RF exposure compliance assessment

Massive MIMO Adaptive Antenna Products – AQQE, AQQK, AQQL

Author	Kamil Bechta
Owner	Christophe Grangeat
Organization	MN RAN Arch
Approver	Yi Rao
Document Type	Final test report
Document ID	LPITPN2I4Q5L-1109616211-1870
Document location	https://nokia.sharepoint.com/:f:/r/sites/EMFProductManagement/Shared%20Documents/General/Products-RF-exposure-assessment/AQQE%20AQQK%20AQQL?csf=1&web=1&e=U4LVfX

Change History

Version	Status	Date	Author	Owner	Reviewed by	Reviewed date	Approver	Approval date	Description of changes
1.0	Final	28-06-2021	K. Bechta	C. Grangeat	C. Grangeat	29-06-2021	Y. Rao	05-07-2021	

Contents

List of Tables

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 AQQE AirScale MAA 64T64R 192AE n78 320W
- Nokia AQQK AirScale MAA 64T64R 192AE n77 320W
- Nokia AQQL AirScale MAA 64T64R 192AE n78 320W

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 [16]).

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” DN207523773, Issue 07, 08-06-2020.

[12] Microwave Vision Group (MVG), “EMF Visual User Manual”, SEWB/EMF-VISUAL-UM.1/v2020.2.

[13] 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.

[14] 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.

[15] IEC TR62669, “Case studies supporting the implementation of IEC 62232”, (106/463/CD, July 2018).

[16] NGMN white paper, “Recommendation on Base Station Active Antenna System Standards v1.0”, July 2020, https://www.ngmn.org/wp-content/uploads/Publications/2020/NGMN_BASTA-AA_WP_1_0.pdf

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 n78 band expressed in power density

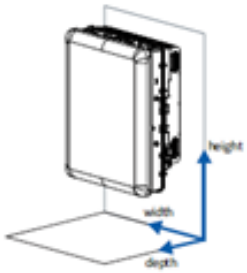
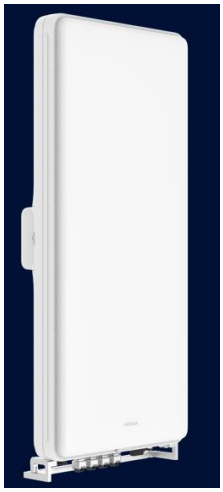
Region of application	General Population/Uncontrolled Exposures	Occupational/Controlled Exposures
EU/ICNIRP, Australia/NZ, US/related	10 W/m²	50 W/m²
Canada	6.6 W/m²	37.0 W/m²

4 Description of the equipment under test (EUT)

The main technical characteristics of AQQE, AQQK and AQQL products are reproduced in Table 2.

Table 2 – AQQE, AQQK and AQQL products general technical characteristics

Product name	Nokia AQQE AirScale MAA 64T64R 192AE n78 320W Nokia AQQK AirScale MAA 64T64R 192AE n77 320W Nokia AQQL AirScale MAA 64T64R 192AE n78 320W
Model number	AQQE: 475544A AQQK: 475795A AQQL: 475732A
Rated max Tx power	320 W
Number of TXRX	64TX64RX
Beamforming	Yes
SW supported techno.	3GPP NR compliant, TDD
Frequency range	AQQE: 3420 - 3800 MHz AQQK: 3700 - 3980 MHz AQQL: 3400 - 3800 MHz
Nb of antenna elements	12 (row) x 8 (column) x 2 (polarization)

Typical Antenna Gain	24.0 dBi ±1 dB	
Total average EIRP	79 dBm (from datasheet)	
Azimuth scanning range	±45° (3dB), ±50° (4dB)	
Vertical pre-tilt angle	+6°	
Elevation scanning range	±7° (upper SLS > 6dB)	
Dimensions 	Height: 1001 mm Width: 448 mm Depth: 113 mm	
Technology duty cycle factor	75 %	
Transmitted power tolerance	1.5 dB	

The pattern model used for the RF exposure assessment is derived from the model of the antenna array (pattern and gain) and represents the envelope over all possible beam patterns considering all tilt offset values, which are configurable in the product by real beamforming weights (BFW). The pattern model is validated with the product antenna model. Table 4 includes the comparison of the pattern model for RF exposure assessment and the product antenna model used for the assessment of the compliance boundary. Selected pattern ensures that maximum compliance distance, applicable to evaluated product, is obtained.

Azimuth and elevation angles indicated in this report are provided according to the reference system used in product data sheets (see Table 3), unless otherwise stated.

