A2632_5G_Product-mmWave-MPE_Simulation_Report-withsimPDPlots

Model No	FCC ID:
A2632	BCG-E8139A

Date of Simulation:
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Location:
Apple Inc., Cupertino, CA, USA

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1 Introduction

This document provides an overview of the methodology used for MPE (averaged power density) RF exposure compliance of the 5G mmWave radios on next generation iPhone.

Due to the presence of multiple antenna arrays, and multiple antenna beams for each antenna array, we propose to use a combination of simulation and measurement to demonstrate MPE (sPD) compliance. At a high level, the discussion is grouped into the following topics:

- Brief introduction to MPE simulation methodologies
- Explanation of the approach to demonstrate MPE (sPD) compliance in a device with measurement to validate simulation
- Brief review of the device configuration and operation, and detailed description of the simulation methodology and results

A few things to be noted are

1. The simulation and validation methods described herein follow QC guidance for SAR Char and PD Char for determining the worst-case beam for static transmission measurements.
2. The PD simulation models are built with different CAD models for different programs.
3. Based on guidance, we intend to characterize the three highest MPE beams per polarization per module to choose the scaling factor for all other beams on that module/polarization.

2 MPE Simulation Methodology

3D full-wave simulation is used to evaluate power density (MPE) for each antenna array module's beam. Each beam is created by invoking a pre-defined codebook that has the proper array elements' excitation (i.e., magnitude and phase) to create the beam.

As is shown in Figure 1, the following steps are taken to verify the validity of the model used for MPE simulations and then the verified model is used for the MPE calculations:

1) **EM Simulation:**
    - Import a CAD model that represents the actual product in the simulation tool
    - Define material properties inside the product based on vendor's inputs
    - Perform mesh seeding and solve
2) **Compile Fields and Codebook:**
    - Extract field data from solved model and arrange in format required by Qualcomm Module Group (MG) Script [1]
    - Input PD char codebook generated by Qualcomm Webchar tool
3) **MPE Calculations:**
    - Set averaging area to 4cm^2 using MG Script configuration xml file
    - Run MG script to generate MPE and power limit tables for each beam ID in codebook
4) **Validate Simulation Model:**
    - Measure MPE

- Compare measurement vs simulation
- Once a correlation is established, and model's accuracy is verified, this model will be used for computational MPE assessments

5) **Run Additional Verifications:**
   - Use verification data generated by MG Script
   - Measure MPE for worst case beams given by MG Script
   - Use EM tools, MG Script to complete additional verifications

