Qualcomm Technologies, Inc.

HTC Smart Hub 2Q6U100 802.11ad FCC RF Exposure Simulation

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March 14, 2019

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Revision history

Revision	Date	Description
A	March 8, 2019	Initial release
B	March 14, 2019	▪ Modified Section 3.4, *Simulation power density results* ▪ Modified Chapter 5, *Conclusion* ▪ Added Table 5-1, *Sector mapping from simulation to device software*.

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1 Scope

The purpose of this report is to identify test configurations for measurement of the 60 GHz 802.11ad radios embedded in the HTC Smart Hub model 2Q6U100 for the FCC RF exposure simulation. This simulation report provides the simulated power density in a 4 cm^2 area at a distance of 10 mm from the device surface.

Two 802.11ad modules were integrated into the 2Q6U100 Smart Hub platform.

- Each 11ad radio consists of two separate modules (see Section 2.1).
- Appendix C shows the two 802.11ad antenna module placements.
- The closest distance between the 802.11ad antenna module and the body or hands of an end user will be in the near field for the 60 GHz frequency.

Final compliance is evaluated through measurements in a third-party test report.

The RF exposure assessment and simultaneous transmission with other radios supported in the Smart Hub are evaluated in a separate HTC test report.

2 Product Description

HTC 2Q6U100 is a Smart Hub integrating the following technologies:

- FCC LTE bands: B2, B3, B4, B5 , B7, B8, B12, B13, B25, B26, B66, B71
- TDD LTE bands: B41
- 5G band: n41
- 802.11a/b/g/n/ac
- Bluetooth
- 802.11ad 60 GHz

2.1 802.11ad antenna modules

The HTC 2Q6U100 Smart Hub integrates two 802.11ad antenna modules operating in the 60 GHz band.

The 11ad antenna modules are connected to a baseboard which receives signals from the baseband unit.

- Each 11ad radio consists of two separate modules:
    - 802.11ad antenna module
        - 60 GHz RF and antenna array elements on a printed circuit board
        - Module interfaces to a baseband unit
    - Baseband unit
        - Provides power, control signals, and IF required for the 802.11ad antenna module
- One 11ad module is located at the right side and the second module is at the left side of the Smart Hub.
    - The 802.11ad antenna module inside HTC 2Q6U100, and the relative position and orientation of right and left antenna modules.
        - For a closer view of the position and orientation of the 11ad antenna module relative to HTC 2Q6U100 and the right and left drawings of the 802.11ad antenna module, see Appendix C.
- Device firmware selects which 11ad antenna is used for transmission when only one antenna module can transmit at any one time.
- These 802.11ad modules (including the antenna modules and baseband unit) support all mandatory channels in IEEE 802.11ad (i.e., Channels 1, 2, 3 and 4) and comply with the IEEE 802.11ad standard.

2.2 802.11ad antenna configurations

An antenna configuration or sector is a given combination of amplitude and phase of array elements.

- There are 32 antenna configurations available for each channel to steer the antenna beam and establish a good communication link with the best signal to noise ratio.
- This results in a total 32 antenna configurations available per 11ad array module to handle surrounding transmission environments.
- Only one antenna configuration is active at any time.

3 Worst-Case Determination Using the Simulation

Depending on the transmission environment, the 802.11ad antenna modules installed inside HTC 2Q6U100 can activate an optimal antenna configuration to establish a good communication link.

NOTE: Simulation modeling drawings are based on the array model provided by Qualcomm Technologies, Inc. and the 3D platform provided by the EUT manufacturer (see Appendix C.2).

Ansys Electromagnetics suite 18.0.0 simulation software evaluated all possible antenna configurations to save time.

- The simulation module includes the 802.11ad antenna module and all components surrounded within 5λ.
- The simulation goal is to perform a relative comparison and determine the worst-case antenna configurations having the highest peak 1 cm^2-averaged power density for each channel, and then perform a power density measurement to demonstrate compliance on the worst cases identified.
  - It is difficult to accurately simulate power density levels to an absolute-level due to the lack of accurate material properties for non-metal components at 60 GHz.
  - Final measurement assessment using a larger averaging area will result in lower reported power density.
  - Based on the placement of the 802.11ad antenna modules, the power density was simulated on four evaluation planes to determine the worst case antenna configurations: front, back, bottom, and side (see Figure C-3).
- The separation distance between the evaluation plane and the corresponding surface of HTC_2Q6U100 is 10 mm per a KDB discussion with the device manufacture.