Table 3 - Reference system used in this report (from NGMN white paper [16])

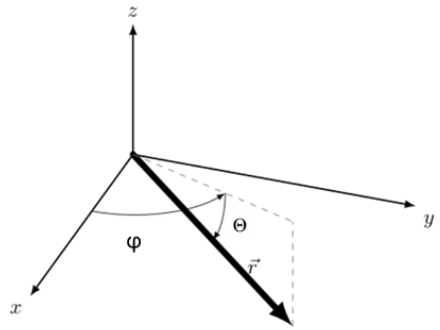
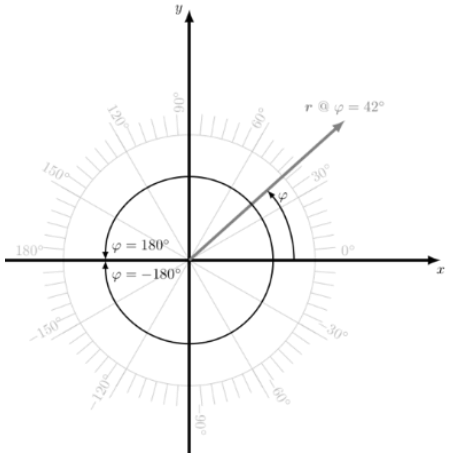
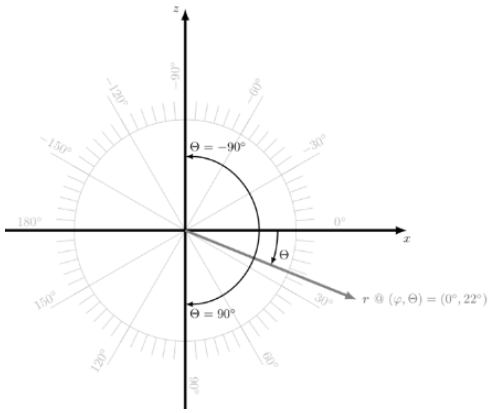
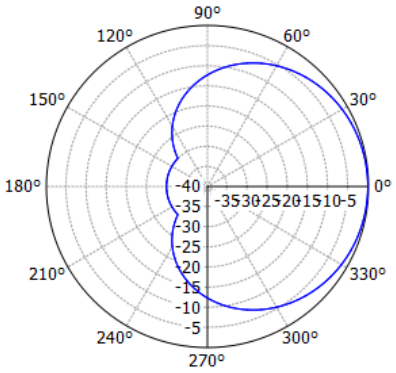
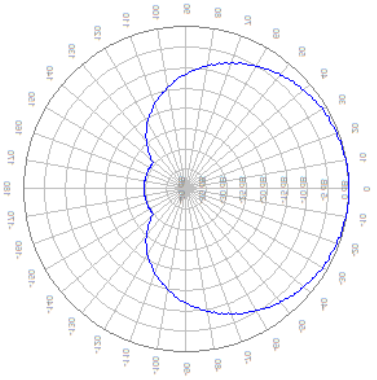
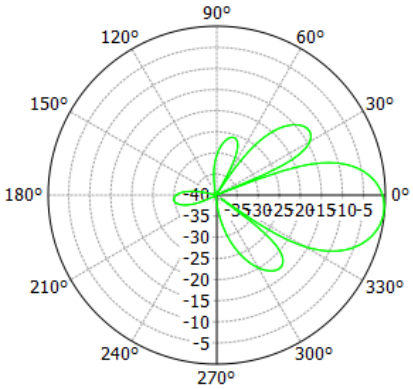
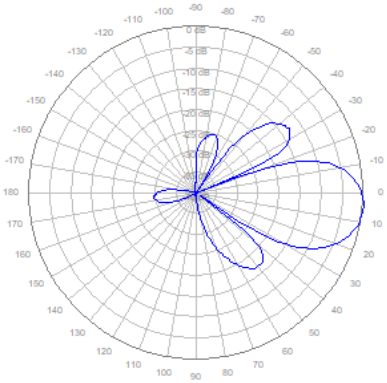
3D view Defintion of azimuth φ and elevation θ	
Top view (horizontal cut) Definition of azimuth φ	
Side view (vertical cut) Definition of elevation θ	

Table 4 – Comparison of antenna model for EMF evaluation with product antenna pattern

	Model for EMF evaluation	Product antenna pattern
Horizontal cut		
Vertical cut		
NOTE: Angle references used in these graphs are derived from EMF Visual (left) and Planet Viewer (right), which may differ from product data sheet (see Table 3)		

The compliance boundary is defined by the box shape perimeter shown in Figure 4 of IEC 62232:2017 [4] and displayed in Figure 1. The distances D_f, $D_{s,a}$, $D_{u,a}$ and $D_{d,a}$ are taken from the nearest point of the antenna. For convenience, the distances $D_{s,c}$, $D_{u,c}$ and $D_{d,c}$ (respectively) taken from antenna center are also provided.

