RF exposure compliance assessment

Nokia AirScale Micro RRH Dual Band 2x4T4R B25/B66 160W - AWMFIA

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1 General content

This RF EMF assessment report is addressing human exposure to radiofrequency electromagnetic fields (RF-EMF) transmitted by the following Nokia Micro Remote Radio Head (RRH) Dual Band product (see §0):

- Nokia AWMFIA AirScale Micro RRH Dual Band 2x4T4R B25/B66 160W

It provides the RF exposure compliance boundaries for this product when it is connected with a typical external antenna, such as Nokia AAFC. The assessment is performed 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] Microwave Vision Group (MVG), “EMF Visual User Manual”, SEWB/EMF-VISUAL-UM.1/v2023.03

[8] 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

[9] 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

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

[11] 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

[12] 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

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

[14] Canada RSS-102, “Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands)”, Issue 5, March 2015, Amendment 1 (February 2, 2021)

[15] 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

[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], [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.

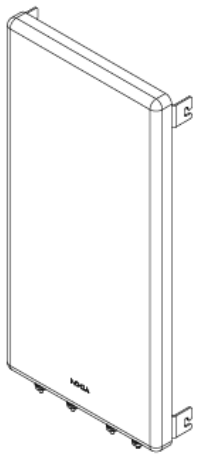
Table 1 – Applicable RF exposure levels in bands B25 and B66 expressed in power density

Region of application	General Population/Uncontrolled Exposures		Occupational/Controlled Exposures	
	B25	B66	B25	B66
US/related	10.0 W/m^2	10.0 W/m^2	50.0 W/m^2	50.0 W/m^2
EU/ICNIRP, Australia/NZ	9.6 W/m^2	10.0 W/m^2	48.2 W/m^2	50.0 W/m^2
Canada	4.6 W/m^2	4.9 W/m^2	28.4 W/m^2	29.6 W/m^2

4 Description of the equipment under test (EUT)

The main technical characteristics of Nokia AWMFIA product, when it is connected with a typical external antenna, such Nokia AAFC, are provided in Table 2.

Table 2 – AWMFIA and AAFC general technical characteristics

RRH Product name	Nokia AWMFIA AirScale Micro RRH Dual Band 2x4T4R B25/B66 160W	
Model number	476353A	
Rated max Tx power	160 W	
Number of TXRX	2 x 4TX4RX	
Beamforming	No	
SW supported techno.	3GPP NR & LTE FDD / FCC, NEBS	
Frequency range	Band 25: UL: 1850 - 1915 MHz / DL: 1930 - 1995 MHz Band 66: UL: 1710 - 1780 MHz / DL: 2110 - 2200 MHz.	
Antenna Product name	Nokia AAFC	
Typical Antenna Gain	11.25dBi ±1.25 (boresight)	
Dimensions	Height: 489 mm Width: 245 mm Depth: 25 mm	 1 x AAFC antenna
Technology duty cycle factor	100 %	
Transmitted power tolerance	1.5 dB	

NOTE: Nokia AWMFIA AirScale Micro RRH Dual Band 2x4T4R B25/B66 160W radio is capable to transmit with the max power of 80 W per band and with the max power of 40 W per antenna port. In the special mode the product can transmit with the max power of 120 W in one band and with 40 W in another band. Therefore, to establish the conservative compliance distances the max power of 120 W in band B25 is assumed, while remaining 40 W is assumed for band B66.

The EMF Visual antenna model used for the RF exposure assessment is derived based on the datasheet of Nokia AAFC. The EMF Visual model is validated with the product antenna model using the same pattern and gain. Table 4 and Table 5 present EMF Visual models of beam patterns in 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])

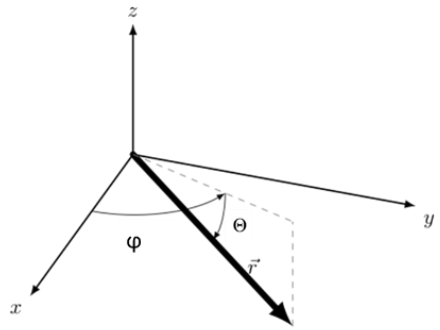
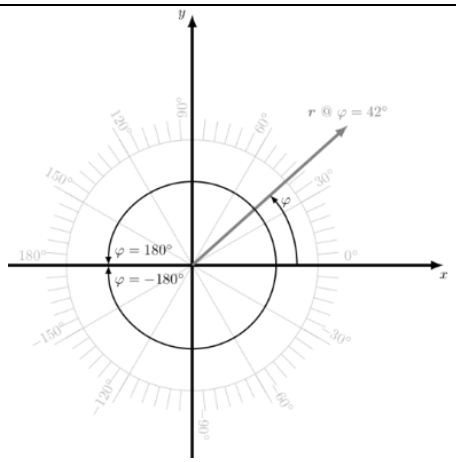
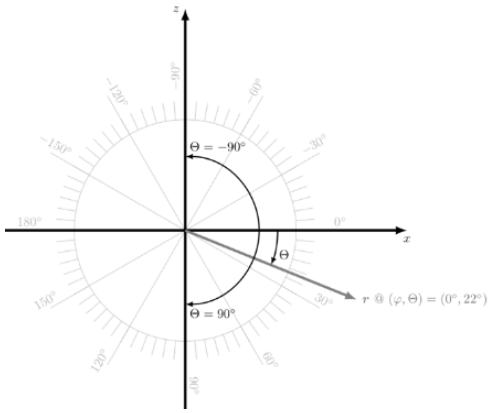
3D view Defintion of azimuth φ and elevation θ	
Top view (horizontal cut) Definition of azimuth φ	
Side view (vertical cut) Definition of elevation θ	

Table 4 – Antenna beam pattern models for bands B25 and B66 used for EMF evaluation