3.1 Modeling

Complete models of the top and bottom of the 802.11ad antenna modules are from the antenna manufacturer, Murata, respectively (see Appendix C.2).

The entire mechanical structure within 4λ surrounding the antenna module are also included in the simulation.

- The 3D platform of the device was provided by HTC.
- With the exception of adhesive materials used in the Smart Hub, all components within a 2 mm radius of 11ad antennas modules are part of the simulation model.
- All other antennas in the device were also included in the simulation.

3.2 Setup

Finite element analysis (FEM) simulations were performed to assess the power density of the 802.11ad antenna module (see Appendix C).

A layered breakdown of the mechanical structure included in the top and bottom modules of the simulation model:

- Full model: Entire assembly.
- Without screen: LCD screen removed (shields, battery, FPCs, screws, LCD mirror and metal frames) and were modeled as aluminum
- Only plastic components: All metal parts removed, all non-conductive components were modeled as lossless ABS material with a relative permittivity of 3.3 and loss tange

The worst-case exposure is expected from the front of HTC 2Q6U100 because exposure from other directions will be significantly reduced by the surrounding metal components (see top (Side A) Figure C-1).

3.2.1 Platform

The simulation includes the edge of the platform.

The simulation of the left module was performed with a chuck of the platform that is 34 mm from the top edge and 43 mm from the left edge.

- The platform was cut at 20 mm away from the left module's bottom and right edges to reduce simulation time.
  - The simulation of the right module was performed with a chuck of the platform that is 32 mm from the top edge and 43 mm from the left edge.
- The platform was cut at 20 mm away from the left module's bottom and right edges to reduce simulation time.
- The modules are mostly shielded by metallic structures in the –y direction.
  - All components in the vicinity of the module were simulated by assuming they were mostly made of metal.

3.2.2 Channels

HTC 2Q6U100 supports 801.11ad Channels 1 to 4. Simulations were performed at the center frequencies of each channel:

- Channel 1: 58.32 GHz
- Channel 2: 60.48 GHz
- Channel 3: 62.64 GHz
- Channel 4: 64.8 GHz

3.2.3 Error computation and convergence

In the simulation setup, auto initial mesh was:

- Selected.
- Defined "lambda refinement" (Ansys Electromagnetics Suite 18.0.0 refines the initial mesh based on the material-dependent wavelength).
- Used 30% maximum refinement per pass as our adaptive option.

Ansys Electromagnetics Suite 18.0.0 computes the error, and the iterative process (solve → error analysis → adaptive refinement) repeats until convergence criteria are satisfied.

NOTE: As long as convergence is reached, the converged results are accurate.

Convergence was verified by changing the convergence criteria, maximum magnitude delta S, from 5% to 3%.

- The influence in power density was less than 0.5%.
  - This influence was included in our uncertainty budget (Appendix A).
- The simulation mesh setup was used over the top (Side A) surface and bottom (Side B) surface of the 802.11ad antenna module (see Figure 3-1 and Figure 3-2).
- The convergence error (maximum magnitude delta S) setting used in all simulations was less than 3%.

