RF exposure compliance assessment

AirScale High Power Wide Band Massive MIMO Adaptive Antenna Product – AVQQA

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Document Type	Final
Document ID	HATNKVKZMJPP-1868097887-1987
Document location	https://nokia.sharepoint.com/:f:/r/sites/EMF-ProductsRFexposureassessment/Shared%20Documents/Original/Products-RF-exposure-assessment/AVQQA?csf=1&web=1&e=PUQaWC

Change History

Version	Status	Date	Author	Owner	Reviewed by	Reviewed date	Approver	Approval date	Description of changes
1.0	Final	06-11-2023	K. Stopa, K. Bechta	C. Grangeat	C. Grangeat	13-11-2023	Yi Rao	17-11-2023	
2.0	Final	04-07-2024	K. Bechta	C. Grangeat	C. Grangeat	06-08-2024	O. Keskitalo	06-08-2024	Simulation model update; editorial corrections

FCC ID: VBNAVQQA-01

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1 General content

This assessment report is addressing human exposure to radiofrequency electromagnetic fields (RF EMF) transmitted by the following AirScale High Power Wide Band MAA product (see §2.2):

- Nokia AVQQA AirScale MAA 64T64R n77/78 340 W

It provides the RF exposure compliance boundaries for this product 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] ICNIRP-2020, International Commission on Non-Ionizing Radiation Protection (ICNIRP), "Guidelines for limiting exposure to electromagnetic fields (100 kHz to 300 GHz)", Health Physics, 118(5):483-524; 2020

[2] 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

[3] 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

[4] ARPANSA "Standard for Limiting Exposure to Radiofrequency Fields – 100 kHz to 300 GHz", Radiation Protection Series S-1, Feb 2021

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

[6] US FCC 47CFR 1.1310 "Radiofrequency radiation exposure limits", August 1997

2.2 Product and assessment method

[7] Nokia, "Massive MIMO Adaptive Antenna Product Description" DN207523773, Issue 07, 08-06-2020

[8] Microwave Vision Group (MVG), "EMF Visual User Manual", SEWB/EMF-VISUAL-UM.1/v2024.02

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[9] 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

[10] 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

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

[12] IEC 62232:2022 ED3, “Determination of RF field strength, power density and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure”, 2022

[13] 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

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

[15] Canada RSS-102, “Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands)”, Issue 6, December 15, 2023

[16] 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

[17] 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], [2] and [3] in Europe and ICNIRP countries, by [4] in Australia and New Zealand, by [5] in Canada and by [6] 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.

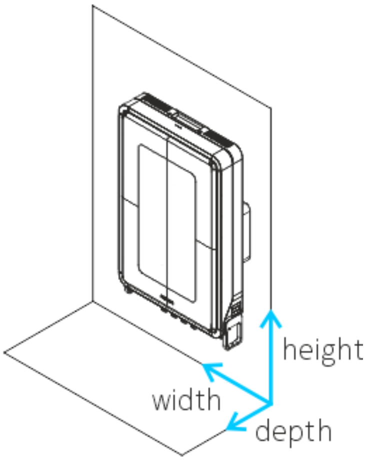
Table 1 – Applicable RF exposure levels in n77 band expressed in power density

Region of application	General Population/Uncontrolled Exposures	Occupational/Controlled Exposures
EU/ICNIRP, Australia/NZ, US/related,	10 W/m²	50 W/m²
Canada	6.8 W/m²	37.9 W/m²

4 Description of the equipment under test (EUT)

The main technical characteristics of AVQQA product are reproduced in Table 2.

Table 2 – AVQQA product general technical characteristics

Product name	Nokia AVQQA AirScale MAA 64T64R n77 340 W	
Model number	476345A	
Rated max Tx power	340 W	
Number of TXRX	64TX64RX	
Beamforming	Yes	
Standard	3GPP/FCC/ISED	
Frequency range	3450-3550 MHz 3700-3980 MHz	
Nb of antenna elements	12 (row) x 8 (column) x 2 (polarization)	
Typical Antenna Gain	25 dBi ±1 dB	
Total average EIRP	80.3 dBm ±1 dB	
Azimuth scanning range	±45° (3dB), ±50° (4dB)	
Vertical pre-tilt angle	+6°	
Elevation scanning range	±7° (upper SLS > 6dB); ±4° (upper SLS >10dB)	
Dimensions 	Height: 760 mm Width: 405 mm Depth: 185 mm	
Technology duty cycle factor	75 %	
Transmitted power tolerance	1.5 dB	

The pattern models used for the RF exposure assessment are derived from the model of the antenna array (pattern and gain) using the real beamforming weights (BFW) configured in the product. The pattern models are validated with the product antenna model using the same BFW, pattern and gain. Table 4 to Table 8 include the comparison of the pattern model for RF exposure assessment and the product antenna model for beam configurations used for the assessment of the compliance boundary. Selected patterns ensure 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 [17])

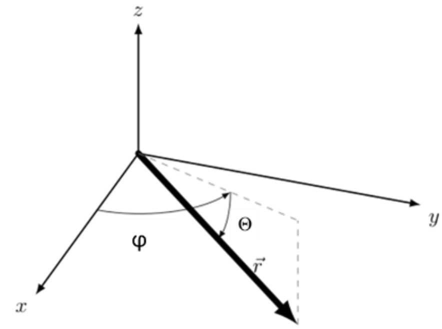
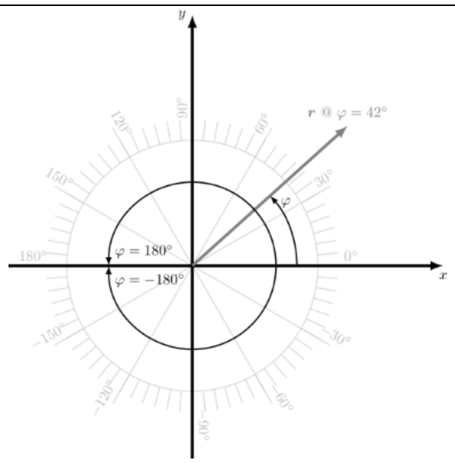
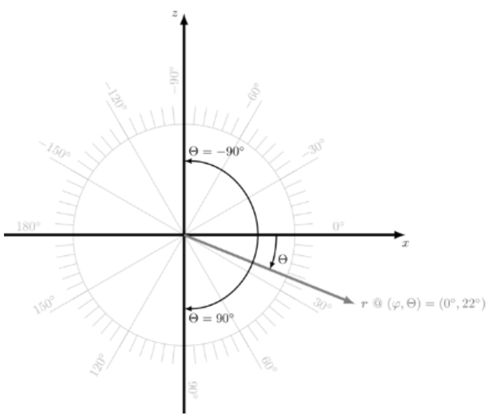
3D view Defintion of azimuth φ and elevation θ	
Top view (horizontal cut) Definition of azimuth φ	
Side view (vertical cut) Definition of elevation θ	

Table 4 – Antenna patterns for the boresight direction for 3500 MHz

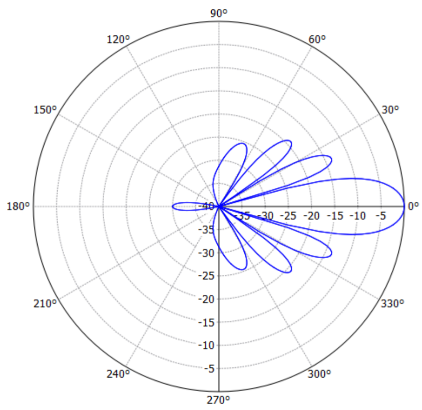
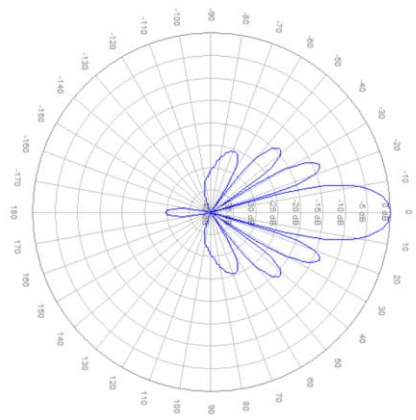
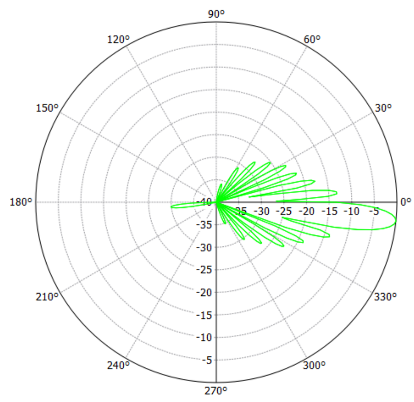
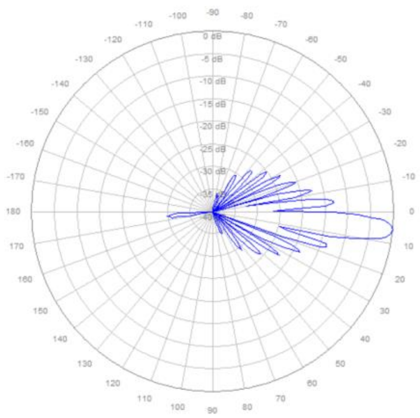
	Model for EMF evaluation	Product antenna model
Horizontal cut		
Vertical cut		
NOTE: Angle references used in these graphs are derived from EMF Visual (left) and Planet Viewer (right), which may differ from product data sheet (see Table 3)		

