RF exposure compliance assessment

5G Airscale mmWave Radio Solution – AWGUC/D

US - FCC ID: 2AD8UAWGUCD01

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1 General content

This test report is addressing human exposure to radiofrequency electromagnetic fields (RF-EMF) transmitted by the following 5G AirScale mmWave Radio Product (see §2.2):

- Nokia AWGUC/D AirScale mmWave 2T2R n258 60 dBm EIRP

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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/v2021.2.

[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.

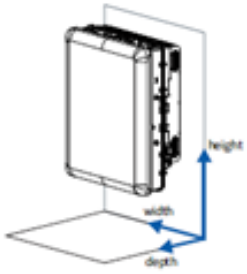
Table 1 – Applicable RF exposure levels in n258 band expressed in power density

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

4 Description of the equipment under test (EUT)

The main technical characteristics of AWGUC/D product are reproduced in Table 2.

Table 2 – AWGUC/D product general technical characteristics

Product name	AWGUC/D AirScale mmWave 2T2R n258 60 dBm EIRP
Model number	AWGUC - 475946A (AC), AWGUD – 475947A (DC)
Certification ID	US - FCC ID: 2AD8UAWGUCD01
Rated max Tx power	34 dBm (2.5 W)
Number of TXRX	2T2R
Beamforming	Yes
SW supported techno.	5G NR TDD
Frequency range	24250 – 27500 MHz
Nb of antenna elements	16 (row) x 12 (column) x 2 (polarization)
Max Antenna Gain	27 dBi
Total average EIRP	61 dBm
Azimuth scanning range	+/- 45 deg (3dB)
Elevation scanning range	+/- 15 deg (3dB)
Dimensions 	Height: 325mm Width: 270mm Depth: 155mm 
Technology duty cycle factor	80 %
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 5 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 [16])

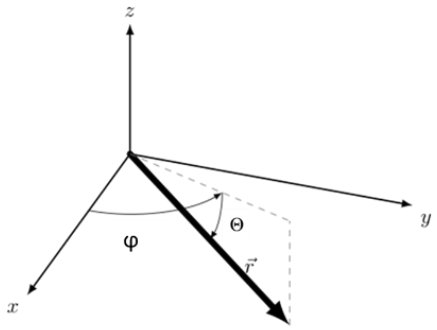
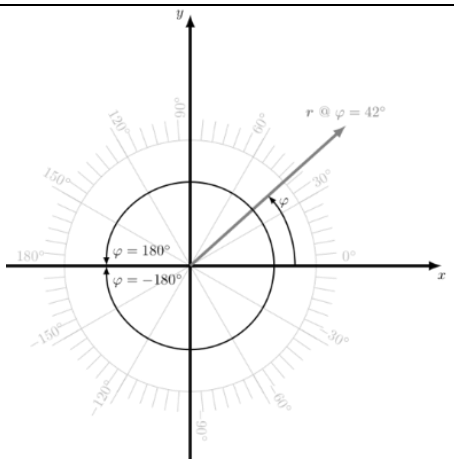
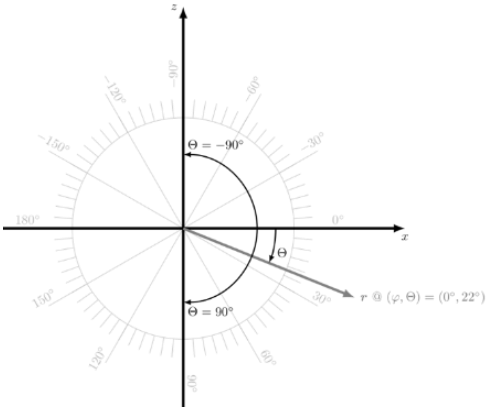
3D view Defintion of azimuth φ and elevation θ	
Top view (horizontal cut) Definition of azimuth φ	
Side view (vertical cut) Definition of elevation θ	