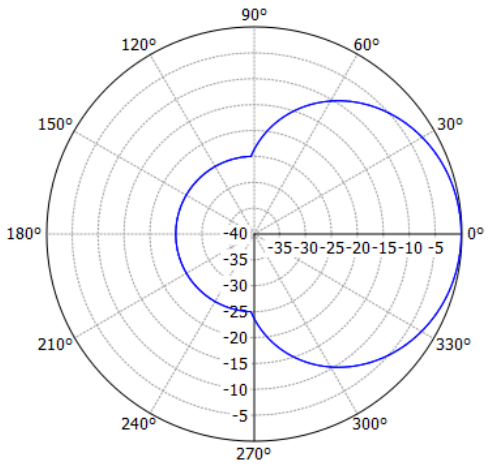
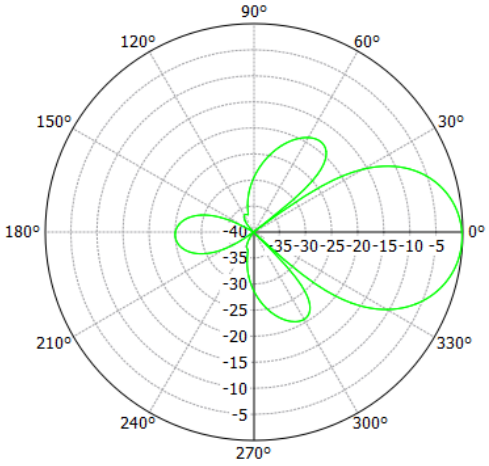
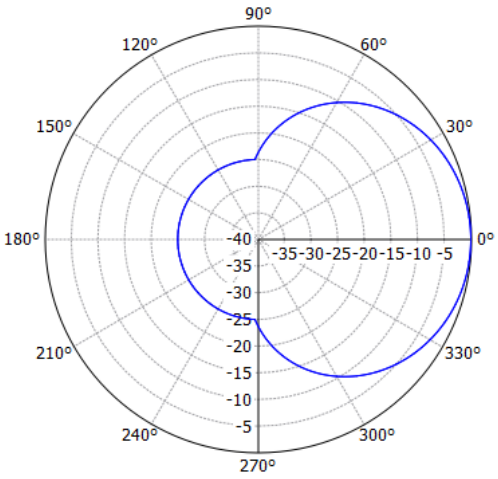
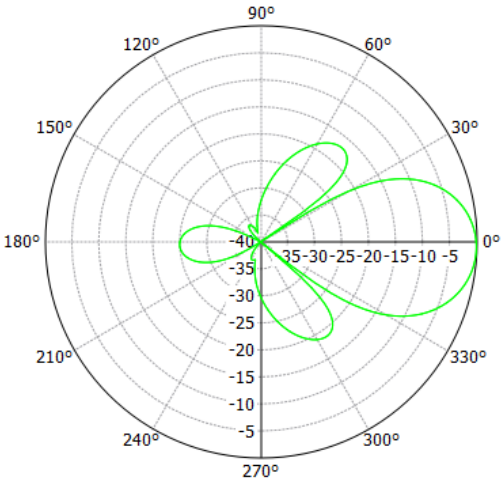
Band	Horizontal cut	Vertical cut
B25		
B66		
NOTE: Angle references used in these graphs are derived from EMF Visual, which may differ from product data sheet (see Table 3)		

Table 5 – Antenna gain characteristics used during EMF evaluation

Band	Azimuth pointing angle	Elevation pointing angle	Gain (dBi)
B25	0°	+2.0°	12.5 dBi
B66	0°	+2.0°	12.5 dBi

The compliance boundary is defined by the box shape perimeter shown in Figure 4 of IEC 62232:2022 [11] 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.

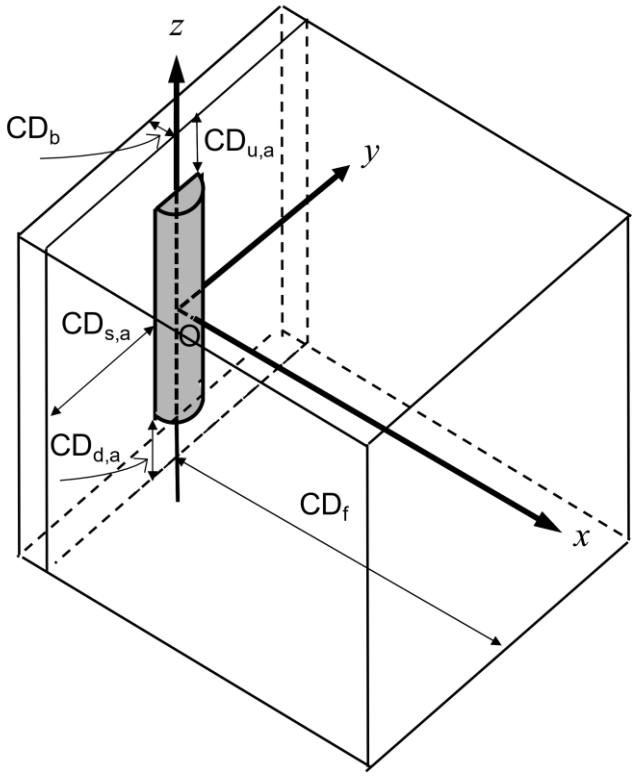


Figure 1 – Shape of the compliance boundary used for the RF exposure compliance assessment (from [11]).

5 RF exposure assessment method

RF exposure assessment is performed using the synthetic model computation method defined in B.7 of IEC 62232:2022. Calculations are performed with the “EMF Visual” software release OKTAL Version 4.0 2023.03 (see [7] and [8]).

The validation of the model is performed in the configuration with the beam in front and max available gain in bands B25 and B66 (azimuth = 0.0° and elevation = +2.0°). The validation results are provided in Table 6.

Table 6 - Validation of the antenna model for bands B25 and B66

	Band	Product	EMF Visual model	Deviation
Gain	B25	12.5 dBi	12.5 dBi	0.0 dB
	B66	12.5 dBi	12.5 dBi	0.0 dB
Horizontal half-power beamwidth	B25	65° ± 10°	65.5°	0.5°
	B66	65° ± 10°	65.5°	1.5°
Vertical half-power beamwidth	B25	35° ± 10°	31.5°	3.5°
	B66	35° ± 10°	29.5°	5.5°

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 total configured maximum transmitted power of 227 W, assuming 170 W in band B25 and 57 W in band B66. The RF compliance distances are also provided for the total actual maximum transmitted power of 91 W, applying a power reduction factor of – 4 dB as defined in [10] and [11].