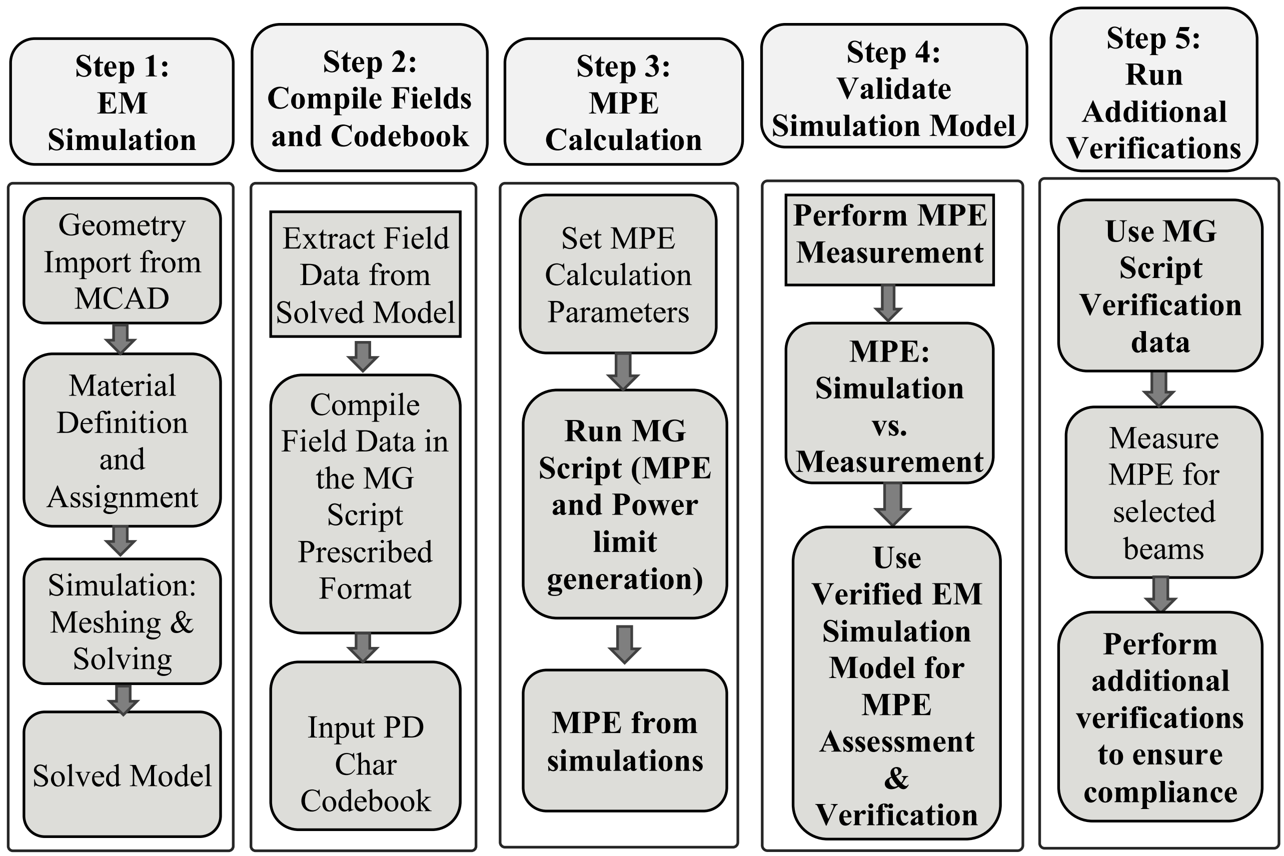


Figure 1. Model validation workflow for MPE simulation and evaluation.

3 MPE Measurements

A mmWave DAE SN 1411 module from SPEAG is used to measure the MPE (sPD) above the DUT. Figure 2 shows the setup of measurement. The mmWave E-field probe is used to measure the electric field above DUT. The near-field magnetic field and MPE are further obtained using this setup. The measurement algorithm can be found in [2] in detail.

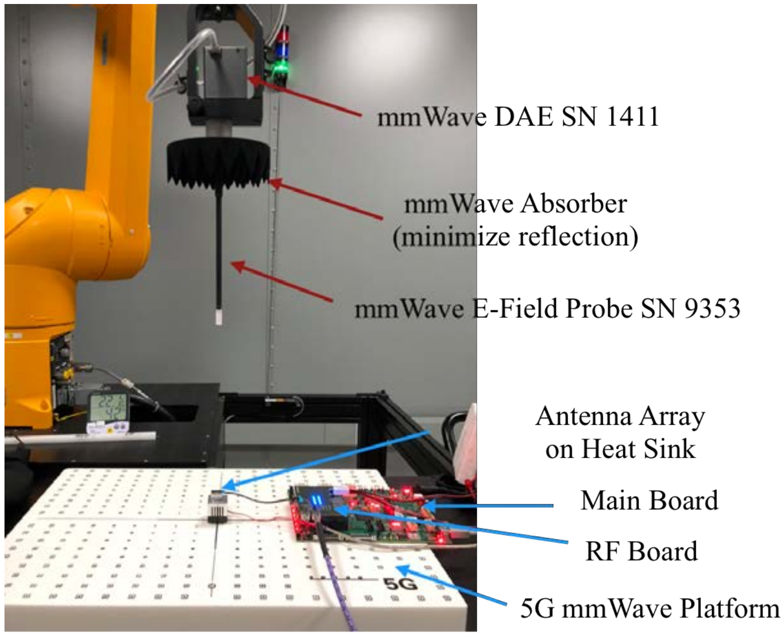


Figure 2. MPE measurement setup.

The distance from probe sensor tip to the edge of the housing is 1.5 mm, and there is 0.5 mm gap between probe tip and the DUT surface to prevent mechanical damage. Therefore, the closest distance that the setup can measure is 2 mm as shown below in Figure 3.

