile approach are summarized in Table 7 and Table 8. These values are provided for information about the RF exposure levels that may be reached in operational conditions considering a time-averaging window of 6 minutes according to [4], [15] and [16].

Table 7 - AEUD RF exposure compliance distances based on the time-averaged actual maximum transmitted power of 0.17 W per AM (corresponding to 0.16 W per AM rated max transmitted power)

For information in EU/ICNIRP, Australia/NZ, Canada [7] and US/related countries based on IEC/EN 62232:2017 [4] and IEC TR62669 [16]	General Population/Uncontrolled Exposures	Occupational/Controlled Exposures
RF-EMF power density exposure limits	10 W/m²	50 W/m²
Radius of the half-pipe (Rp)	0.7 m	0.3 m
Distance to the back (Db)	0.0 m	0.0 m
Distance below and above (Da,d and Da,u)	0.3 m	0.0 m
Distance below and above (Ddc and Duc)	0.4 m	0.1 m

Table 8 – AEUD+AEUE RF exposure compliance distances based on the time-averaged actual maximum transmitted power of 0.17 W per AM (corresponding to 0.16 W per AM rated max transmitted power)

For information in EU/ICNIRP, Australia/NZ, Canada [7] and US/related countries based on IEC/EN 62232:2017 [4] and IEC TR62669 [16]	General Population/Uncontrolled Exposures	Occupational/Controlled Exposures
RF-EMF power density exposure limits	10 W/m²	50 W/m²
Radius of the full pipe (Rp)	0.7 m	0.3 m
Distance below and above (Da,d and Da,u)	0.3 m	0.0 m
Distance below and above (Ddc and Duc)	0.4 m	0.1 m

Installation of Nokia AirScale MAA 2x2T2R 256AE n257 4W AEUD/E product shall be performed in accordance with all applicable manufacturer's recommendations and national laws and regulations related to human exposure to radiofrequency fields. In particular:

- The operator or entity putting the equipment into service shall take the necessary measures to ensure that the general population cannot access the area within the general population/uncontrolled compliance boundary in the vicinity of the transmitting antennas (see Table 5 – Table 6).
- Depending on the site installation configuration, the operator or the entity putting the equipment into service determines the most suitable place to display the appropriate warning signs and any other necessary information or precautionary measures.
- Workers that are required to operate in the close proximity of the transmitting antennas connected to the equipment, for example installation and maintenance personnel, need to be informed about the potential risks of human exposure to RF fields and how to protect against them. They should strictly follow instructions provided by their employer. They should stand-off the occupational/controlled exposure compliance boundary defined in the vicinity of transmitting antennas (see Table 5 – Table 6). If it is necessary to operate within this compliance boundary, workers shall make sure that the transmitters contributing to exposure in this area are all switched off, or they must contact the relevant operator(s) to switch off emissions during operation period.

----- end of the test report ---------