Table 5 – Antenna patterns for max azimuth steering for 3500 MHz

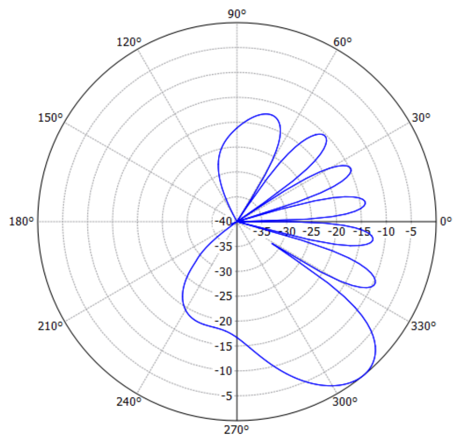
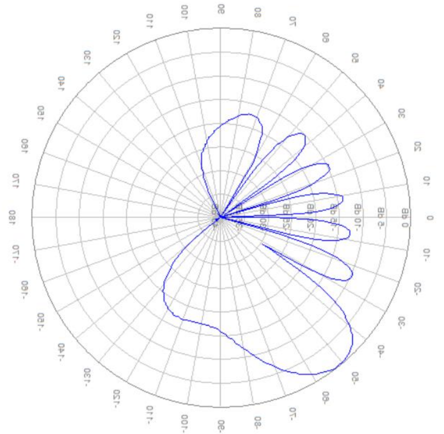
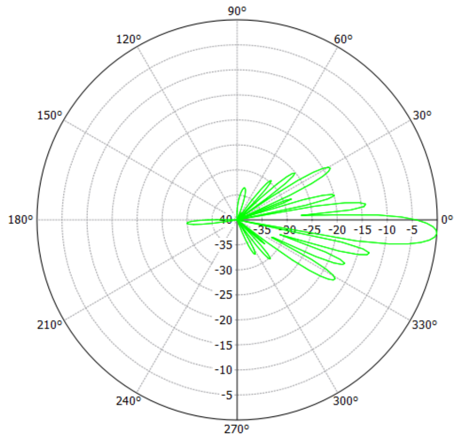
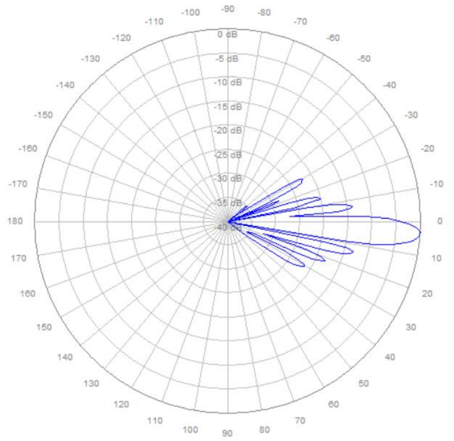
	Model for EMF evaluation	Product antenna model
Horizontal cut		
Vertical cut		
NOTE: Angle references used in these graphs are derived from EMF Visual (left) and Planet Viewer (right), which may differ from product data sheet (see Table 3)		

Table 6 – Antenna patterns for max down-tilt steering for 3500 MHz

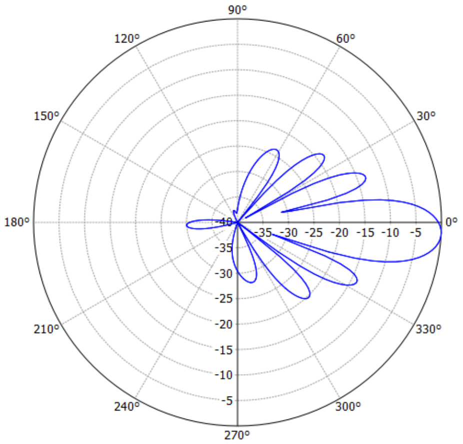
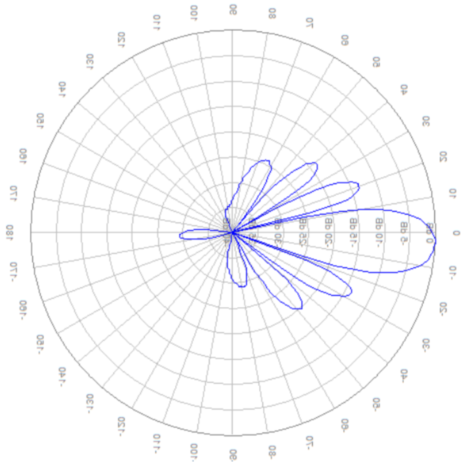
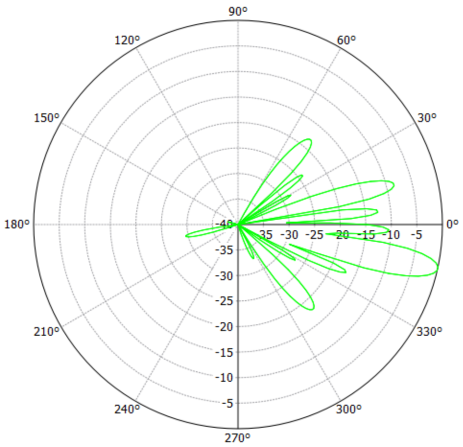
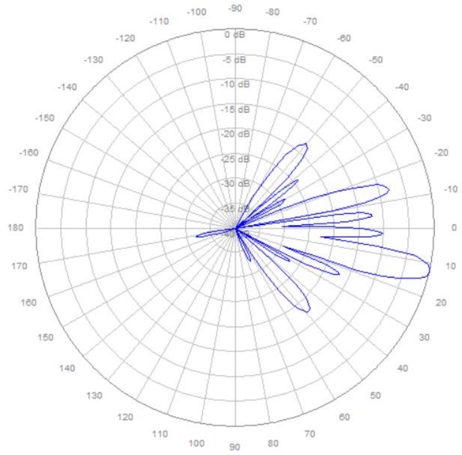
	Model for EMF evaluation	Product antenna model
Horizontal cut		
Vertical cut		
NOTE: Angle references used in these graphs are derived from EMF Visual (left) and Planet Viewer (right), which may differ from product data sheet (see Table 3)		