Table 4 – Antenna pattern models for RF exposure assessment

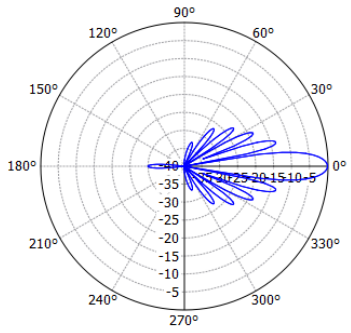
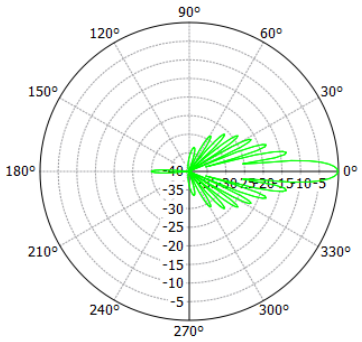
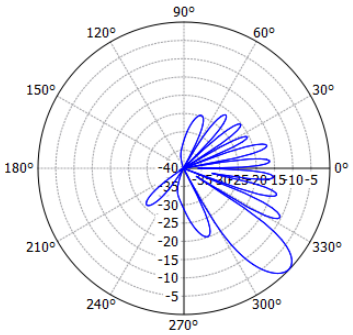
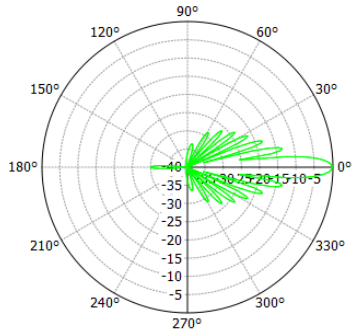
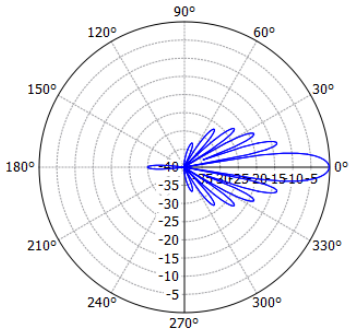
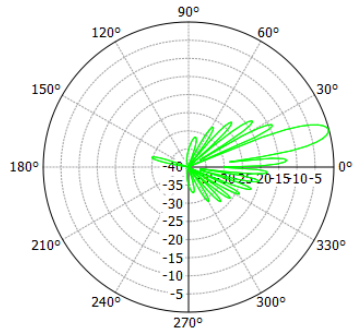
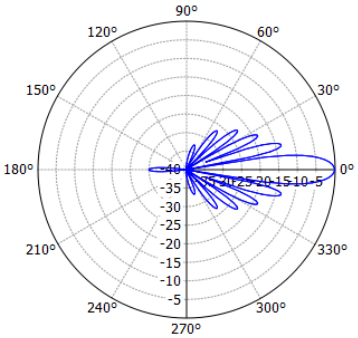
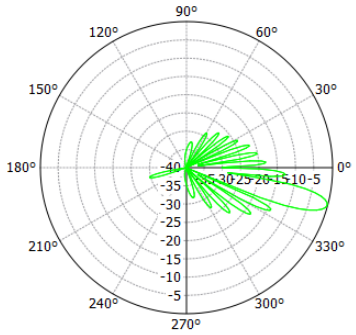
	Horizontal cut	Vertical cut
Boresight		
Max azimuth		
Max up-tilt		
Max down-tilt		
NOTE: Angle references used in these graphs are derived from EMF Visual (left) and Planet Viewer (right), which may differ from product data sheet (see Table 3)		

Table 5 – Antenna gain characteristics for various beam steering directions used during EMF evaluation

	Azimuth	Elevation	Gain (dBi)
			25875 MHz
Boresight	0°	0°	27.0
Max azimuth	-45°	0°	24.1
Max down-tilt	0°	-15°	26.7
Max up-tilt	0°	+15°	26.7

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.

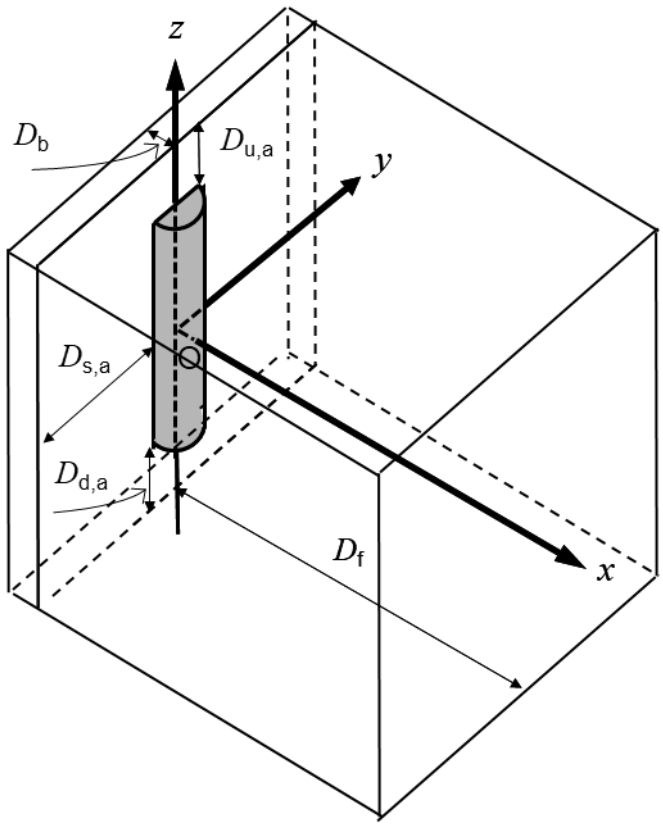


Figure 1 – Shape of the compliance boundary used for the RF exposure compliance assessment (from [4]).