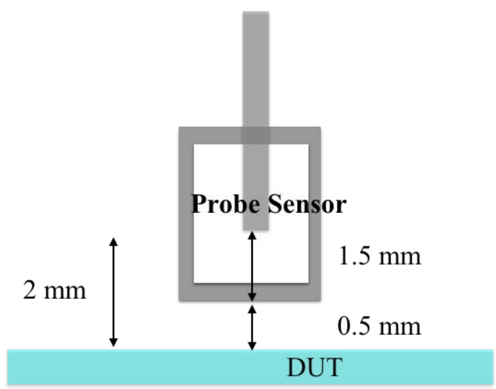


Figure 3. Sketch of the probe showing that the minimum measurable distance is 2 mm.

4 MPE (sPD) Simulations

In 5G, MIMO antennas are designed to orient the beam to specific directions to improve link budgets. Most MIMOs can be configured by using the codebook with each code resulting in a different exposure. The number of codes in the codebook can be very large and measurements of all possible configurations have been shown to be impractical. Therefore, simulation is used to determine the modes/configurations that result in the highest MPE.

All elements are dual polarized patch antennas with horizontal and vertical feeds.

Simulation Models

Figure 4 is a schematic of the simulation model. There are three antenna arrays in the phone, which are back-firing array 1, back-firing array 2 and side-firing array.

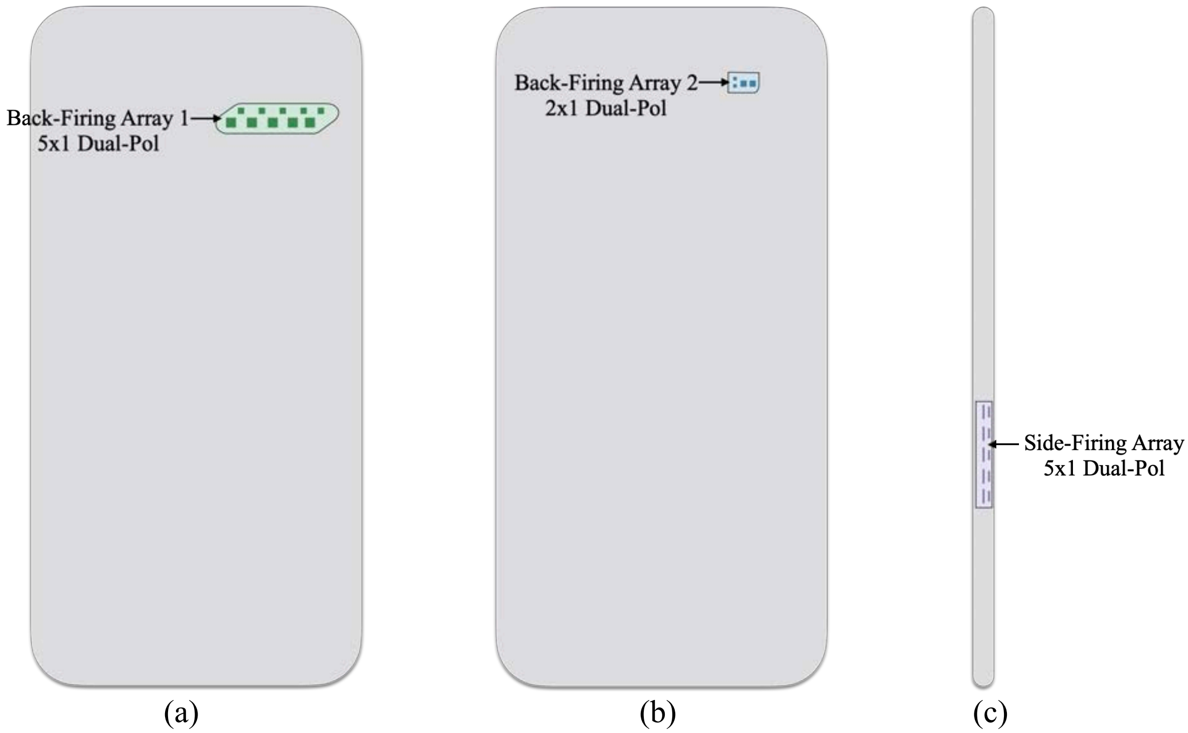


Figure 4. Schematic of the simulation mode, which consists of three 5G antenna arrays, (a) back-firing array 1 (rear view), (b) back-firing array 2 (rear view), and (c) side-firing array (side view).