Table 7 – Antenna patterns for max up-tilt steering for 3500 MHz

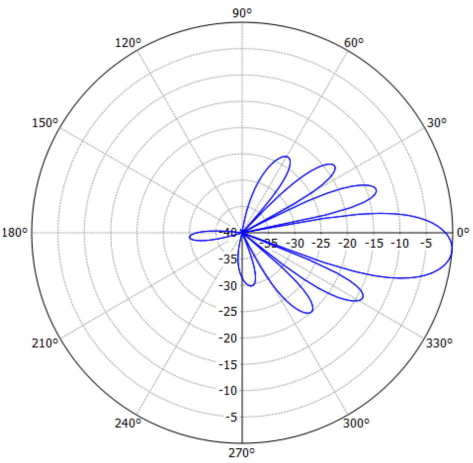
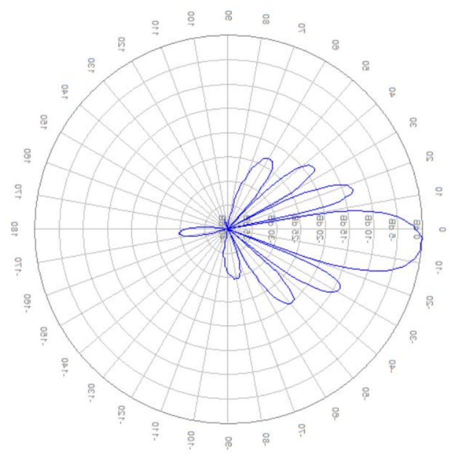
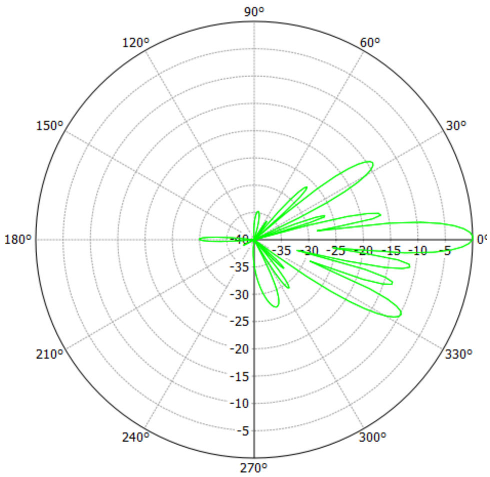
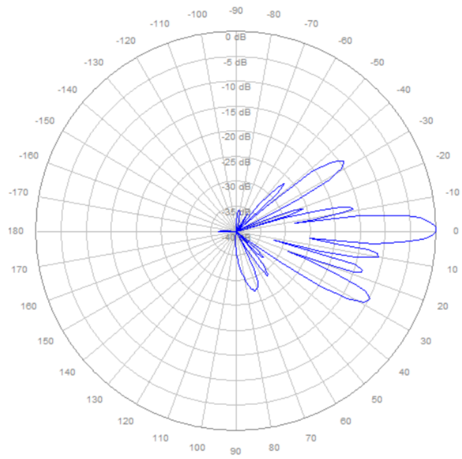
	Model for EMF evaluation	Product antenna model
Horizontal cut		
Vertical cut		
NOTE: Angle references used in these graphs are derived from EMF Visual (left) and Planet Viewer (right), which may differ from product data sheet (see Table 3)		

Table 8 – Antenna gain characteristics for various beam steering directions used during EMF evaluation

	Azimuth	Elevation	Gain (dBi)
Boresight	0°	+6°	24.9
Max azimuth	-51°	+4°	20.8
Max down-tilt	-3°	+12°	23.8
Max up-tilt	-5°	-1°	24.2

The compliance boundary is defined by the box shape perimeter shown in Figure 4 of IEC 62232 [12] and displayed in Figure 1. The distances CD_f, $CD_{s,a}$, $CD_{u,a}$ and $CD_{d,a}$ are taken from the nearest point of the antenna. For convenience, the distances $CD_{s,c}$, $CD_{u,c}$ and $CD_{d,c}$ (respectively) taken from antenna center are also provided.

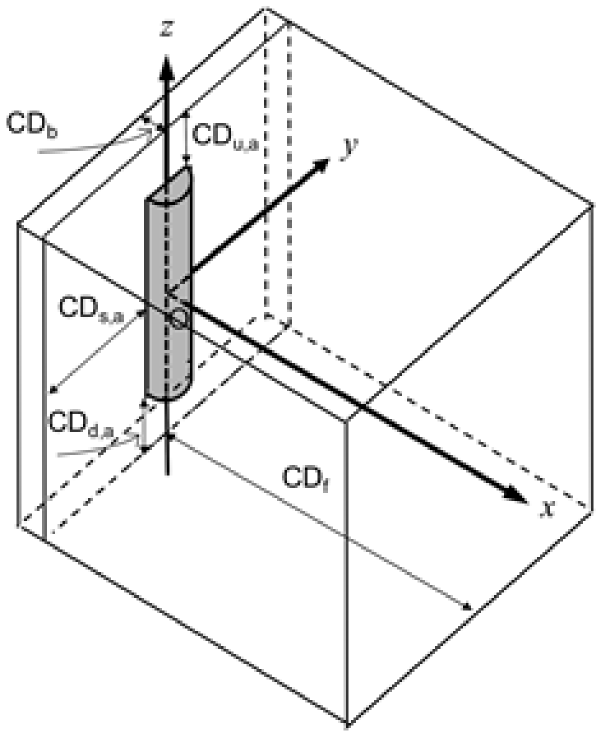


Figure 1 – Shape of the compliance boundary used for the RF exposure compliance assessment (from [12]).

5 RF exposure assessment method

RF exposure assessment is performed using the synthetic model computation method defined in B.7.2.1 of IEC 62232 [12]. Calculations are performed with the “EMF Visual” software release OKTAL 2024.02 Version 4.0 (see [8] and [9]).

The validation of the model is performed in the configuration with the beam in front (azimuth = 0° and elevation = +6°). The validation results are provided in Table 9.

Table 9 - Validation of the antenna model at 3500 MHz

	Product model	EMF Visual model	Deviation
Gain	24.9 dBi	24.9 dBi	0 dBi
Horizontal half-power beamwidth	14.0°	14.0°	0.0 °
Vertical half-power beamwidth	8.0°	6.75°	1.25°

For each configuration, 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 360.2 W. This value corresponds to the time-averaged maximum EIRP of 80.5 dBm in the boresight direction. The RF compliance distances are also provided for the actual EIRP threshold of 74.5 dBm, applying a power reduction factor of – 6 dB as defined in [10], [11] and [12]. 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 3D distributions of power density are displayed in Figure 2 to Figure 9 for both general public and occupational RF exposure limits defined in [1],[2] and [3] for EU/ICNIRP countries, [4] for Australia/NZ and [6] for US/related countries.

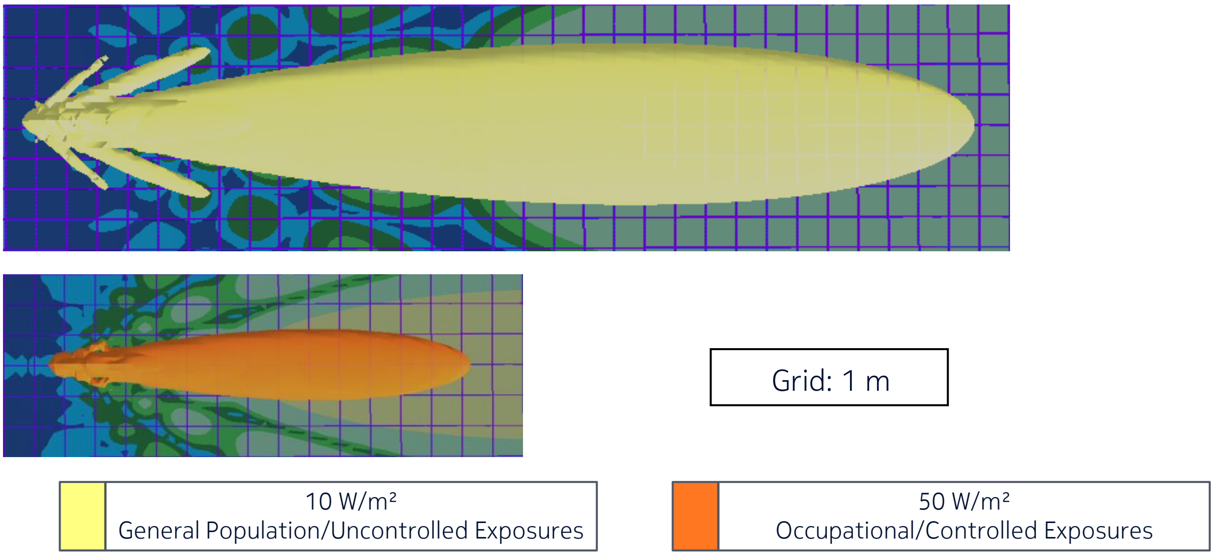


Figure 2 – Top view of the power density for the time-averaged maximum transmitted power of 360.2 W and beam oriented in azimuth = 0° & elevation = +6° with a gain of 24.9 dBi (EU/ICNIRP, Australia/NZ and US/related)