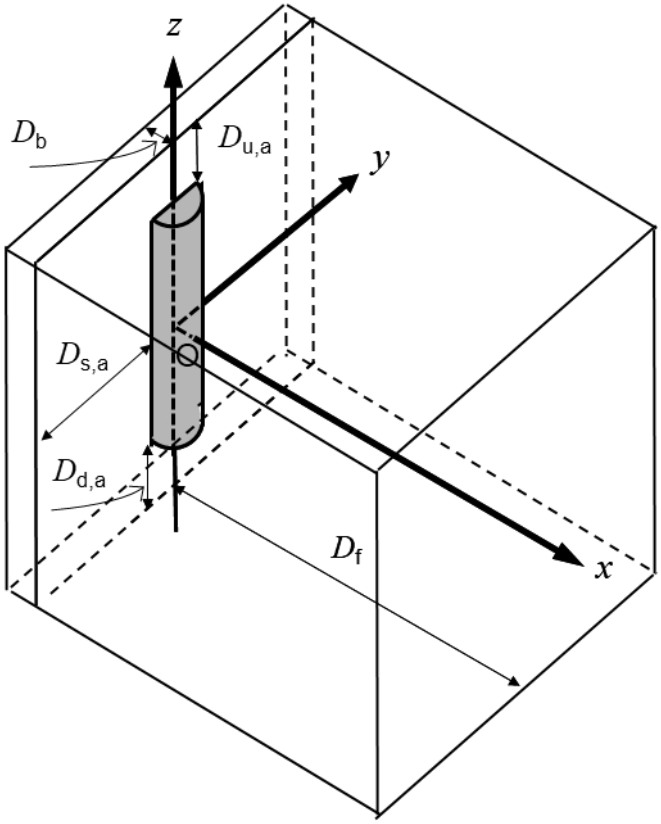


Figure 1 – Shape of the compliance boundary used for the RF exposure compliance assessment (from [4]).

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. Calculations are performed with the "EMF Visual" software release OKTAL 2020 Version 4.0 (see [12] and [13]).

The validation results are provided in Table 5.

Table 5 - Validation of the antenna model at 3500 MHz

	Product model	EMF Visual model	Deviation
Gain	25.0 dBi	25.0 dBi	0.0 dB
Horizontal half-power beamwidth	90.0°	90.5°	0.5°
Vertical half-power beamwidth	24.0°	24.2°	0.2°

The directivity pattern is derived from the simulation model and the antenna gain is adjusted to match exactly the simulated values for accurate scaling.

The RF compliance distances are provided for the time-averaged maximum transmitted power of 339 W and, for information, the time-averaged actual maximum transmitted power of 85 W taking a 95th percentile approach as defined in [4], [14] and [15]. 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