The measurements and simulations are correlated across different evaluating surfaces 2 mm away from each DUT surface (drawn not to scale), as shown in Figure 5 below. Six surfaces will be evaluated, respectively: front (S1), back (S2), left (S3), right (S4), top (S5) and bottom (S6). As Table 1 shows, for the three antenna arrays, only the evaluating planes within 2.5 cm from the edges of the antenna modules will be considered. This does not apply to the back-to-front or front-to-back condition since fields from the back module will be blocked at the front evaluating plane (and vice versa) by the metal parts (such as battery, MLB) in between.

The “left” and “right” edges in the report are defined relative to the front of the device.

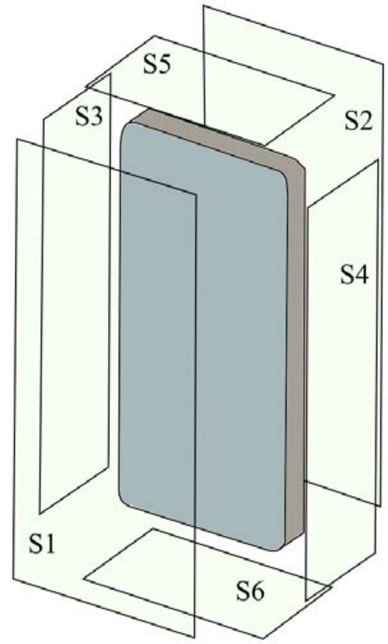


Figure 5. Evaluating surfaces for MPE (sPD).

Table 1- PD Evaluation Planes

	Front (S1)	Rear (S2)	Left from Front View (S3)	Right from Front View (S4)	Top (S5)	Bottom (S6)
Side Array	**Yes (0.4 cm)**	**Yes (0.4 cm)**	No (7 cm)	**Yes (0 cm)**	No (8 cm)	No (4 cm)
Back Array 1	No (0.6 cm)	**Yes (0 cm)**	**Yes (0.9 cm)**	No (4 cm)	No (2.7 cm)	No (12 cm)
Back Array 2	No (0.6 cm)	**Yes (0 cm)**	**Yes (0.9 cm)**	No (4 cm)	**Yes (0.8 cm)**	No (12 cm)

MPE (sPD) Definition

After solving the 3D full-wave electromagnetic simulation, various physical quantities can be derived. To calculate PD evaluation, two physical quantities, an electric field $\vec{E}$ and a magnetic field $\vec{H}$ are needed. The actual consumption power can be expressed as the real term of the Poynting vector $\vec{S}$ from the cross product of $\vec{E}$ and complex conjugation of $\vec{H}$ as shown below:

$$\vec{S} = \frac{1}{2}\mathrm{Re}(\vec{E} \times \vec{H}^{*})$$

$\vec{S}$ can be expressed as localized power density based on a peak value of each spatial point on mesh grid. From the localized power density $\vec{S}$, the spatial-averaged power density (PD) on an evaluated area (A) can be shown as below

$$\mathrm{PD} = \frac{1}{\mathrm{A}}\int_{\mathrm{A}} \vec{\mathrm{S}} \cdot d\vec{\mathrm{A}} = \frac{1}{2\mathrm{A}}\int_{\mathrm{A}} \mathrm{Re}(\vec{\mathrm{E}} \times \vec{\mathrm{H}}^{*}) \cdot \mathrm{d}\vec{\mathrm{A}}$$

For the purposes of these simulations, PD is the total power density value considering the contributions of x, y, and z components of localized power density $\vec{S}$. The evaluated area A is 4 cm^2. To capture worst-case power density conditions, simulations and measurements were performed assuming a 100% duty cycle.

Simulation Methodology:
A time domain 3D Full-Wave Electromagnetic Simulation is performed using CST Studio Suite. The solver calculates electric and magnetic fields at discrete locations and time samples. To achieve high accuracy at all locations, the total electromagnetic energy inside the calculation domain is used as a convergence criterion. The solvers terminate when the normalized energy is decayed to -40 dB ensuring high accuracy of simulation output.

Boundary Conditions:
The boundary condition for simulating electromagnetic behavior in CST is to allow the electromagnetic waves to be electrically open at the boundary and radiated far away without reflection. CST can support the absorption boundary condition (ABC) for radiation boundary and normally requires a quarter-wavelength separation from the structure.