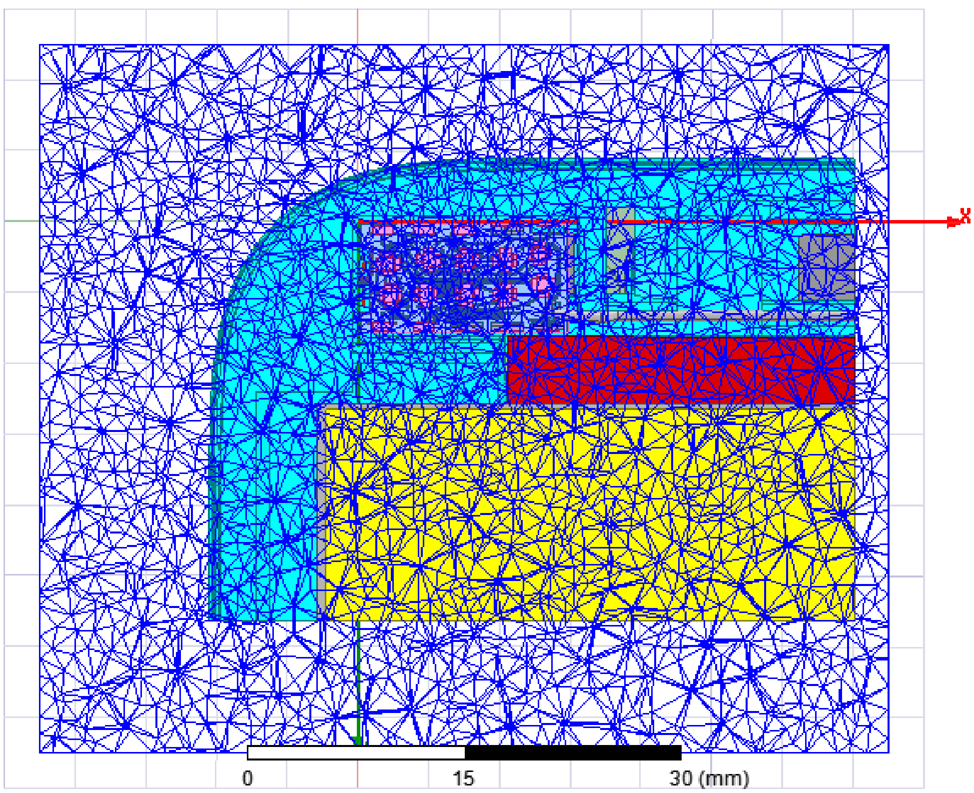

Figure 3-1 Simulation mesh setup antenna module – Right module

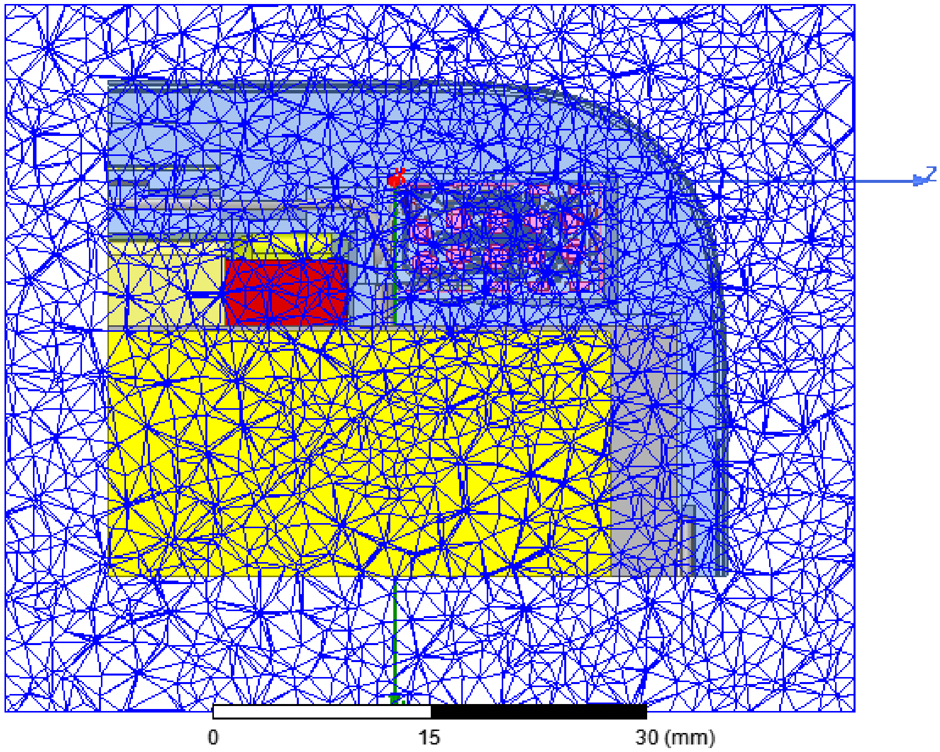

Figure 3-2 Simulation mesh setup used in antenna module – Left module

3.2.4 Absorbing boundary condition

The second-order absorbing boundary condition (ABC) served as a radiation boundary for all simulations in this report.

- ABC simulates an electrically open surface that allows waves to radiate infinitely far into space.
- The system absorbs the wave by the second-order ABC, essentially ballooning the boundary infinitely far away from the structure and into space.
- The radiation boundaries may also be placed relatively close to a structure and can be of arbitrary shape.

Per the Ansys Electromagnetics recommendation for their simulation tool, the radiation boundary plane must be located at least a quarter wavelength from a strong radiating structure, or at least $\frac{1}{10}$ of a wavelength from a weak radiating structure.

- In this simulation, a spacing of at least two wavelengths was used in all directions surrounding the 802.11ad antenna module to ensure minimal influence of reflections from the boundaries.
- This spacing was determined to be sufficient by moving the boundaries closer towards the module by 30% to see the influence on simulated power density.
- Influence was less than 0.05 dB, which confirms that the space between module and computational boundary is sufficient.
- This influence on power density was also included in the simulation uncertainty budget.