6.1 Regions of application: EU/ICNIRP, Australia/NZ and US/related

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

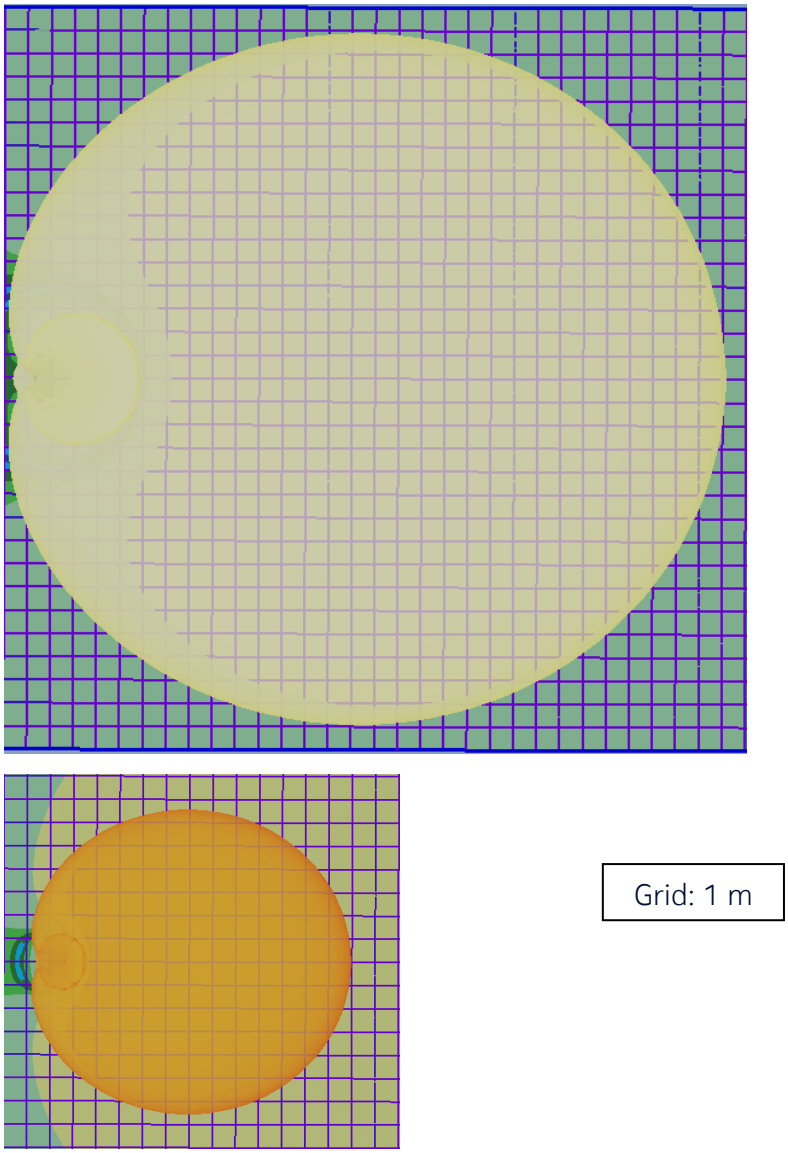


Figure 2 – Top view of the power density for the time-averaged maximum transmitted power of 339 W (EU/ICNIRP, Australia/NZ and US/related)

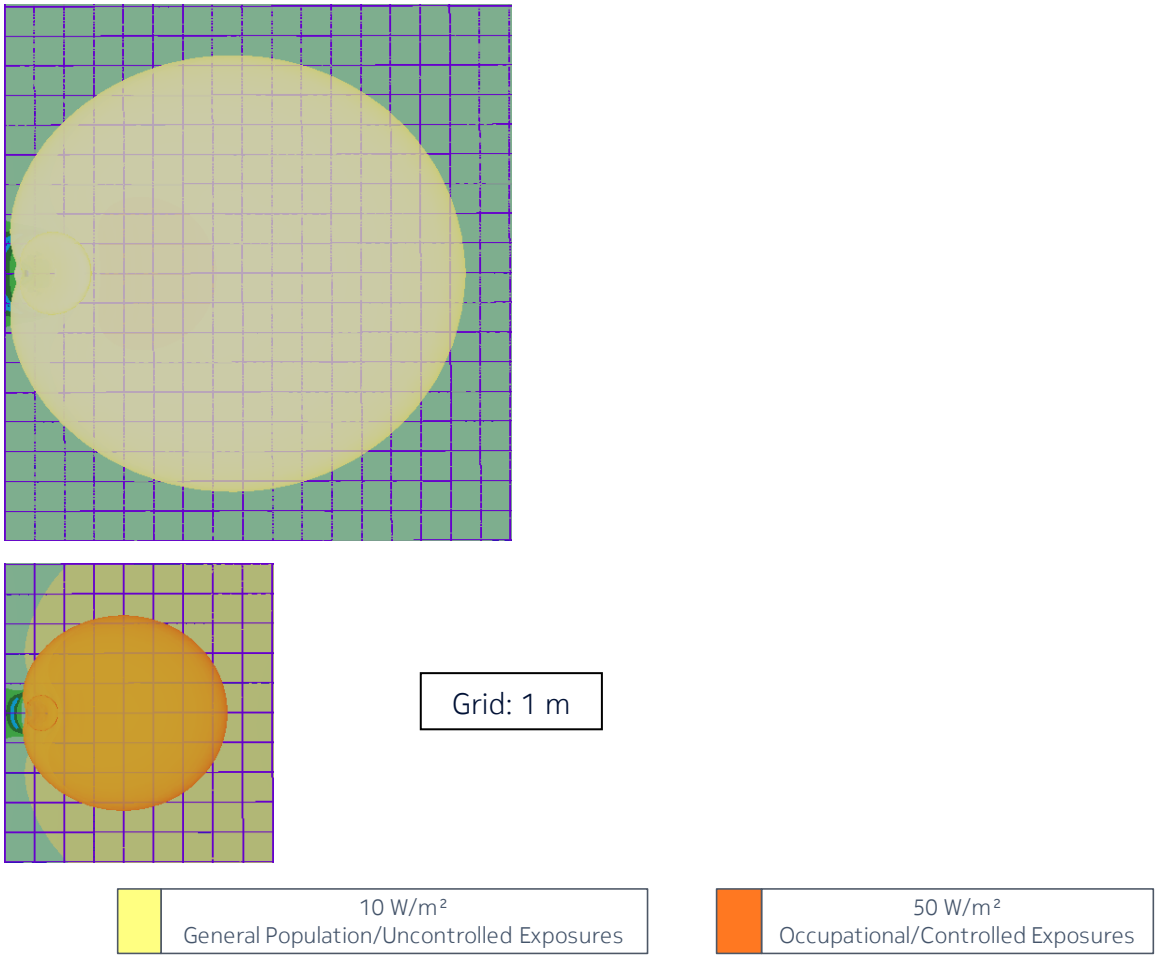


Figure 3 – Top view of the power density for the time-averaged actual maximum transmitted power of 85 W (EU/ICNIRP, Australia/NZ and US/related)