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 2021 Version 4.0 (see [12] and [13]).

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

Table 6 - Validation of the antenna model at 25875 MHz

	Product model	EMF Visual model	Deviation
Gain	27.0 dBi	27.0 dBi	0 dBi
Horizontal half-power beamwidth	8.8°	9.0°	0.2°
Vertical half-power beamwidth	6.6°	7.0°	0.4°

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 2.8 W and, for information, the time-averaged actual maximum transmitted power of 0.7 W taking a 95th percentile approach as defined in [4], [14] and [15]. These values include a technology duty cycle factor of 80 % (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, Canada, Australia/NZ and US/related

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

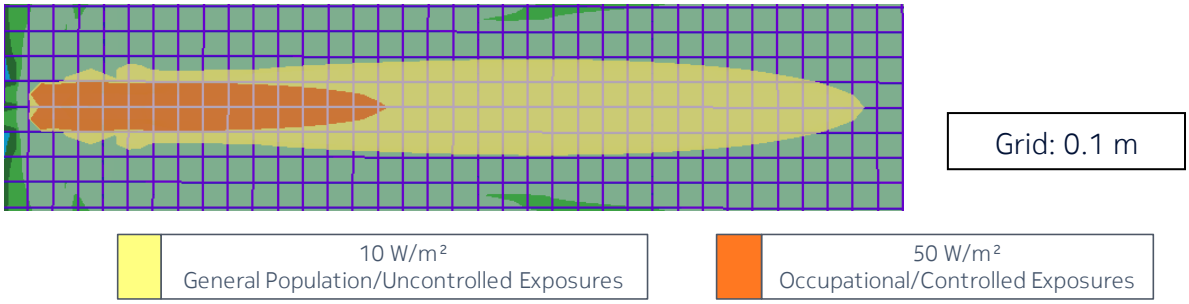


Figure 2 – Top view of the power density for the time-averaged maximum transmitted power of 2.8 W and the beam oriented in azimuth = 0° & elevation = 0° (EU/ICNIRP, Canada, Australia/NZ and US/related)

Figure 3 - Top view of the power density for the time-averaged actual maximum transmitted power of 0.7 W and the beam oriented in azimuth = 0° & elevation = 0° (EU/ICNIRP, Canada, Australia/NZ and US/related)

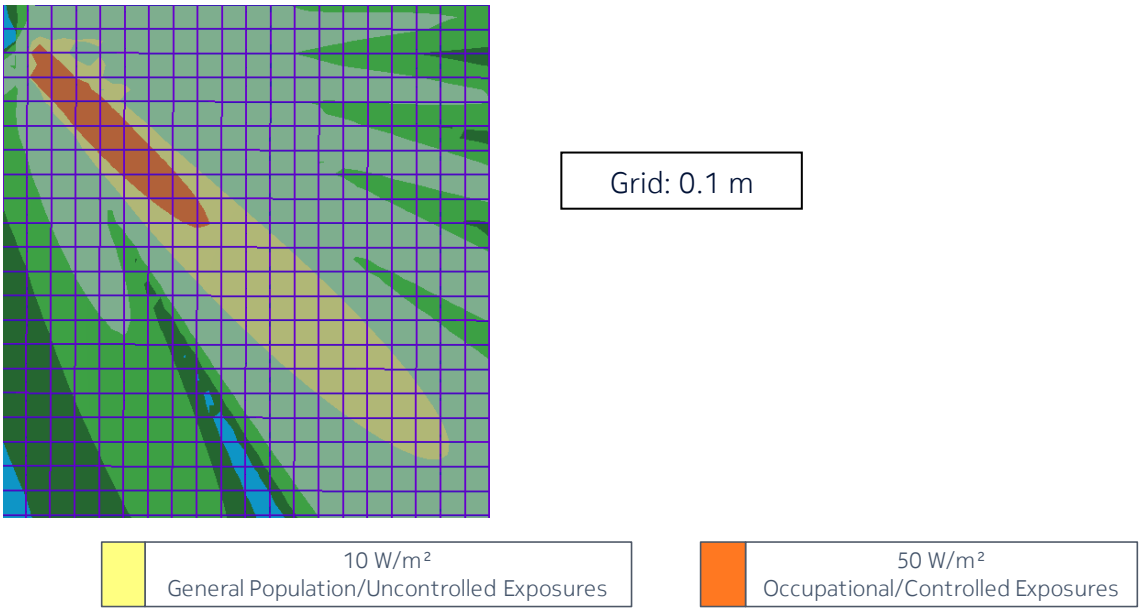


Figure 4 - Top view of the power density for the time-averaged maximum transmitted power of 2.8 W and the beam oriented in azimuth = -45° & elevation = 0° (EU/ICNIRP, Canada, Australia/NZ and US/related)