All above power values include a technology duty cycle factor of 100 % (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: US/related

The computed 3D distributions of power density corresponding to a total exposure ratio (TER) of 1, for both general public and occupational exposure limits, are displayed in Figure 2 through Figure 5 for RF exposure limits defined in [6] for US/related countries.

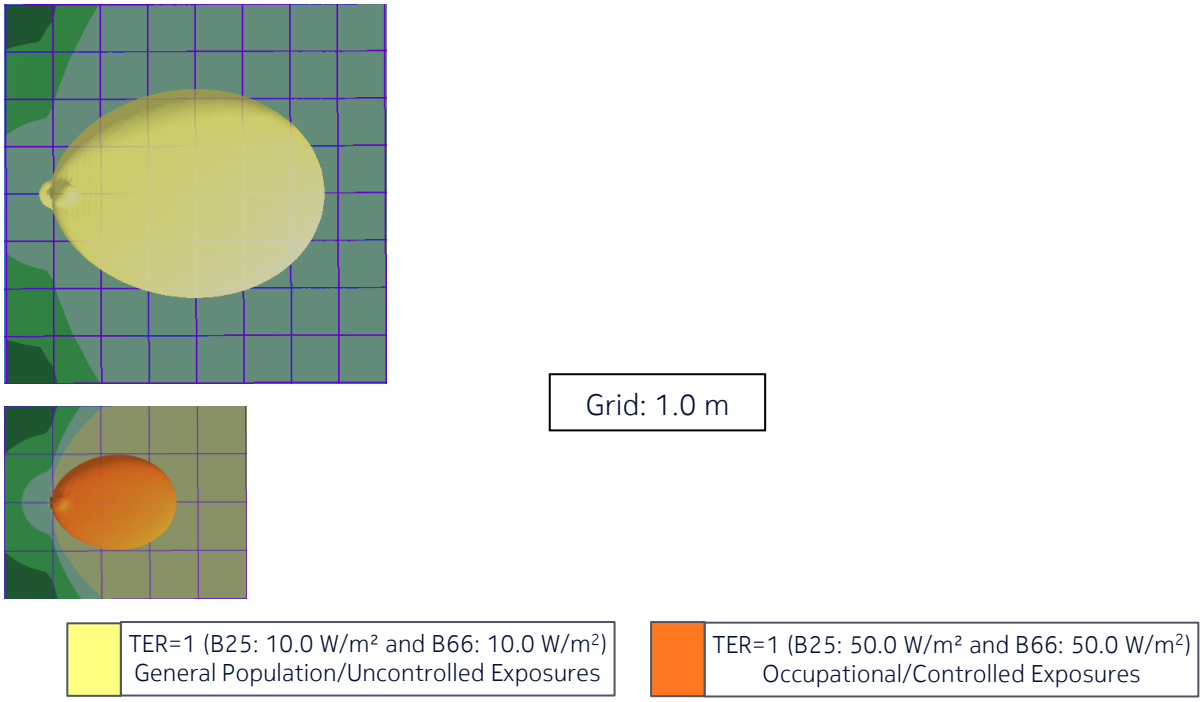


Figure 2 – Top view of the power density for the total maximum transmitted power of 227 W and the beams oriented in azimuth = 0° & elevation = +2° (US/related)

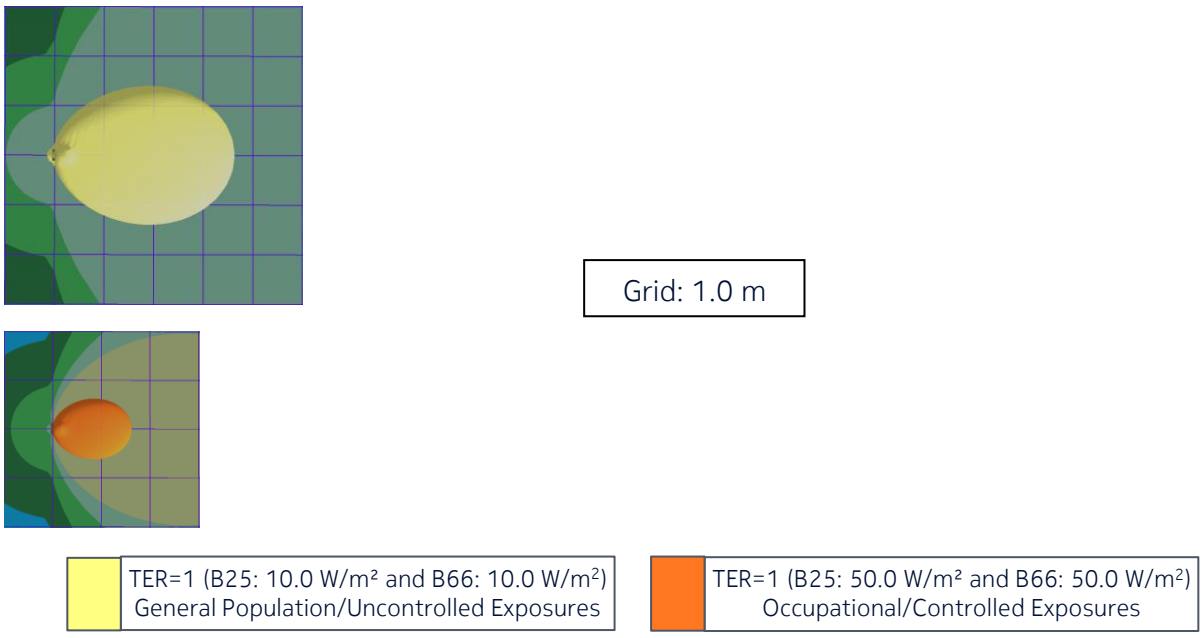


Figure 3 - Top view of the power density for the total actual maximum transmitted power of 91 W and the beams oriented in azimuth = 0° & elevation = +2° (US/related)