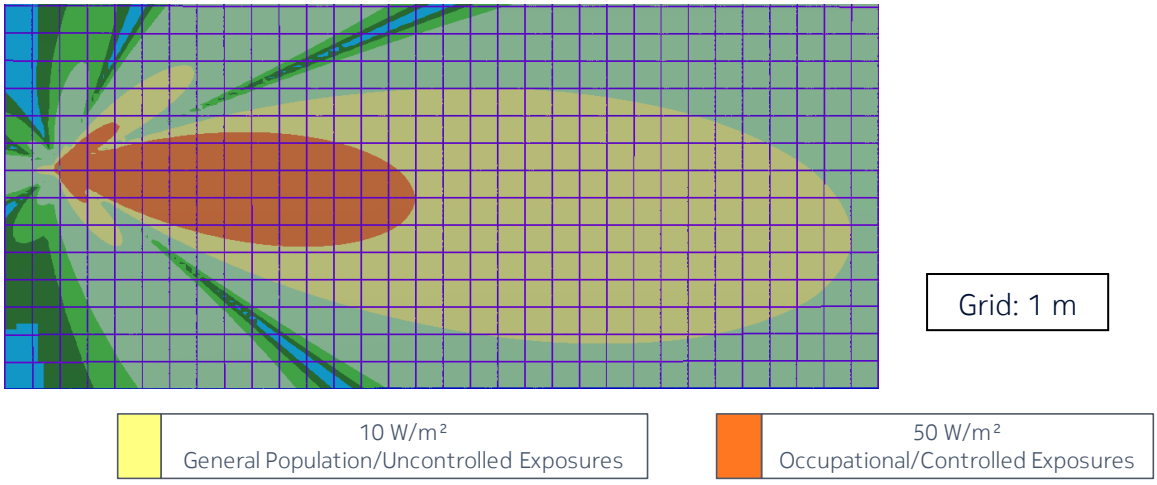


Figure 4 – Side view of the power density for the time-averaged maximum transmitted power of 339 W (EU/ICNIRP, Australia/NZ and US/related

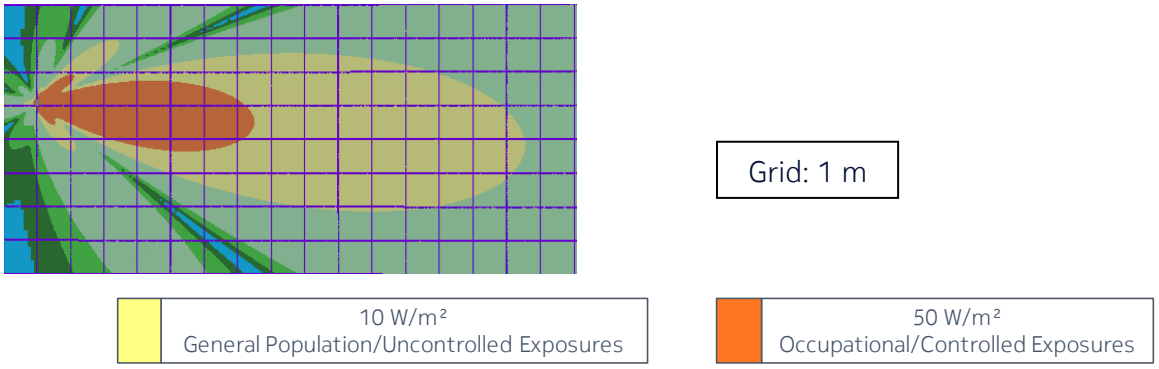


Figure 5 – Side view of the power density for the time-averaged actual maximum transmitted power of 85 W (EU/ICNIRP, Australia/NZ and US/related)

6.2 Regions of application: Canada

The computed power density distributions are displayed in Figure 6 to Figure 9 for RF exposure limits defined in [7] for Canada.