For the complete estimated total simulation uncertainty, see Appendix A.

3.3 EIRP comparison measured vs. simulation

Measured EIRP was compared to simulated EIRP to verify accuracy of the simulation model for selected test configurations in Table 3-1.

- As expected, due to unknowns in the device materials, the measured EIRP was less than the simulated EIRP.
- The variance was not fully investigated with the expectation that measured power density results will have greater than 3 dB of margin.

Table 3-1 Measured and Simulated EIRP

Antenna Module	Channel	Sector	Simulated EIRP (dBm)	Measured EIRP (dBm)	Delta (dB)
Left	1	39	19.68	18.21	1.47
Left	2	40	20.66	20.12	0.54
Left	3	38	16.03	17.79	-1.76
Right	1	5	18.9	16.84	2.06
Right	2	5	18.23	19.49	-1.26
Right	3	6	18.24	20.74	-2.5

3.4 Simulation power density results

A total of 1024 antenna configurations (32 configurations per channel) were evaluated at each evaluation plane for each antenna module.

- This represents a total of 1024 configurations evaluated to determine the worst-case power density configurations (32 array configurations x 4 channels x 4 device surfaces x 2 arrays).
- The surface furthest from the 11ad array on the bottom of the device was not included as it was >5 cm from the array.
- The objective of the simulation was to compare the power density levels among antenna configurations for all evaluation planes to determine the worst-case antenna configuration for each channel.
- Then, power density is measured for the identified worst-case antenna configurations to demonstrate compliance. For measurement setup and test results, see Chapter 4.
- The term *Cut* is used to represent a device surface. The mapping of device surface to *Cut* is shown in figure Figure C-3.
  - Cut 1= Front surface of the device (closed surface to the array)
  - Cut 2= Rear surface of device
  - Cut 3 = Side surface of the device
  - Cut 4 = Top surface of the device

For each channel, the simulated peak 4 cm^2 averaged power density for all antenna configurations at each evaluation plane with a separation distance of 10 mm from the device surface (see Figure 3-3 and Figure 3-4).

The highest 4 cm^2-averaged power density antenna configurations identified for measurement are noted with red circles. These power densities are total power densities (PD_{total}) where

$$PD_{total} = \sqrt{PD_x + PD_y + PD_z}$$

The simulation uses sectors 0-31 for both arrays. The software implements as sectors 0-31 for the right module and 32-64 for the left module as shown in Table 5-1.