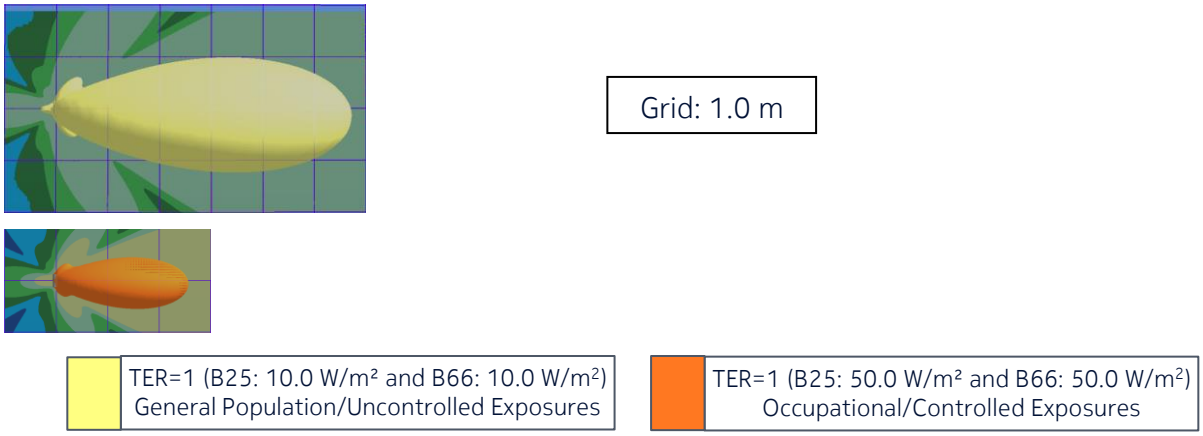


Figure 4 – Side view of the power density for the total maximum transmitted power of 227 W and the beams oriented in azimuth = 0° & elevation = +2° (US/related)

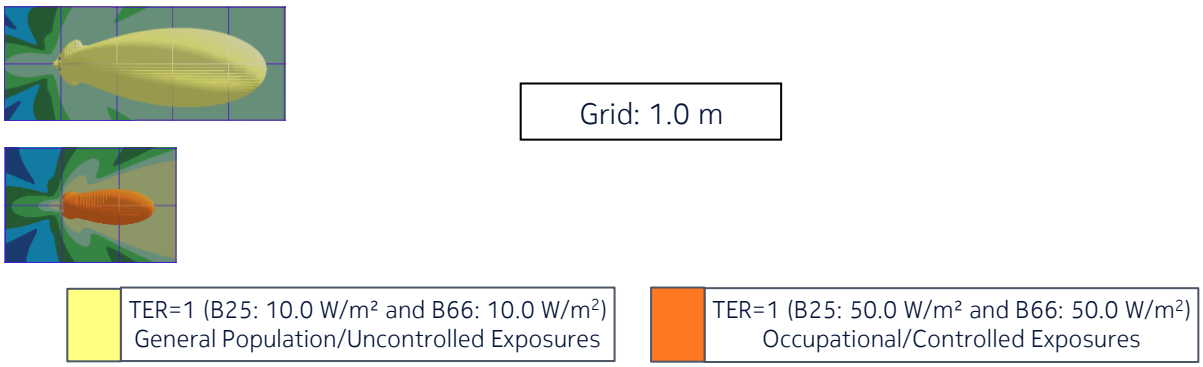


Figure 5 - Side view of the power density for the total actual maximum transmitted power of 91 W and the beams oriented in azimuth = 0° & elevation = +2° (US/related)

6.2 Regions of application: EU/ICNIRP and Australia/NZ

The computed 3D distributions of power density corresponding to a total exposure ratio (TER) of 1, for both general public and occupational exposure limits, are displayed in Figure 6 through Figure 9 for RF exposure limits defined in [1], [2] and [3] for EU/ICNIRP countries and [4] for Australia/NZ.

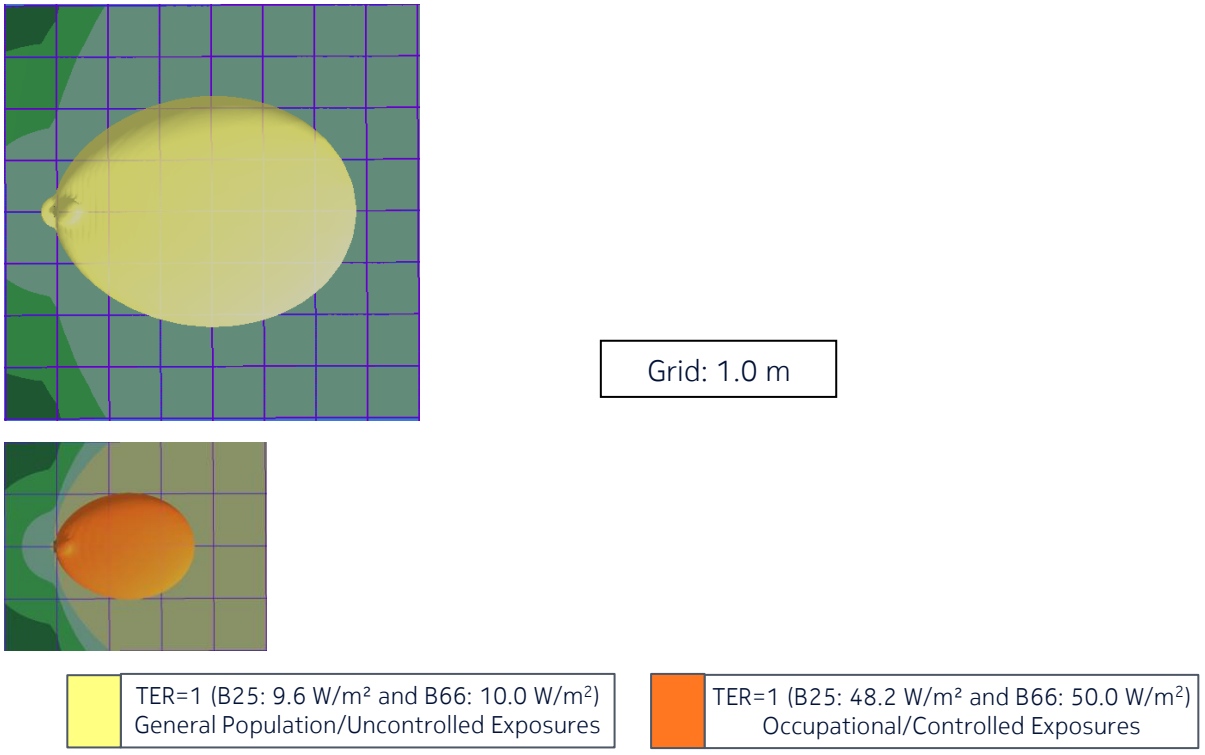


Figure 6 – Top view of the power density for the total maximum transmitted power of 227 W and the beams oriented in azimuth = 0° & elevation = +2° (EU/ICNIRP, Australia/NZ)