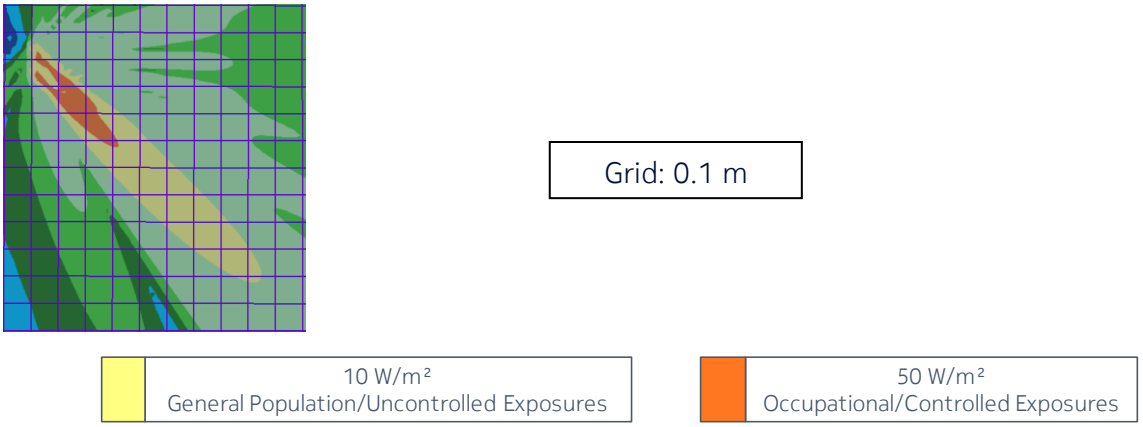


Figure 5 - Top view of the power density for the time-averaged actual maximum transmitted power of 0.7 W and the beam oriented in azimuth = -45° & elevation = 0° (EU/ICNIRP, Canada, Australia/NZ and US/related) (EU/ICNIRP, Canada, Australia/NZ and US/related)

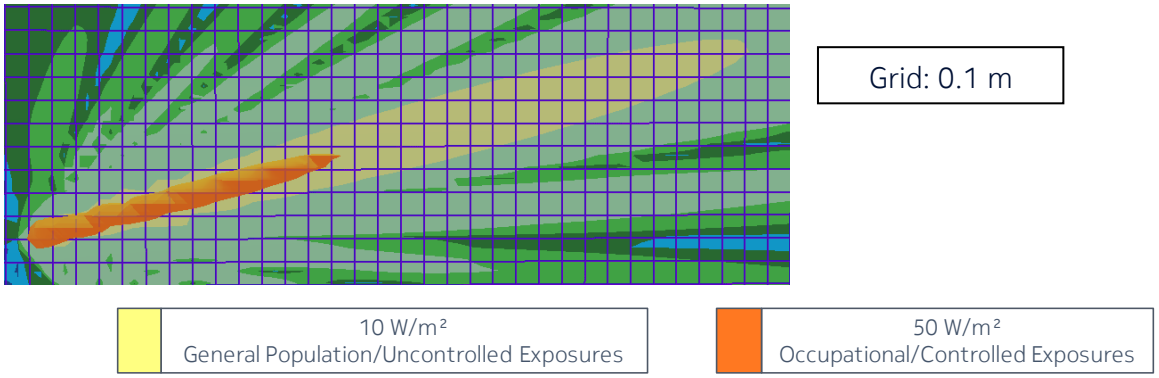


Figure 6 - Side view of the power density for the time-averaged maximum transmitted power of 2.8 W and the beam oriented in azimuth = 0° & elevation = -15° (EU/ICNIRP, Canada, Australia/NZ and US/related)