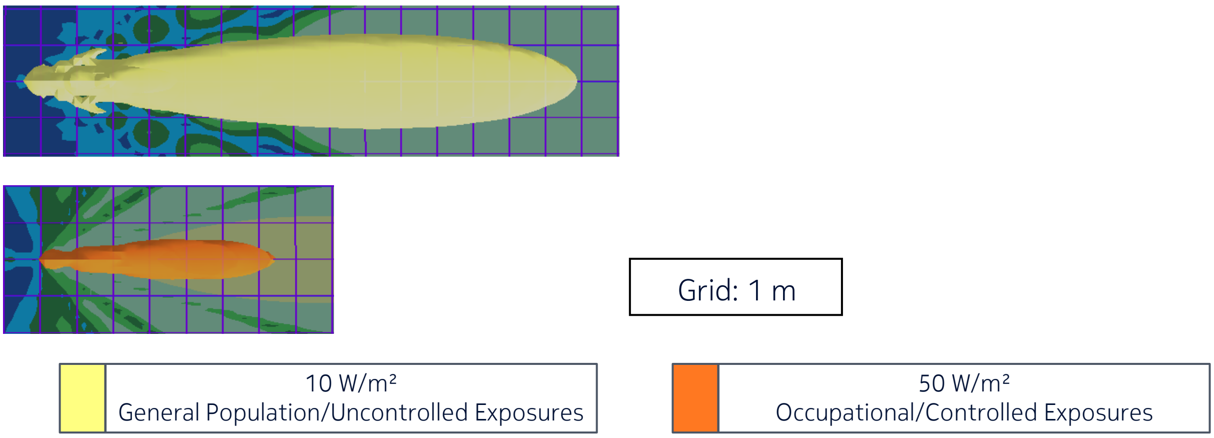


Figure 3 - Top view of the power density for the actual maximum transmitted power of 90 W (corresponding to the actual EIRP threshold of 74.5 dBm) and beam oriented in azimuth = 0° & elevation = +6° with a gain of 24.9 dBi (EU/ICNIRP, Australia/NZ and US/related)

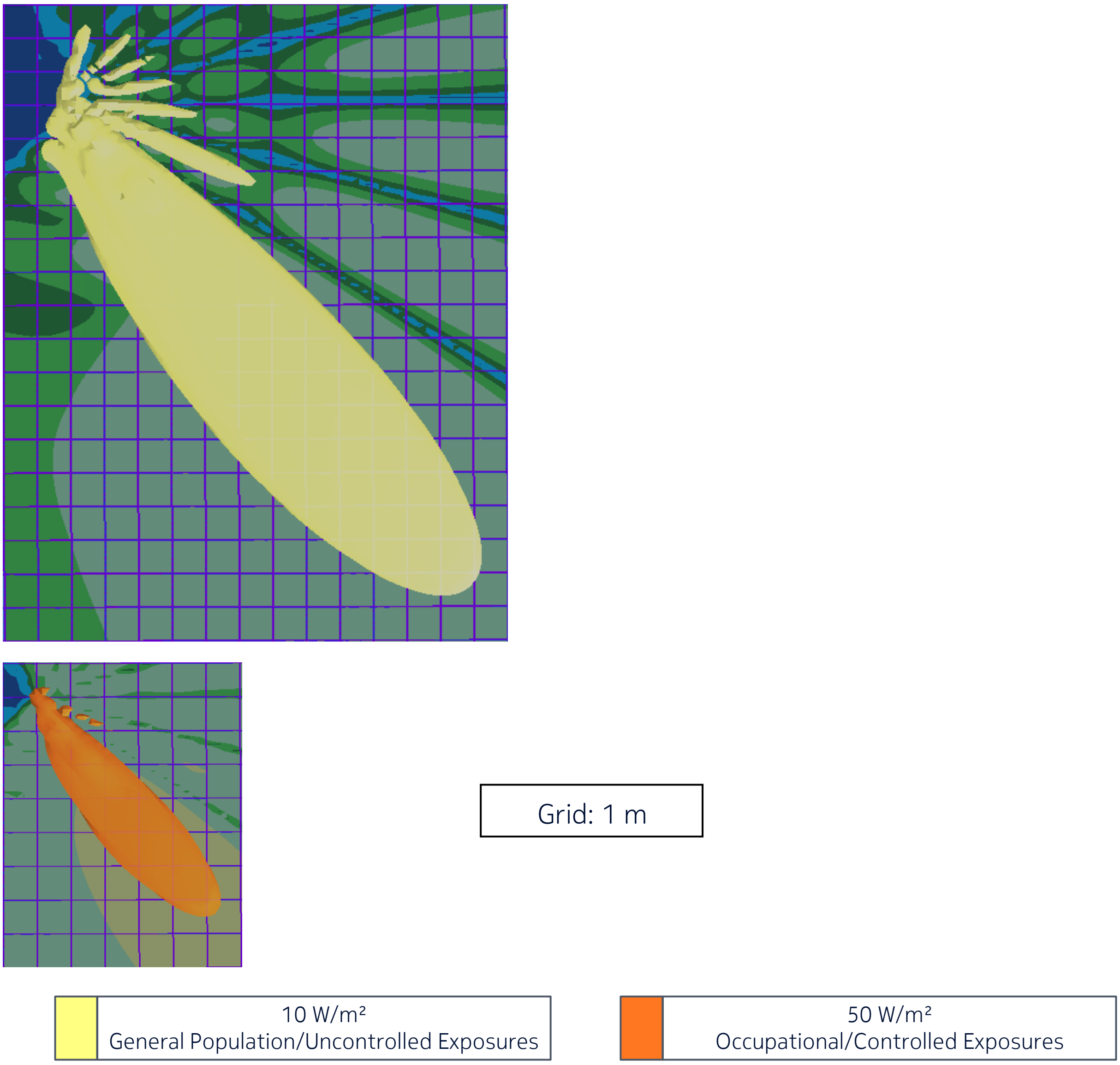
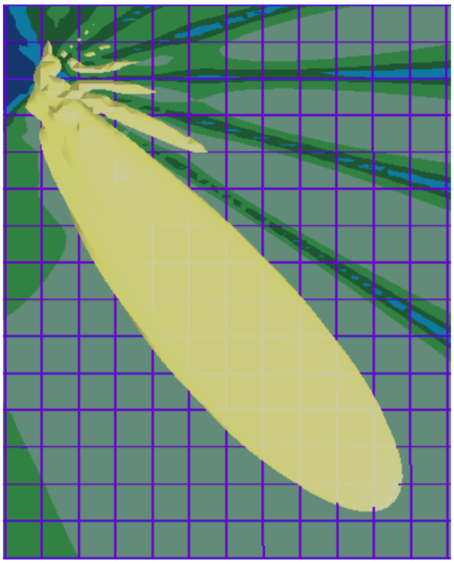
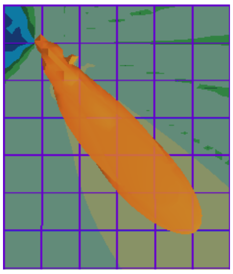


Figure 4 – Top view of the power density for the time-averaged maximum transmitted power of 360.2 W and beam oriented in azimuth = -51° & elevation = +4° with a gain of 20.8 dBi (EU/ICNIRP, Australia/NZ and US/related)





Grid: 1 m

	10 W/m² General Population/Uncontrolled Exposures		50 W/m² Occupational/Controlled Exposures

Figure 5 – Top view of the power density for the actual maximum transmitted power of 232 W (corresponding to the actual EIRP threshold of 74.5) and beam oriented in azimuth = -51° & elevation = +4° with a gain of 20.8 dBi (EU/ICNIRP, Australia/NZ and US/related)