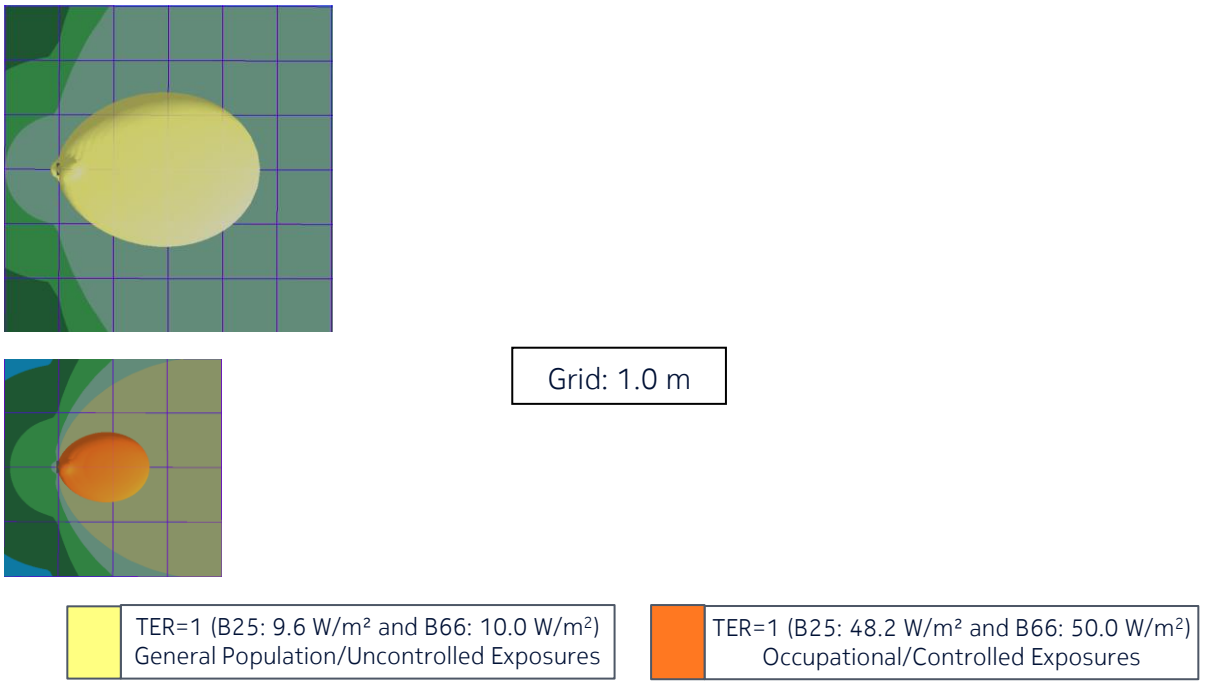


Figure 7 - Top view of the power density for the total actual maximum transmitted power of 91 W and the beams oriented in azimuth = 0° & elevation = +2° (EU/ICNIRP, Australia/NZ)

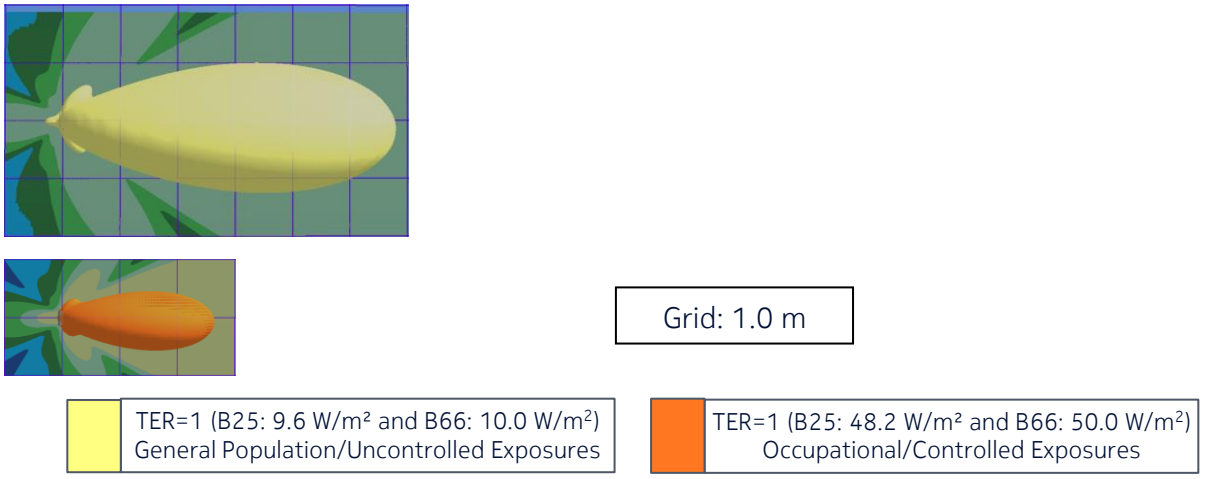


Figure 8 – Side view of the power density for the total maximum transmitted power of 227 W and the beams oriented in azimuth = 0° & elevation = +2° (EU/ICNIRP, Australia/NZ)