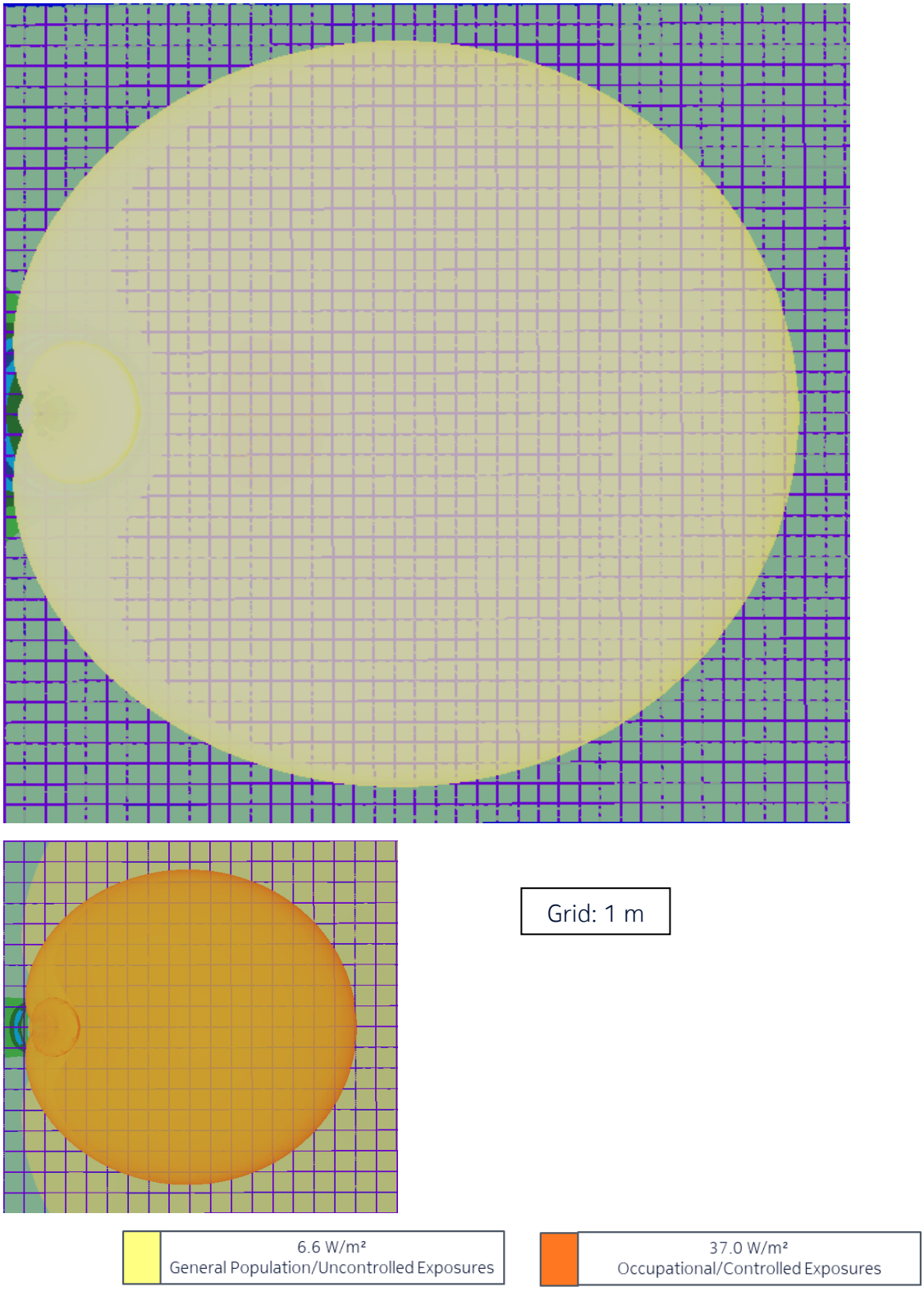


Figure 6 – Top view of the power density for the time-averaged maximum transmitted power of 339 W (Canada)