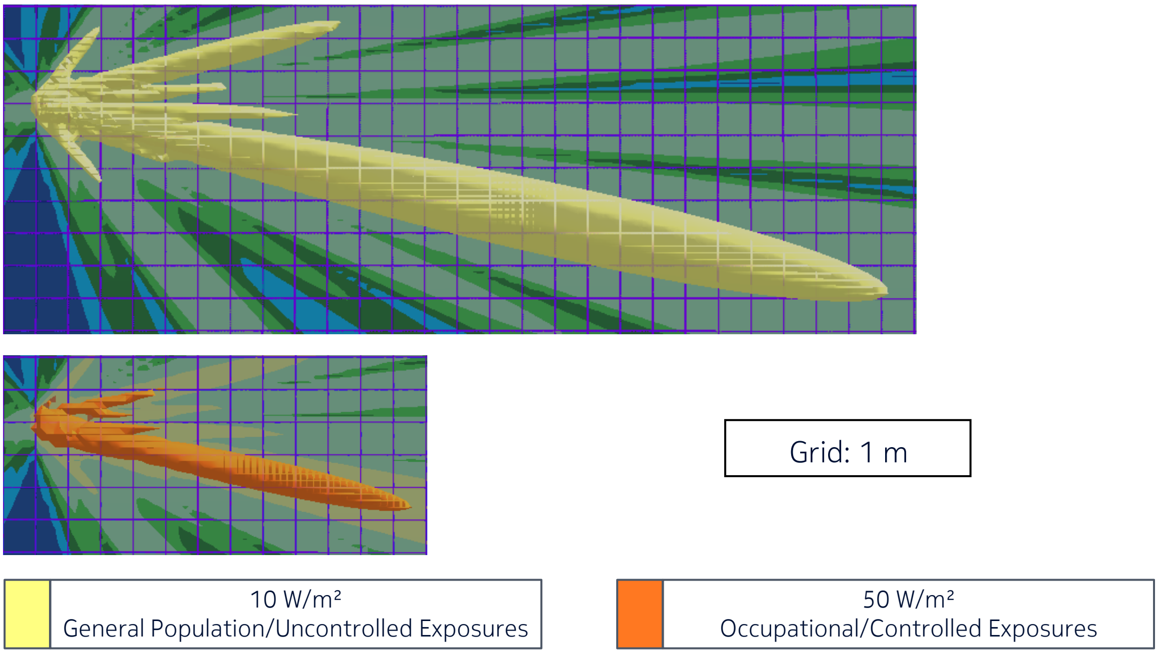


Figure 6 – Side view of the power density for the time-averaged maximum transmitted power of 360.2 W and beam oriented in azimuth = -3° & elevation = +12° with a gain of 23.8 dBi (EU/ICNIRP, Australia/NZ and US/related)

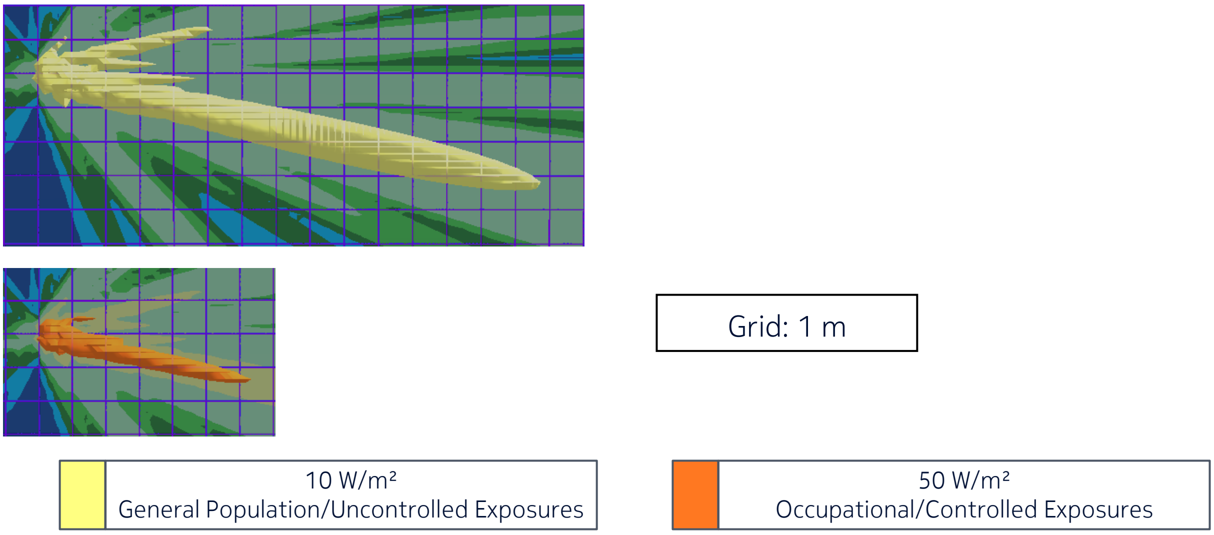


Figure 7 – Side view of the power density for the actual maximum transmitted power of 116 W (corresponding to the actual EIRP threshold of 74.5 dBm) and beam oriented in azimuth = -3° & elevation = +12° with a gain of 23.8 dBi (EU/ICNIRP, Australia/NZ and US/related)

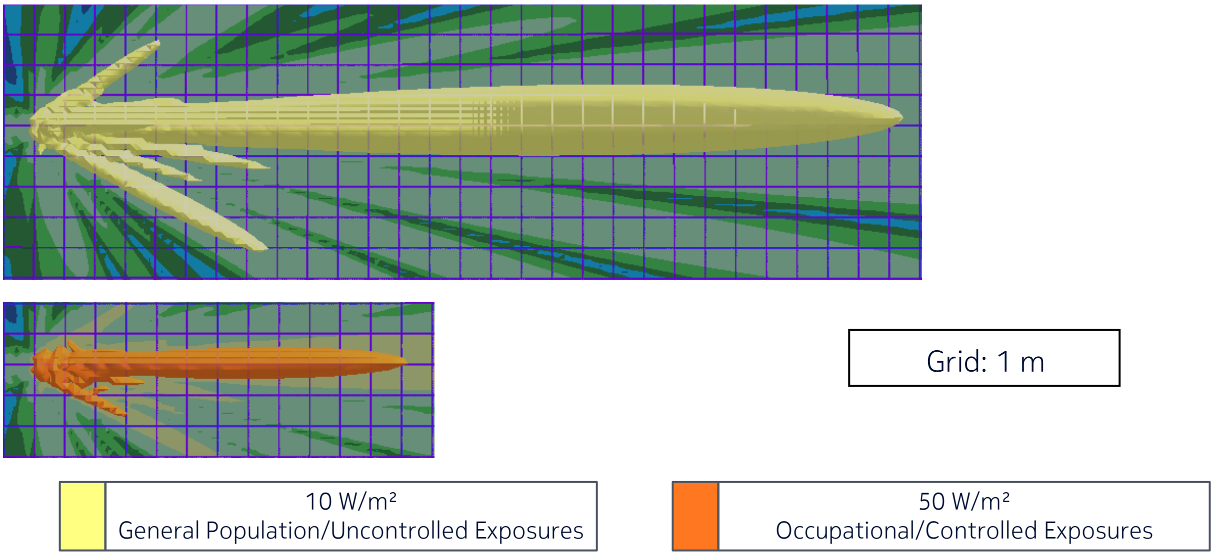


Figure 8 – Side view of the power density for the time-averaged maximum transmitted power of 360.2 W and beam oriented in azimuth = -5° & elevation = -1° with a gain of 24.2 dBi and (EU/ICNIRP, Australia/NZ and US/related)

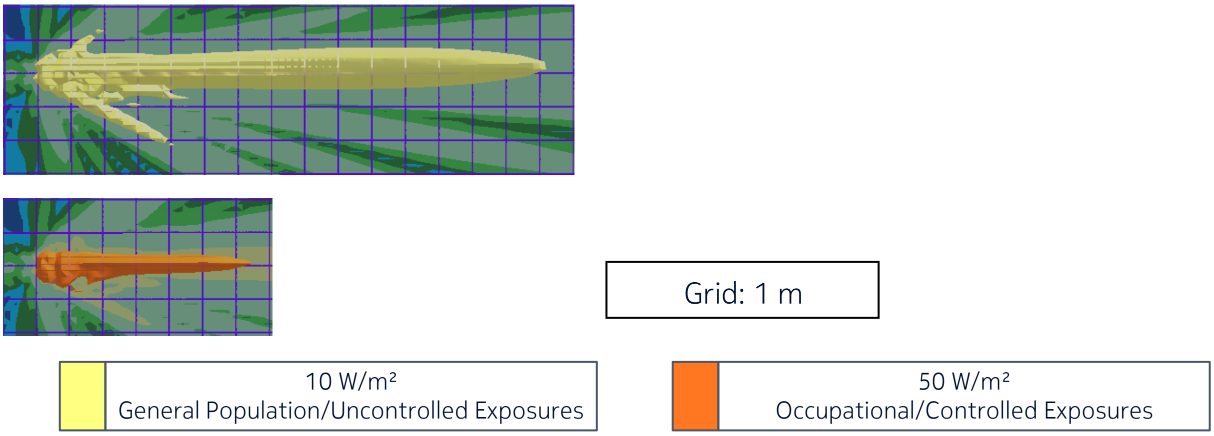


Figure 9 - Side view of the power density for the actual maximum transmitted power of 106 W (corresponding to the actual EIRP threshold of 74.5) and beam oriented in azimuth = -5° & elevation = -1° with a gain of 24.2 dBi (EU/ICNIRP, Australia/NZ and US/related)

6.2 Regions of application: Canada

The computed 3D distributions of power density are displayed in Figure 10 to Figure 17 for both general public and occupational RF exposure limits defined in [5] for Canada.