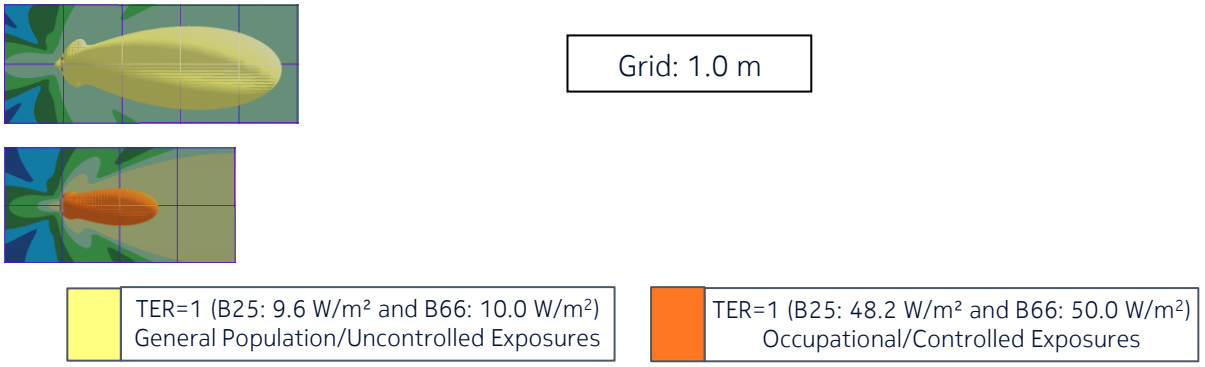


Figure 9 - Side view of the power density for the total actual maximum transmitted power of 91 W and the beams oriented in azimuth = 0° & elevation = +2° (EU/ICNIRP, Australia/NZ)

6.3 Regions of application: Canada

The computed 3D distributions of power density corresponding to a total exposure ratio (TER) of 1, for both general public and occupational exposure limits, are displayed in Figure 10 through Figure 13 for RF exposure limits defined in [5] for Canada.

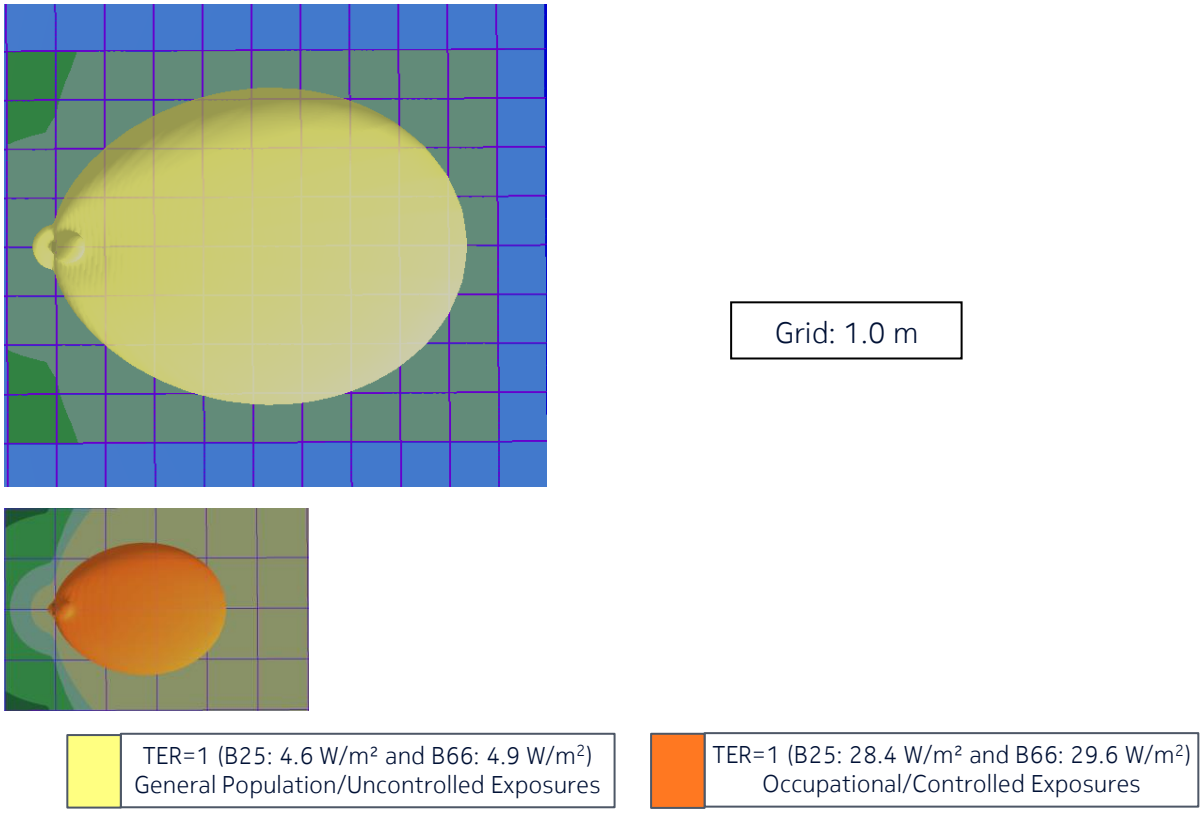


Figure 10 – Top view of the power density for the total maximum transmitted power of 227 W and the beams oriented in azimuth = 0° & elevation = +2° (Canada)