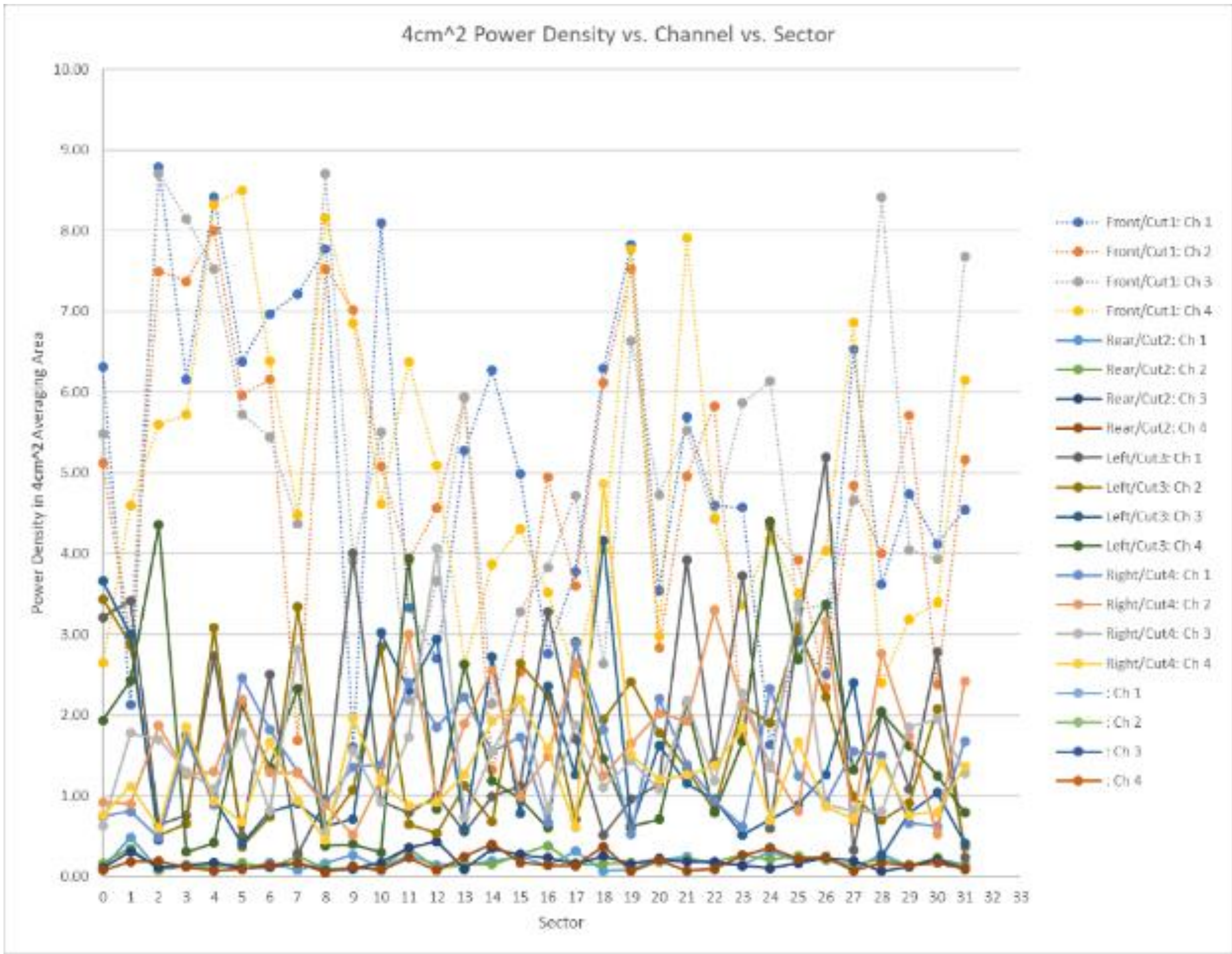

Figure 3-3 Simulated peak power density in 4 cm^2-averaged area – Left antenna

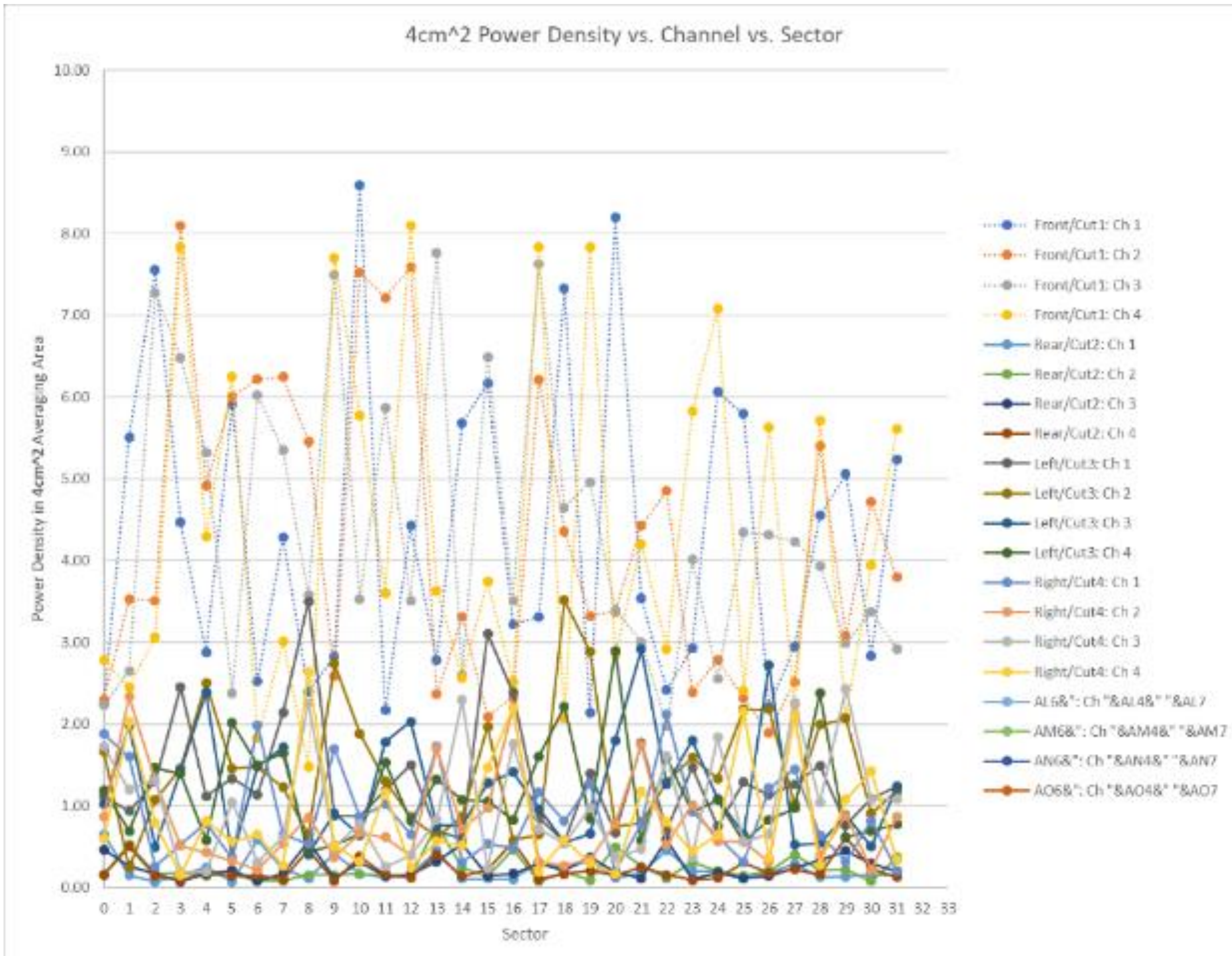

Figure 3-4 Simulated peak power density in 4 cm^2-averaged area – Right antenna

4 Power Density Measurement

Power density measurements are not assessed in this test report.

NOTE: See the SPORTON test report for measured test results.

5 Conclusion

The worst-case antenna configurations having the highest 4 cm^2-averaged power density for each channel and 11ad module, and the 4 cm² results for comparison in the measurement report are identified in Table 5-2.

Simulation results are provided for both the top and bottom 11ad antenna arrays on the front, rear, top, and bottom device surfaces near the antenna array.

Table 5-1 Sector mapping from simulation to device software

Simulation Sector (Used in Figure 3-3 and Figure 3-4)	**Right Module Software Sector ID** (Shown in Table 5-2)	**Left Module Software Sector ID** (Shown in Table 5-2)
0-31	0-31	32-64

Table 5-2 Highest simulated power density summary used to define power density measurements

Module	Channel	Sector	Exposure Plane	Simulated Pd 4 cm^2 at 10 mm with 100% duty cycle	Simulated Pd 4 cm^2 at 10 mm with 85%
Left	1	34	1	8.79	7.47
Left	1	36	1	8.41	7.15
Left	3	34	1	8.71	7.40
Left	3	40	1	8.70	7.40