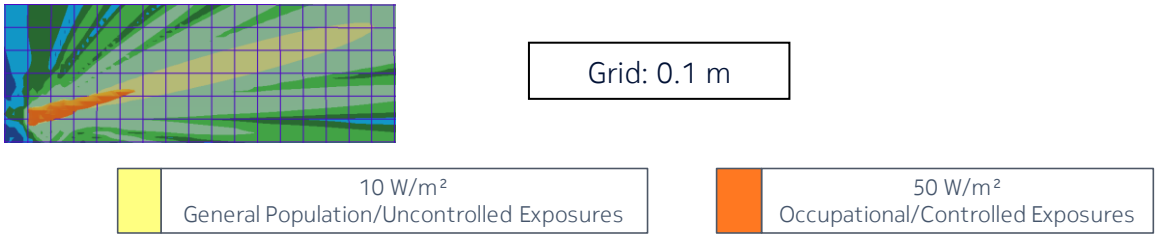


Figure 7 - Side view of the power density for the time-averaged actual maximum transmitted power of 0.7 W and the beam oriented in azimuth = 0° & elevation = -15° (EU/ICNIRP, Canada, Australia/NZ and US/related)

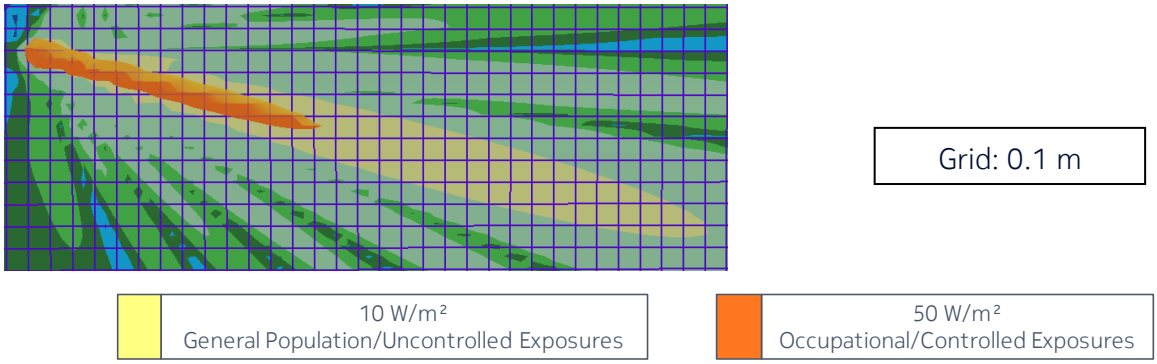


Figure 8 – Side view of the power density for the time-averaged maximum transmitted power of 2.8 W and the beam oriented in azimuth = 0° & elevation = +15° (EU/ICNIRP, Canada, Australia/NZ and US/related)

Figure 9 - Side view of the power density for the time-averaged actual maximum transmitted power of 0.7 W and the beam oriented in azimuth = 0° & elevation = +15° (EU/ICNIRP, Canada, Australia/NZ and US/related)

7 Conclusion and installation recommendations

The RF exposure compliance distances for the Nokia AWGUC/D AirScale n258 60 dBm EIRP product are summarized in Table 7 for EU/ICNIRP [1][2], Australia/NZ [5] and US/related [9] requirements and Canada [7] requirements.

Table 7 – AWGUC/D RF exposure compliance distances based on the time-averaged maximum transmitted power of 2.8 W (corresponding to 2.5 W rated max transmitted power) for EU/ICNIRP, Canada, Australia/NZ and US/related

Region of application: EU/ICNIRP, Canada, 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)	3.4 m	1.5 m
Distance to the side ($D_{s,a}$)	1.6 m	0.7 m
Distance below ($D_{d,a}$)	0.8 m	0.3 m
Distance above ($D_{u,a}$)	0.8 m	0.3 m
Distance to the side ($D_{s,c}$)	1.7 m	0.8 m
Distance below ($D_{d,c}$)	0.9 m	0.4 m
Distance above ($D_{u,c}$)	0.9 m	0.4 m

Table 8 – AWGUC/D RF exposure compliance distances based on the time-averaged actual maximum transmitted power of 0.7 W (corresponding to 2.5 W rated max transmitted power) for EU/ICNIRP, Canada, Australia/NZ and US/related

For information in EU/ICNIRP, Canada, 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)	1.7 m	0.6 m
Distance to the side ($D_{s,a}$)	0.8 m	0.3 m
Distance below ($D_{d,a}$)	0.4 m	0.1 m
Distance above ($D_{u,a}$)	0.4 m	0.1 m
Distance to the side ($D_{s,c}$)	0.9 m	0.4 m
Distance below ($D_{d,c}$)	0.5 m	0.2 m
Distance above ($D_{u,c}$)	0.5 m	0.2 m

Installation of the Nokia AWGUC/D AirScale n258 60 dBm EIRP 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 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 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 ---------