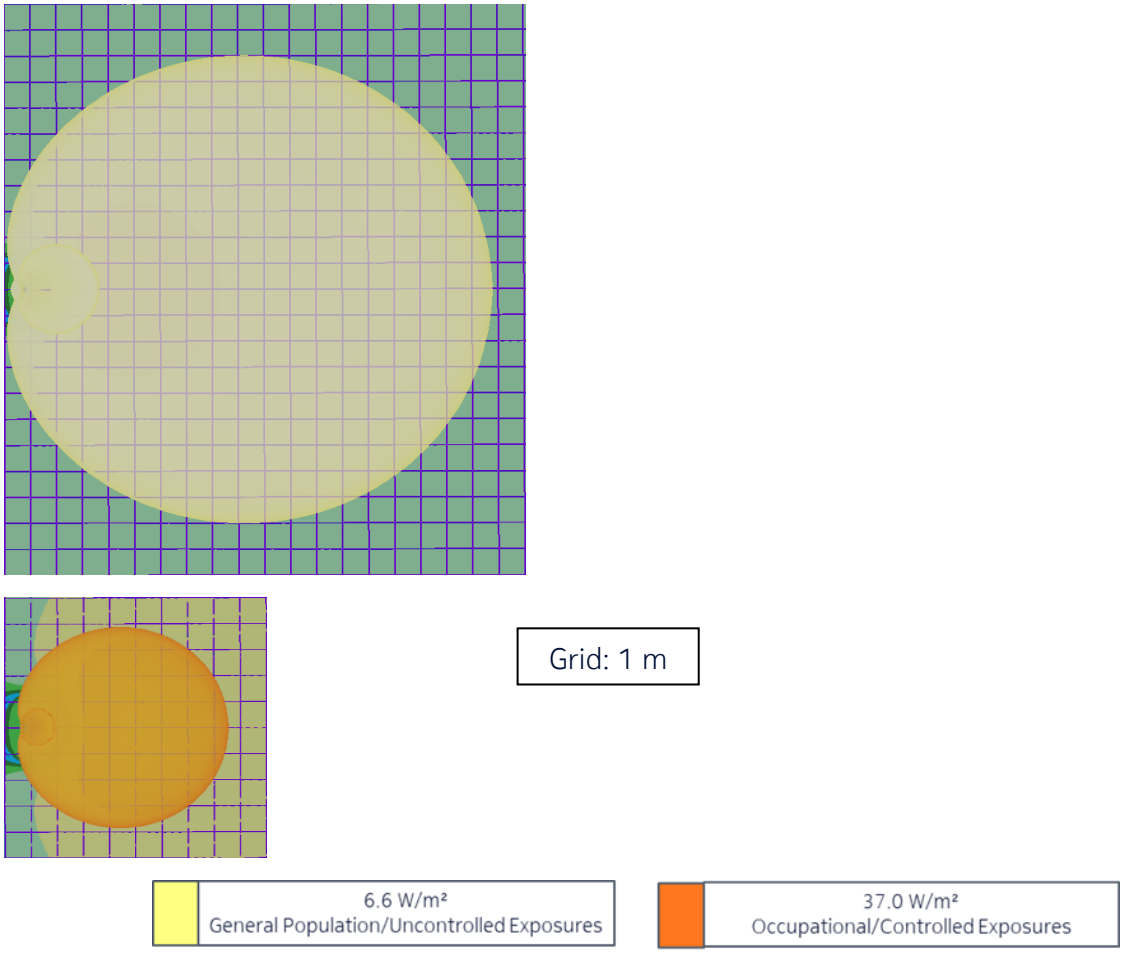


Figure 7 – Top view of the power density for the time-averaged actual maximum transmitted power of 85 W (Canada)

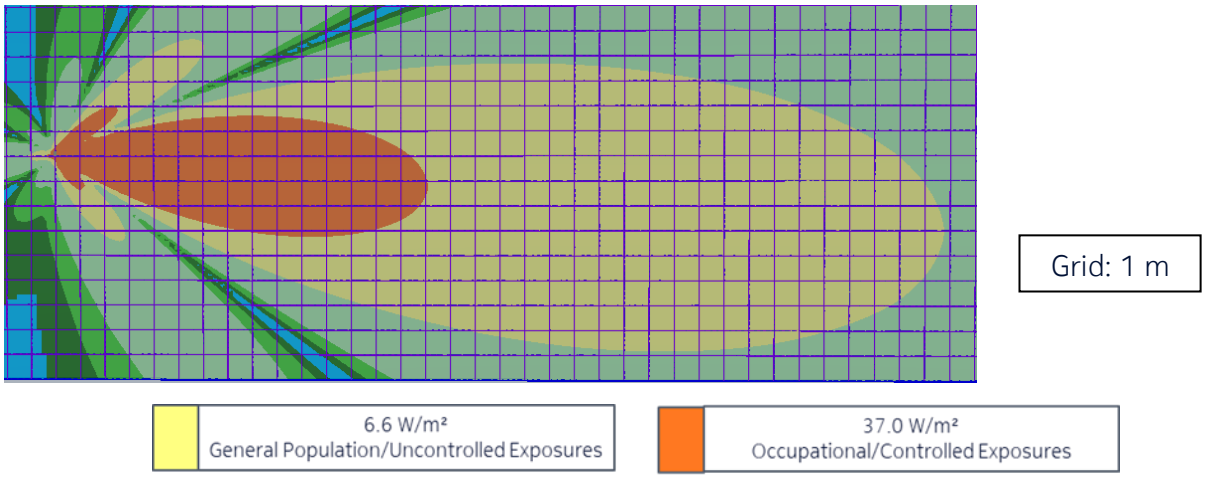


Figure 8 – Side view of the power density for the time-averaged maximum transmitted power of 339 W (Canada)

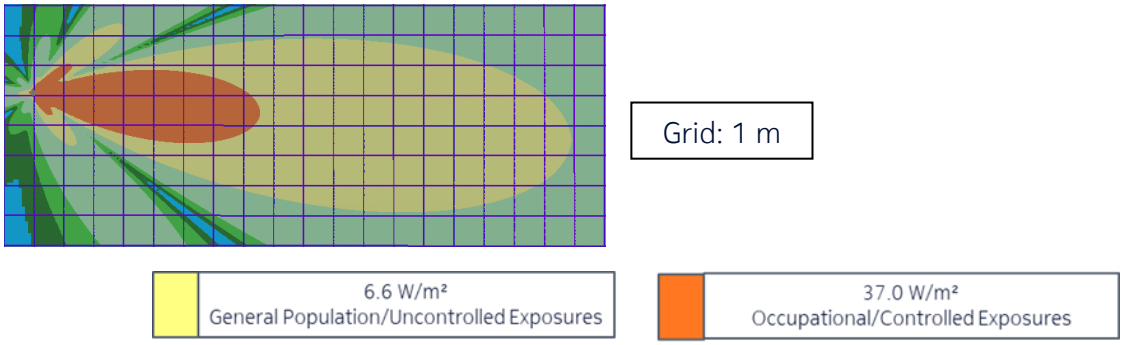


Figure 9 – Side view of the power density for the time-averaged actual maximum transmitted power of 85 W (Canada)

7 Conclusion and installation recommendations

The RF exposure compliance distances for the Nokia AQQE AirScale MAA 64T64R 192AE n78 320W, AQQK AirScale MAA 64T64R 192AE n77 320W and AQQL AirScale MAA 64T64R 192AE n78 320W products are summarized in Table 6 for EU/ICNIRP [1][2], Australia/NZ [5] and US/related [9] requirements and in Table 7 for Canada [7] requirements.