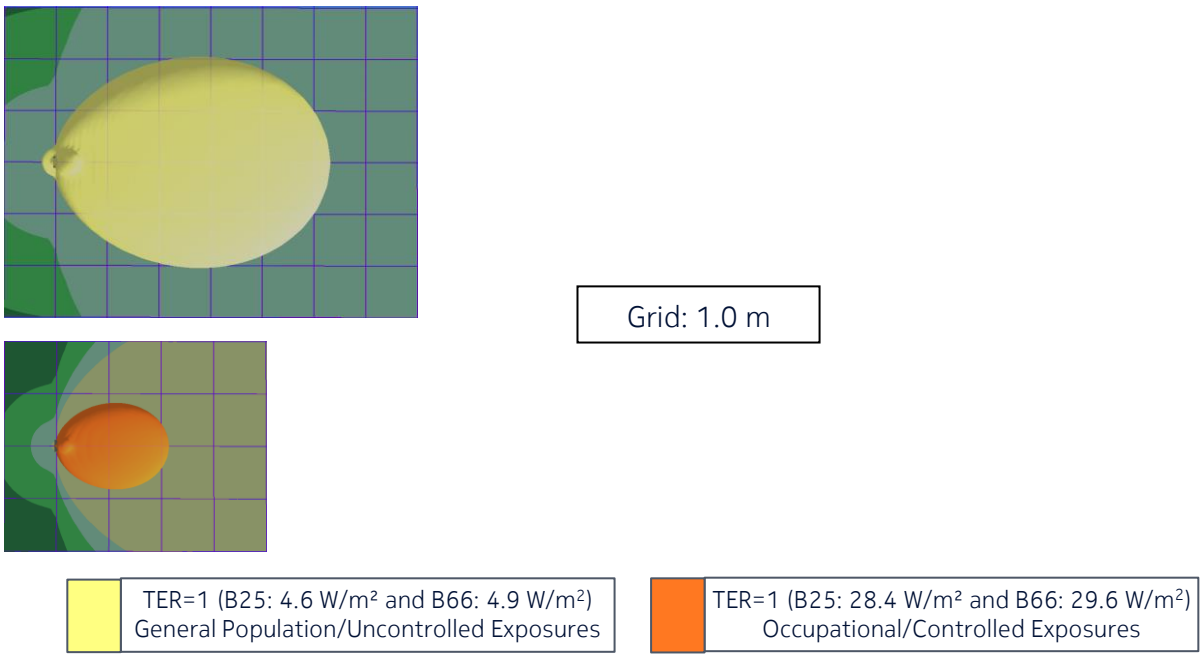


Figure 11 - Top view of the power density for the total actual maximum transmitted power of 91 W and the beams oriented in azimuth = 0° & elevation = +2° (Canada)

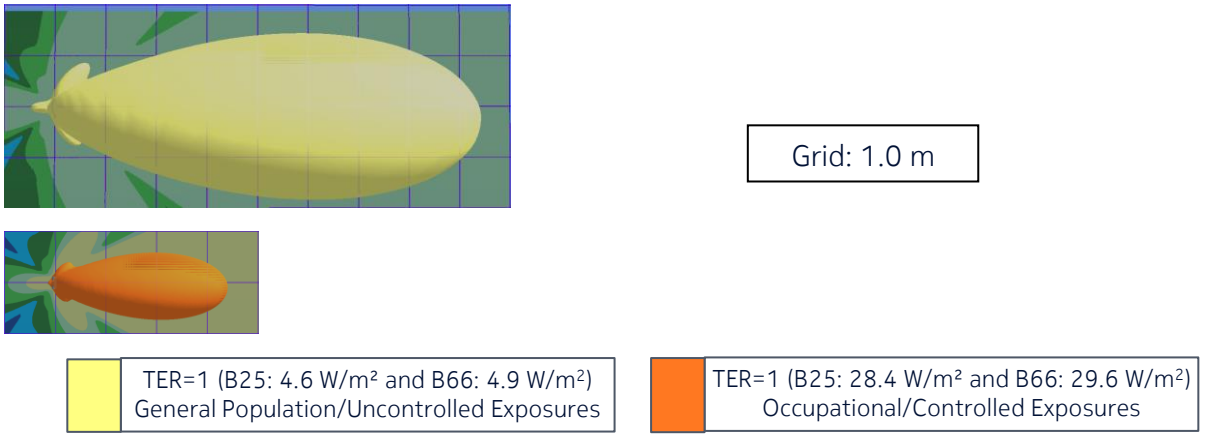


Figure 12 – Side view of the power density for the total maximum transmitted power of 227 W and the beams oriented in azimuth = 0° & elevation = +2° (Canada)

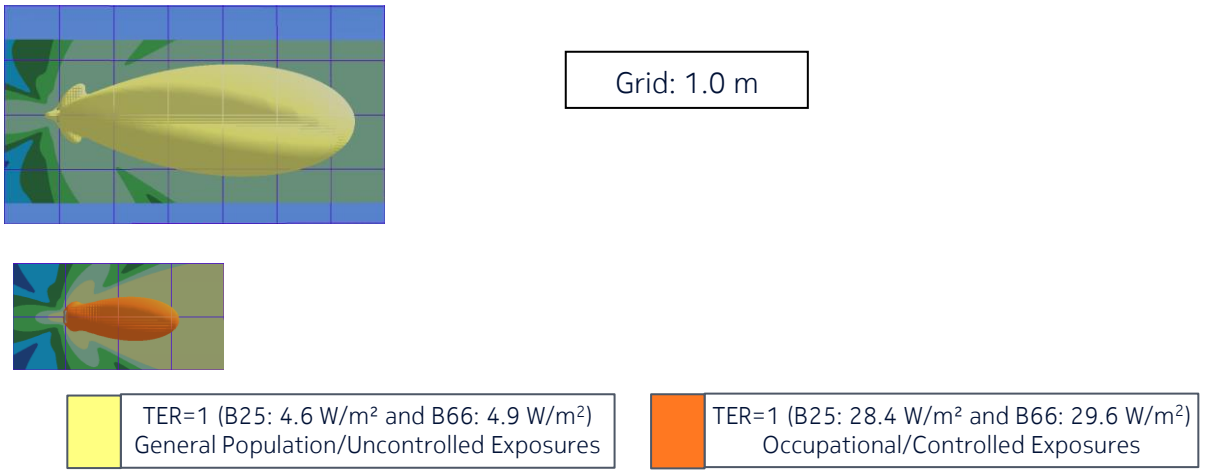


Figure 13 - Side view of the power density for the total actual maximum transmitted power of 91 W and the beams oriented in azimuth = 0° & elevation = +2° (Canada)

7 Conclusion and installation recommendations

The RF exposure compliance distances for the Nokia AWMFIA AirScale Micro RRH Dual Band 2x4T4R B25/B66 160W when it is connected with a typical external antenna, such as Nokia AAFC, are summarized in Table 7 for US/related [6] requirements, in Table 8 for EU/ICNIRP [1][2][3], Australia/NZ [4] and in Table 9 for Canada [5] requirements.