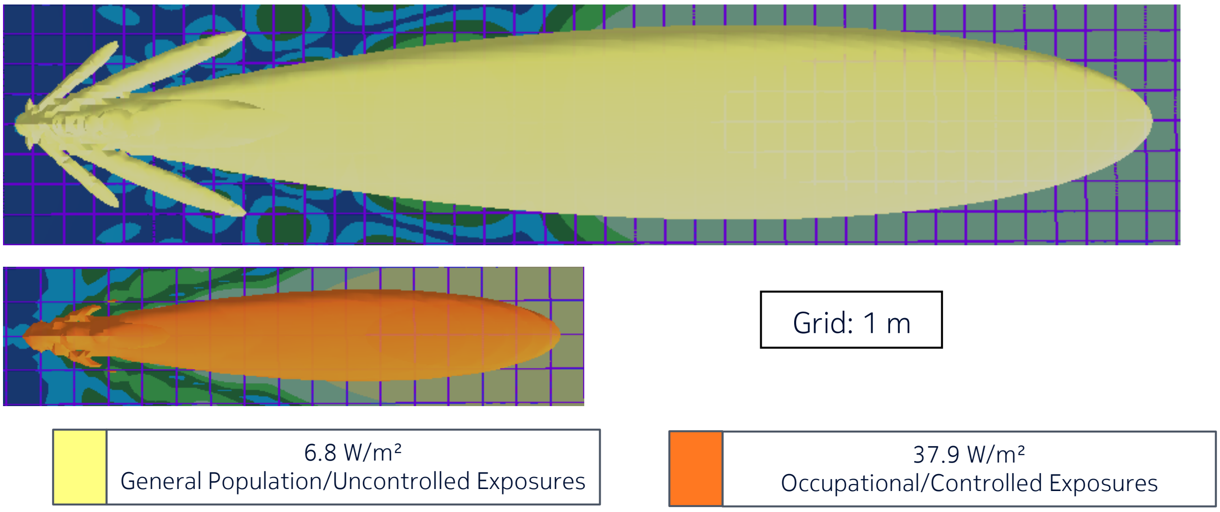


Figure 10 – Top view of the power density for the time-averaged maximum transmitted power of 360.2 W and beam oriented in azimuth = 0° & elevation = +6° with a gain of 24.9 dBi (Canada)

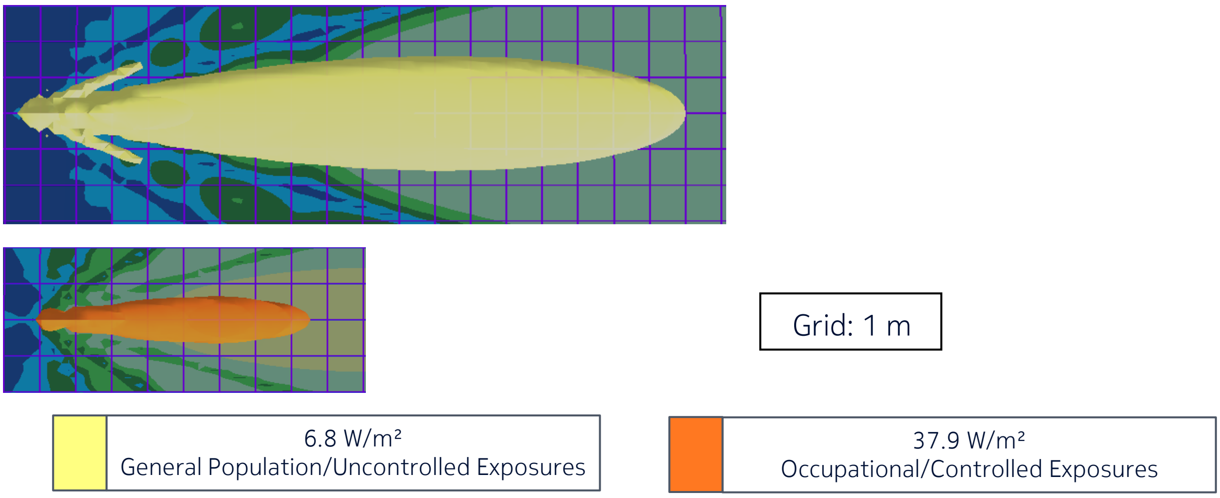
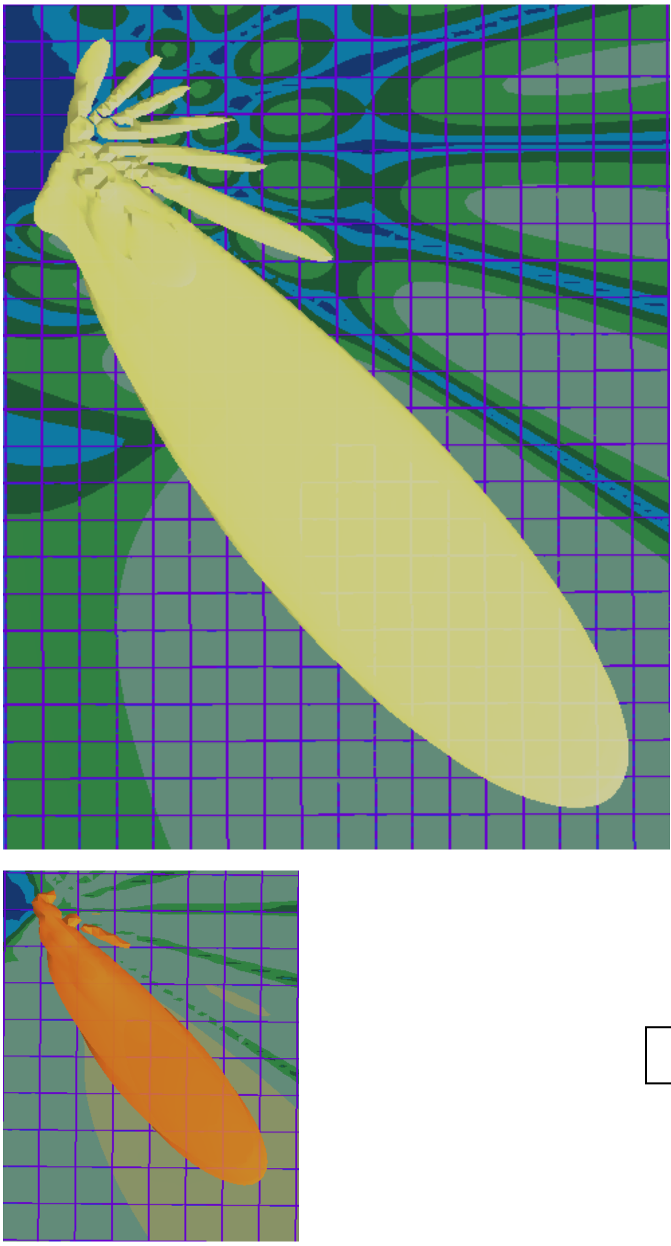


Figure 11 – Top view of the power density for the actual maximum transmitted power of 90 W (corresponding to the actual EIRP threshold of 74.5 dBm) and beam oriented in azimuth = 0° & elevation = +6° with a gain of 24.9 dBi (Canada)



Grid: 1 m

Yellow	6.8 W/m² General Population/Uncontrolled Exposures
Orange	37.9 W/m² Occupational/Controlled Exposures

Figure 12 - Top view of the power density for the time-averaged maximum transmitted power of 360.2 W and beam oriented in azimuth = -51° & elevation = +4° with a gain of 20.8 dBi (Canada)