Source Excitation and Example Codebook:
Figure **6**6 shows an example of the codebook for the antenna modules. The first column of the codebook is the beam ID. "Amplitude" and "Phase" are the excitation amplitude and phase for each antenna element. Each beam has a "Paired_With" beam for concurrent MIMO streams. The last column is the index of the beam which is paired with the index shown in the second column. The "Amplitude" is in dBm, and "Phase" is in degrees. In real applications, amplitude of the input power for n258, n261 and n260 is 6 dBm.

Band	Beam_ID	Module	Ant_Group	Subarray	Ant_Type	Ant_Feed	Amplitude	Phase	Paired_With
258	0	0	0	7	PATCH	14	0	0	128
258	1	0	0	9	PATCH	9	0	0	129
258	2	1	0	11	PATCH	10	0	0	130
258	3	0	0	7	PATCH	12	0	0	131
258	4	0	0	9	PATCH	10	0	0	132
258	5	1	0	11	PATCH	11	0	0	133
258	6	0	0	7	PATCH	13	0	0	134
258	7	1	0	11	PATCH	12	0	0	135
258	8	0	0	7	PATCH	15	0	0	136
258	9	1	0	11	PATCH	13	0	0	137
258	10	0	0	7	PATCH	16	0	0	138
258	11	1	0	11	PATCH	14	0	0	139
258	12	0	0	7	PATCH	14;12	0;0	123.75;67.5	140
258	13	0	0	7	PATCH	14;12	0;0	157.5;168.75	141
258	14	0	0	7	PATCH	12;13	0;0	191.25;146.25	142
258	15	0	0	7	PATCH	14;12	0;0	303.75;78.75	143
258	16	0	0	9	PATCH	9;10	0;0	270;67.5	144
258	17	0	0	9	PATCH	9;10	0;0	258.75;0	145
258	18	0	0	9	PATCH	9;10	0;0	303.75;0	146
258	19	0	0	9	PATCH	9;10	0;0	101.25;0	147
258	20	1	0	11	PATCH	12;13	0;0	337.5;225	148
258	21	1	0	11	PATCH	10;11	0;0	168.75;90	149
258	22	1	0	11	PATCH	10;11	0;0	202.5;22.5	150
258	23	1	0	11	PATCH	10;11	0;0	67.5;225	151
258	24	0	0	7	PATCH	14;12	0;0	67.5;56.25	152

Figure 6. An example version of the antenna codebook.

One thing to be noted is that the codebook is defined at the chipset, not at the antenna elements.

Averaging the Power Density for MPE (sPD):
Spatial averaging is needed to determine the MPE values from power density simulation results over the 4 cm^2 area required by the FCC.

5 Uncertainty Budget for Simulation

Below is a table summarizing the budget of the uncertainty contributions of the numerical algorithm and of the rendering of the simulation setup. The table was filled using the IEC 62704-1 ED1 [3].

Table 2 – Preliminary budget of the uncertainty contributions of the numerical algorithm for the validation- or testing-setup

Uncertainty component	Probability distribution	Divisor f(d, h)[1]	c_i [2]	Uncertainty %
Mesh resolution	Normal	1	1	1.2%
ABC	Normal	1	1	0.2%
Power budget	Normal	1	1	0.5%
Model Truncation				0.01%
Convergence	Rectangular	1,73	1	0.2%
DUT dielectrics	Normal	1	1	5.1%
Lossy conductors	Rectangular	1,73	1	2.4%
Combined standard uncertainty (k = 1)				9.6%

Note 1: The divisor is a function of the probability distribution and degrees of freedom (v_i and v_{eff}).
Note 2: c_i is the sensitivity coefficient that is applied to convert the variability of the uncertainty component into a variability of psPD.

6 Simulation vs. Measurement

To validate the accuracy of the model, measured MPE and simulated MPE values for n258 are summarized below in Table 3, with unit W/m^2. The difference between simulated and measured MPE values is in dB. Simulated and measured point PD for different beams for n258 are shown in Figure 7.

a) Side-Firing Array, n258

Beam ID	Ant Pol	Simulation (W/m^2)	Measurement (W/m^2)	Delta = Sim – Meas. (dB)
		S4	**S4**	S4
42	V	**19.25**	**20.4**	-0.25
47	V	**15.77**	**22.7**	-1.58
50	V	**17.68**	**15.9**	0.46
166	H	**15.68**	**17.1**	-0.38
170	H	**18.89**	**19.3**	-0.09
175	H	**17.38**	**16.7**	0.17

b) Back-Firing Array 1, n258

Beam ID	Ant Pol	Simulation (W/m^2)	Measurement (W/m^2)	Delta = Sim – Meas. (dB)
		S2	**S2**	S2
36	V	**22.38**	**17.6**	1.04