Table 7 – AWMFIA RF exposure compliance distances based on the total maximum transmitted power of 227 W for US/related

Region of application: US/related	General Population/Uncontrolled Exposures	Occupational/Controlled Exposures
RF-EMF power density exposure limits	TER=1 (B25: 10.0 W/m², B66: 10.0 W/m2)	TER=1 (B25: 50.0 W/m², B66: 50.0 W/m2)
Distance in front (CD_f)	5.8 m	2.6 m
Distance to the side ($CD_{s,a}$)	2.2 m	0.9 m
Distance below ($CD_{d,a}$)	1.0 m	0.4 m
Distance above ($CD_{u,a}$)	0.8 m	0.3 m
Distance to the side ($CD_{s,c}$)	2.3 m	1.0 m
Distance below ($CD_{d,c}$)	1.2 m	0.6 m
Distance above ($CD_{u,c}$)	1.0 m	0.5 m

Table 8 – AWMFIA RF exposure compliance distances based on the total maximum transmitted power of 227 W for EU/ICNIRP and Australia/NZ

Region of application: EU/ICNIRP and Australia/NZ	General Population/Uncontrolled Exposures	Occupational/Controlled Exposures
RF-EMF power density exposure limits	TER=1 (B25: 9.6 W/m², B66: 10.0 W/m2)	TER=1 (B25: 48.2 W/m², B66: 50.0 W/m2)
Distance in front (CD_f)	5.9 m	2.7 m
Distance to the side ($CD_{s,a}$)	2.2 m	1.0 m
Distance below ($CD_{d,a}$)	1.1 m	0.4 m
Distance above ($CD_{u,a}$)	0.9 m	0.3 m
Distance to the side ($CD_{s,c}$)	2.3 m	1.1 m
Distance below ($CD_{d,c}$)	1.3 m	0.6 m
Distance above ($CD_{u,c}$)	1.1 m	0.5 m

Table 9 – AWMFIA RF exposure compliance distances based on the total maximum transmitted power of 227 W for Canada

Region of application: Canada	General Population/Uncontrolled Exposures	Occupational/Controlled Exposures
RF-EMF power density exposure limits	TER=1 (B25: 4.6 W/m², B66: 4.9 W/m2)	TER=1 (B25: 28.4 W/m², B66: 29.6 W/m2)
Distance in front (CD_f)	8.4 m	3.4 m
Distance to the side ($CD_{s,a}$)	3.2 m	1.2 m
Distance below ($CD_{d,a}$)	1.7 m	0.6 m
Distance above ($CD_{u,a}$)	1.3 m	0.4 m
Distance to the side ($CD_{s,c}$)	3.3 m	1.3 m
Distance below ($CD_{d,c}$)	1.9 m	0.8 m
Distance above ($CD_{u,c}$)	1.5 m	0.6 m

The RF exposure compliance distances based on the actual maximum transmitted power, applying a power reduction factor of – 4 dB, are summarized in Table 10 - Table 12. 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] and [11].

Table 10 – AWMFIA RF exposure compliance distances based on the total actual maximum transmitted power of 91 W for US/related

For information in US/related countries based on IEC/EN 62232:2022 [11] and IEC TR62669 [10]	General Population/Uncontrolled Exposures	Occupational/Controlled Exposures
RF-EMF power density exposure limits	TER=1 (B25: 10.0 W/m², B66: 10.0 W/m2)	TER=1 (B25: 50.0 W/m², B66: 50.0 W/m2)
Distance in front (CD_f)	3.7 m	1.7 m
Distance to the side ($CD_{s,a}$)	1.3 m	0.6 m
Distance below ($CD_{d,a}$)	0.6 m	0.2 m
Distance above ($CD_{u,a}$)	0.5 m	0.1 m
Distance to the side ($CD_{s,c}$)	1.4 m	0.7 m
Distance below ($CD_{d,c}$)	0.8 m	0.4 m
Distance above ($CD_{u,c}$)	0.7 m	0.3 m

Table 11 – AWMFIA RF exposure compliance distances based on the total actual maximum transmitted power of 91 W for EU/ICNIRP and Australia/NZ

For information in EU/ICNIRP and Australia/NZ based on IEC/EN 62232:2022 [11] and IEC TR62669 [10]	General Population/Uncontrolled Exposures	Occupational/Controlled Exposures
RF-EMF power density exposure limits	TER=1 (B25: 9.6 W/m², B66: 10.0 W/m2)	TER=1 (B25: 48.2 W/m², B66: 50.0 W/m2)
Distance in front (CD_f)	3.7 m	1.7 m
Distance to the side ($CD_{s,a}$)	1.4 m	0.6 m
Distance below ($CD_{d,a}$)	0.6 m	0.2 m
Distance above ($CD_{u,a}$)	0.5 m	0.1 m
Distance to the side ($CD_{s,c}$)	1.5 m	0.7 m
Distance below ($CD_{d,c}$)	0.8 m	0.4 m
Distance above ($CD_{u,c}$)	0.7 m	0.3 m

Table 12 - AWMFIA RF exposure compliance distances based on the total actual maximum transmitted power of 91 W for Canada

For information in Canada based on IEC/EN 62232:2022 [11] and IEC TR62669 [10]	General Population/Uncontrolled Exposures	Occupational/Controlled Exposures
RF-EMF power density exposure limits	TER=1 (B25: 4.6 W/m², B66: 4.9 W/m2)	TER=1 (B25: 28.4 W/m², B66: 29.6 W/m2)
Distance in front (CD_f)	5.4 m	2.2 m
Distance to the side ($CD_{s,a}$)	2.0 m	0.8 m
Distance below ($CD_{d,a}$)	1.0 m	0.3 m
Distance above ($CD_{u,a}$)	0.8 m	0.2 m
Distance to the side ($CD_{s,c}$)	2.1 m	0.9 m
Distance below ($CD_{d,c}$)	1.2 m	0.5 m
Distance above ($CD_{u,c}$)	1.0 m	0.4 m

Installation of the Nokia AWMFIA AirScale Micro RRH Dual Band 2x4T4R B25/B66 160W when it is connected with a typical external antenna, such as Nokia AAFC, 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 - Table 9)
- 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 - Table 9). 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 ---------