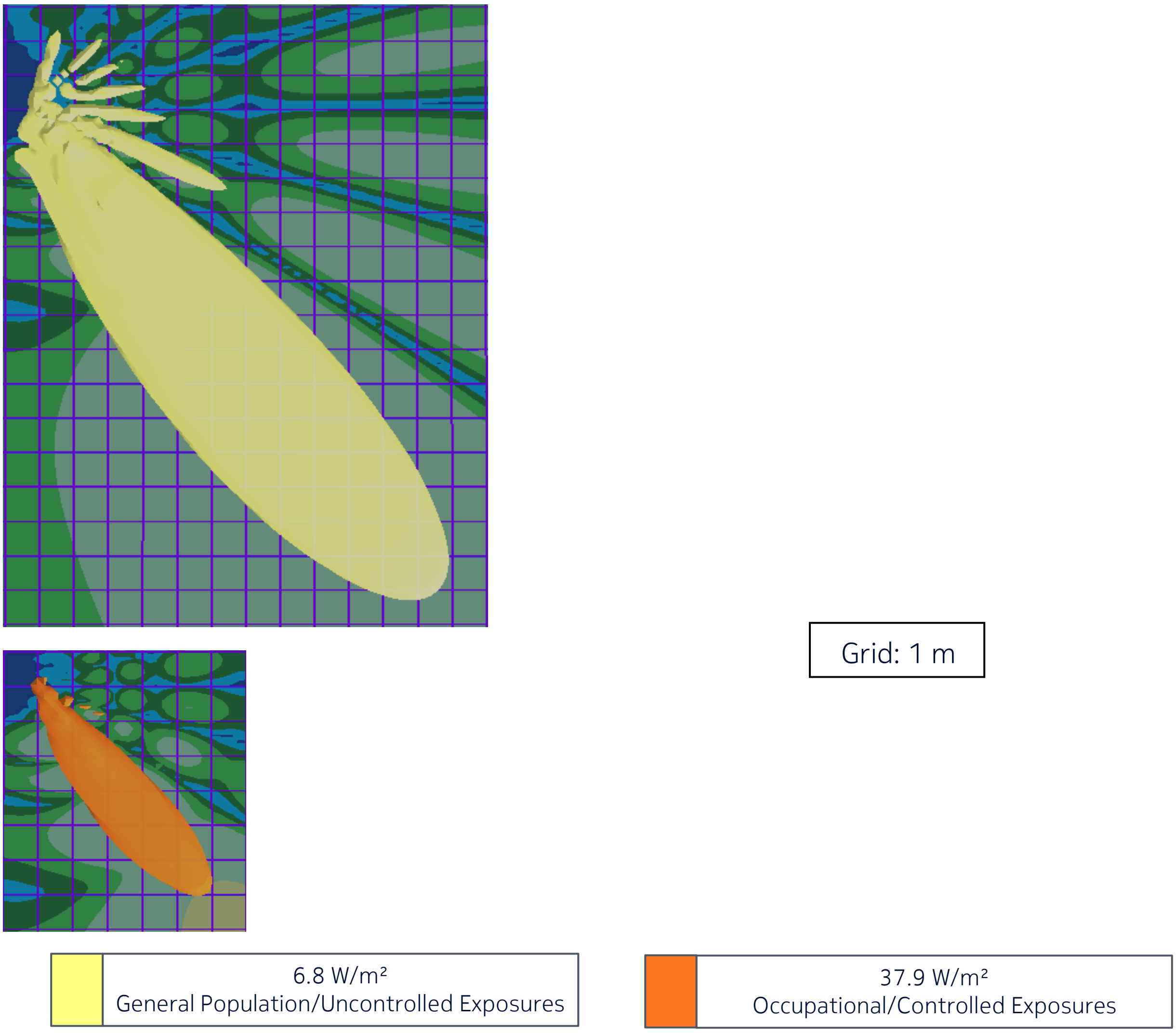
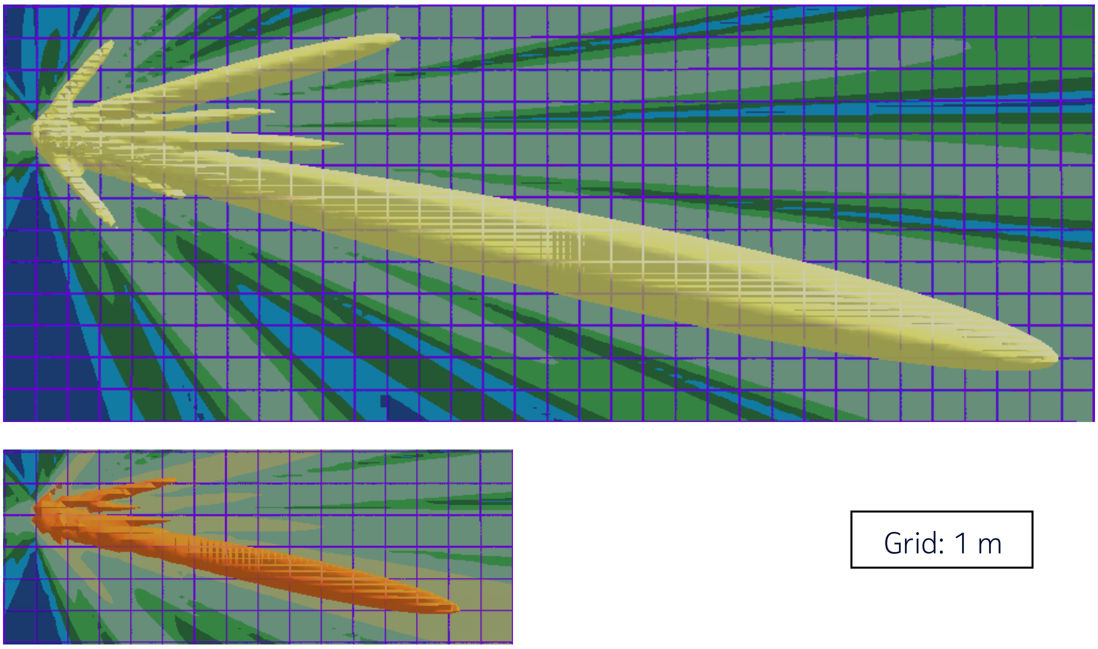


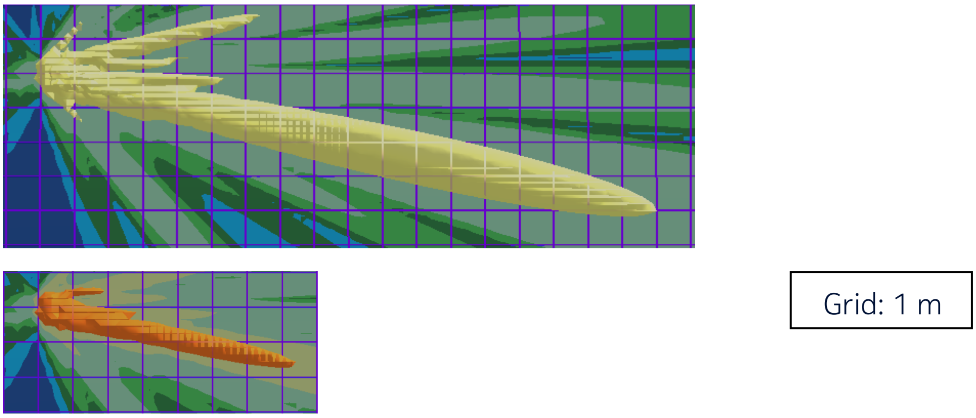
Figure 13 - Top view of the power density for the actual maximum transmitted power of 232 W (corresponding to the actual EIRP threshold of 74.5 dBm) and beam oriented in azimuth = -51° & elevation = +4° with a gain of 20.8 dBi (Canada)



6.8 W/m²
General Population/Uncontrolled Exposures

37.9 W/m²
Occupational/Controlled Exposures

Figure 14 - Side view of the power density for the time-averaged maximum transmitted power of 360.2 W and beam oriented in azimuth = -3° & elevation = +12° with a gain of 23.8 dBi (Canada)



6.8 W/m²
General Population/Uncontrolled Exposures

37.9 W/m²
Occupational/Controlled Exposures

Figure 15 – Side view of the power density for the actual maximum transmitted power of 116 W (corresponding to the actual EIRP threshold of 74.5 dBm) and beam oriented in azimuth = -3° & elevation = +12° with a gain of 23.8 dBi (Canada)