Left	4	37	1	8.50	7.23
Left	4	36	1	8.33	7.08
Left	1	33	2	0.49	0.41
Left	1	58	3	5.19	4.41
Left	4	50	4	4.86	4.13
Right	1	10	1	8.60	7.31
Right	1	20	1	8.20	6.97
Right	2	3	1	8.10	6.89
Right	2	12	1	7.59	6.45
Right	4	12	1	8.10	6.89
Right	4	3	1	7.84	6.67
Right	2	13	2	0.76	0.65
Right	2	18	3	3.52	2.99
Right	4	8	4	2.64	2.24

For complete simulation results of point power density distributions on the back plane (bottom module) and front plane (upper module) for all antenna configurations, see Appendix B.

A Uncertainty Budget

A.1 Simulation uncertainty budget

Table A-1 lists the measurement uncertainty analysis for the simulation.

Table A-1 Standard uncertainty budget for simulated values of power density

#	Description	Uncertainty (± %)	Prob. dist.	Div.	Std. unc (± %)	Std. unc (± dB)
1	FEM mesh density	0.10%	Norm	1	0.10%	0.00
2	Boundary condition	0.80%	Norm	1	0.80%	0.03
3	Convergence	0.50%	Norm	1	0.50%	0.02
Combined standard uncertainty					0.9%	0.04
Expanded standard uncertainty					1.9%	0.08

[1] Mesh density on the exposure plane was changed by limiting the "max length" of mesh size from auto setting (9.6 mm) to 2 mm.

[2] Simulation domain (volume) was decreased by 30% to check the influence of reflections from boundary conditions on power density.

[3] 5% versus 3% convergence criteria were compared in Ansys Electromagnetics Suite 18.0.0.