Table 6 – AQQE, AQQK and AQQL RF exposure compliance distances based on the time-averaged maximum transmitted power of 339 W (corresponding to 320 W rated max transmitted power) for EU/ICNIRP, Australia/NZ and US/related

Region of application: EU/ICNIRP, Australia/NZ and US/related	General Population/Uncontrolled Exposures	Occupational/Controlled Exposures
RF-EMF power density exposure limits	10 W/m²	50 W/m²
Distance in front (D_f)	29.2 m	13.0 m
Distance to the side ($D_{s,a}$)	14.8 m	6.3 m
Distance below ($D_{d,a}$)	5.9 m	2.3 m
Distance above ($D_{u,a}$)	3.4 m	1.3 m
Distance to the side ($D_{s,c}$)	15.0 m	6.5 m
Distance below ($D_{d,c}$)	6.4 m	2.8 m
Distance above ($D_{u,c}$)	3.9 m	1.8 m

Table 7 - AQQE, AQQK and AQQL RF exposure compliance distances based on the time-averaged maximum transmitted power of 339 W (corresponding to 320 W rated max transmitted power) for Canada

Region of application: Canada	General Population/Uncontrolled Exposures	Occupational/Controlled Exposures
RF-EMF power density exposure limits	6.6 W/m²	37.0 W/m²
Distance in front (D_f)	35.8 m	15.1 m
Distance to the side ($D_{s,a}$)	18.0 m	7.4 m
Distance below ($D_{d,a}$)	7.4 m	2.7 m
Distance above ($D_{u,a}$)	4.3 m	1.5 m
Distance to the side ($D_{s,c}$)	18.2 m	7.6 m
Distance below ($D_{d,c}$)	7.9 m	3.2 m
Distance above ($D_{u,c}$)	4.8 m	2.0 m

The RF exposure compliance distances based on the actual maximum transmitted power considering a 95th percentile approach are summarized in Table 8 and Table 9. 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], [14] and [15].

Table 8 – AQQE, AQQK and AQQL RF exposure compliance distances based on the time-averaged actual maximum transmitted power of 85 W (corresponding to 320 W rated max transmitted power) for EU/ICNIRP, Australia/NZ and US/related

For information in EU/ICNIRP, Australia/NZ and US/related countries based on IEC/EN 62232:2017 [4] and IEC TR62669 [15]	General Population/Uncontrolled Exposures	Occupational/Controlled Exposures
RF-EMF power density exposure limits	10 W/m²	50 W/m²
Distance in front (D_f)	14.5 m	6.5 m
Distance to the side ($D_{s,a}$)	7.2 m	3.1 m
Distance below ($D_{d,a}$)	2.7 m	0.9 m
Distance above ($D_{u,a}$)	1.5 m	0.5 m
Distance to the side ($D_{s,c}$)	7.4 m	3.3 m
Distance below ($D_{d,c}$)	3.2 m	1.4 m
Distance above ($D_{u,c}$)	2.0 m	1.0 m

Table 9 – AQQE, AQQK and AQQL RF exposure compliance distances based on the time-averaged actual maximum transmitted power 85 W (corresponding to 320 W rated max transmitted power) for Canada

For information in Canada based on IEC/EN 62232:2017 [4] and IEC TR62669 [15]	General Population/Uncontrolled Exposures	Occupational/Controlled Exposures
RF-EMF power density exposure limits	6.6 W/m²	37.0 W/m²
Distance in front (D_f)	17.8 m	7.6 m
Distance to the side ($D_{s,a}$)	8.8 m	3.7 m
Distance below ($D_{d,a}$)	3.4 m	1.1 m
Distance above ($D_{u,a}$)	2.0 m	0.6 m
Distance to the side ($D_{s,c}$)	9.0 m	3.9 m
Distance below ($D_{d,c}$)	3.9 m	1.6 m
Distance above ($D_{u,c}$)	2.5 m	1.1 m

Installation of the Nokia AQQE AirScale MAA 64T64R 192AE n78 320W, AQQK AirScale MAA 64T64R 192AE n77 320W and AQQL AirScale MAA 64T64R 192AE n78 320W products 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 6 and Table 7).
- 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 6 and Table 7). 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 ---------