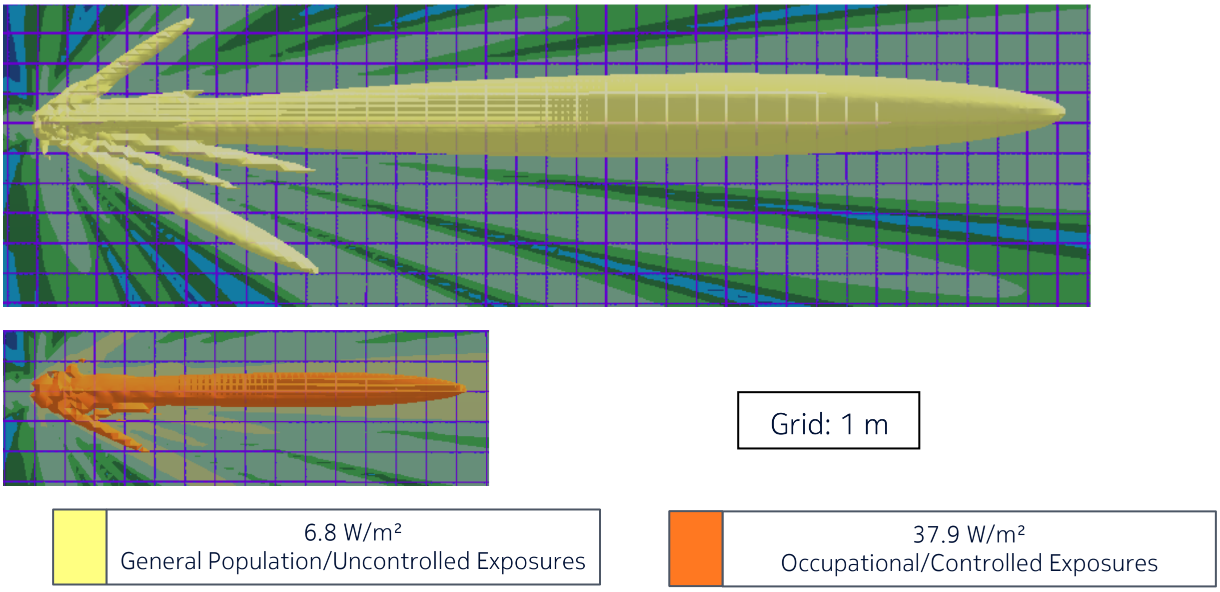


Figure 16 – Side view of the power density for the time-averaged maximum transmitted power of 360.2 W and beam oriented in azimuth = -5° & elevation = -1° with a gain of 24.2 (Canada)

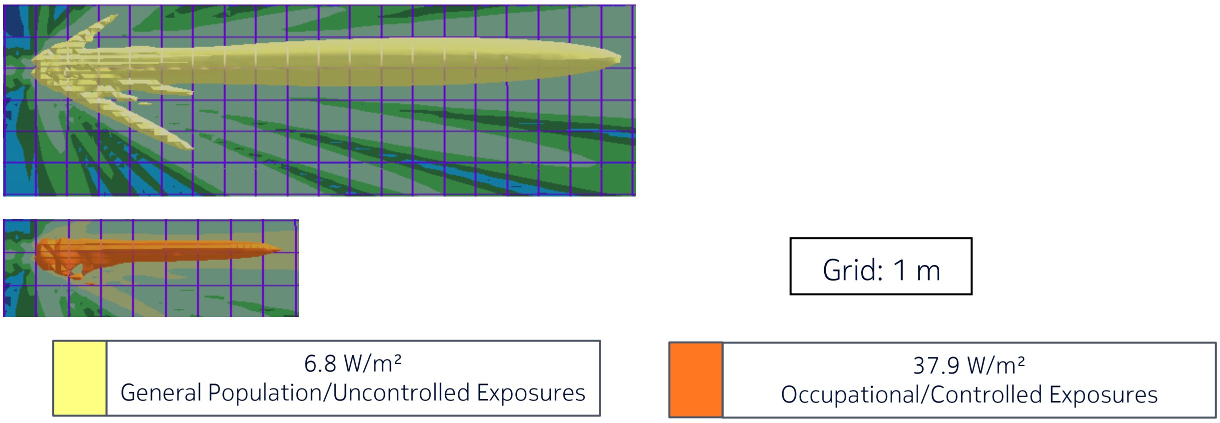


Figure 17 – Side view of the power density for the actual maximum transmitted power of 106 W (corresponding to the actual EIRP threshold of 74.5 dBm) and beam oriented in azimuth = -5° & elevation = -1° with a gain of 24.2 dBi (Canada)

7 Conclusion and installation recommendations

The RF exposure compliance distances for the Nokia AVQQA AirScale Dualband MAA 64T64R n77 340 W product are summarized in Table 10 for EU/ICNIRP [1][2][3], Australia/NZ [4] and US/related [6] requirements and in Table 11 for Canada [5] requirements.

Table 10 – AVQQA RF exposure compliance distances based on the time-averaged maximum transmitted power of 360.2 W 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 (CD_f)	29.9 m	13.3 m
Distance to the side ($CD_{s,a}$)	14.5 m	6.3 m
Distance below ($CD_{d,a}$)	5.8 m	2.5 m
Distance above ($CD_{u,a}$)	2.6 m	0.8 m
Distance to the side ($CD_{s,c}$)	14.7 m	6.5 m
Distance below ($CD_{d,c}$)	6.1 m	2.8 m
Distance above ($CD_{u,c}$)	2.9 m	1.1 m

Table 11 – AVQQA RF exposure compliance distances based on the time-averaged maximum transmitted power of 360.2 W for Canada

Region of application: Canada	General Population/Uncontrolled Exposures	Occupational/Controlled Exposures
RF-EMF power density exposure limits	6.8 W/m²	37.9 W/m²
Distance in front (CD_f)	36.3 m	15.3 m
Distance to the side ($CD_{s,a}$)	17.7 n	7.3 m
Distance below ($CD_{d,a}$)	7.2 m	2.9 m
Distance above ($CD_{u,a}$)	3.2 m	0.9 m
Distance to the side ($CD_{s,c}$)	17.9 m	7.5 m
Distance below ($CD_{d,c}$)	7.5 m	3.2 m
Distance above ($CD_{u,c}$)	3.5 m	1.2 m

The RF exposure compliance distances based on the actual maximum transmitted power considering a 95th percentile approach are summarized in Table 12 and Table 13. 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 [10], [11] and [12].

Table 12 – AVQQA RF exposure compliance distances based on the actual EIRP threshold of 74.5 dBm for EU/ICNIRP, Australia/NZ and US/related

For information in EU/ICNIRP, Australia/NZ and US/related countries based on IEC/EN 62232 [12] and IEC TR62669 [11]	General Population/Uncontrolled Exposures	Occupational/Controlled Exposures
RF-EMF power density exposure limits	10 W/m²	50 W/m²
Distance in front (CD_f)	14.9 m	6.4 m
Distance to the side ($CD_{s,a}$)	11.6 m	5.0 m
Distance below ($CD_{d,a}$)	3.2 m	1.2 m
Distance above ($CD_{u,a}$)	1.2 m	0.3 m
Distance to the side ($CD_{s,c}$)	11.8 m	5.2 m
Distance below ($CD_{d,c}$)	3.5 m	1.5 m
Distance above ($CD_{u,c}$)	1.5 m	0.6 m

Table 13 – AVQQA RF exposure compliance distances based on the actual EIRP threshold of 74.5 dBm for Canada

For information in Canada based on IEC/EN 62232 [12] and IEC TR62669 [11]	General Population/Uncontrolled Exposures	Occupational/Controlled Exposures
RF-EMF power density exposure limits	6.8 W/m²	37.9 W/m²
Distance in front (CD_f)	18.0 m	7.6 m
Distance to the side ($CD_{s,a}$)	14.2 m	5.9 m
Distance below ($CD_{d,a}$)	3.9 m	1.5 m
Distance above ($CD_{u,a}$)	1.5 m	0.4 m
Distance to the side ($CD_{s,c}$)	14.4 m	6.1 m
Distance below ($CD_{d,c}$)	4.2 m	1.8 m
Distance above ($CD_{u,c}$)	1.8 m	0.7 m

Installation of the Nokia AVQQA AirScale Dualband MAA 64T64R n77 340 W 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 10 and Table 11).

- 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 10 and Table 11). 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 ---------