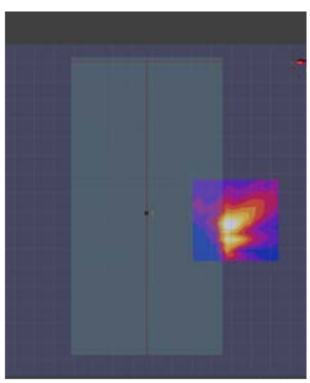
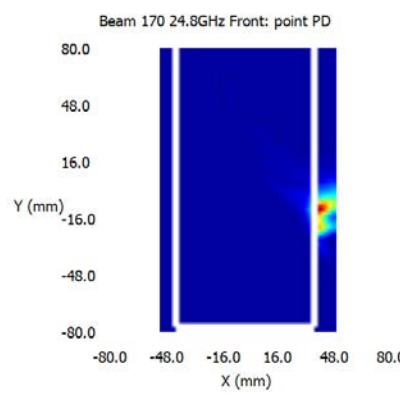
43	V	**17.01**	**16.8**	0.05
46	V	**21.30**	**17.3**	0.90
161	H	**18.74**	**14.2**	1.20
171	H	**20.60**	**17.2**	0.78
174	H	**24.53**	**14.9**	2.17

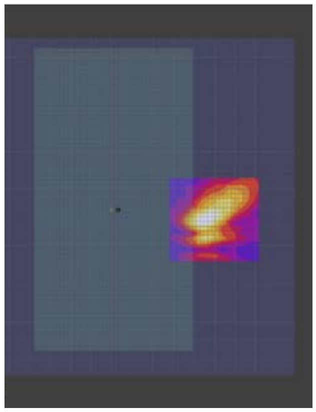
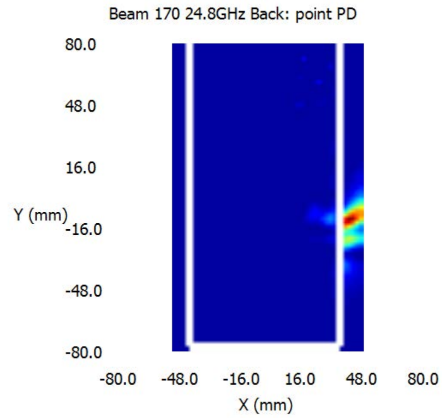
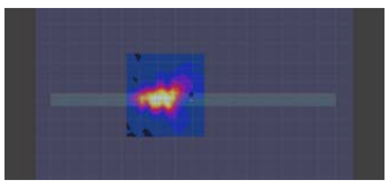
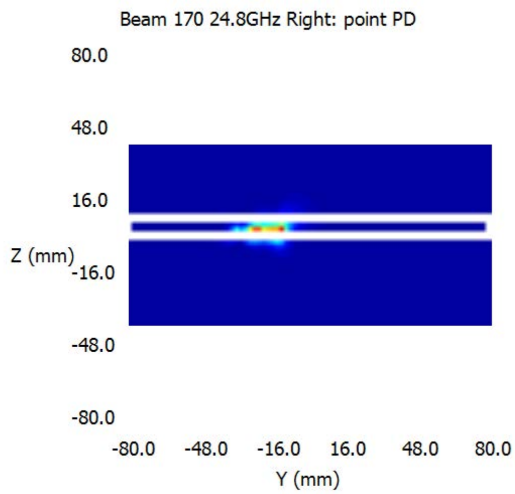
c) Back-Firing Array 2, n258

Beam ID	Ant Pol	Simulation (W/m^2)	Measurement (W/m^2)	Delta = Sim – Meas. (dB)
		S2	**S2**	S2
18	V	**5.82**	**3.19**	2.61
19	V	**3.13**	**2.14**	1.65
28	V	**5.59**	**3.15**	2.49
144	H	**6.51**	**3.77**	2.37
147	H	**7.80**	**5.81**	1.28
155	H	**7.47**	**5.23**	1.55

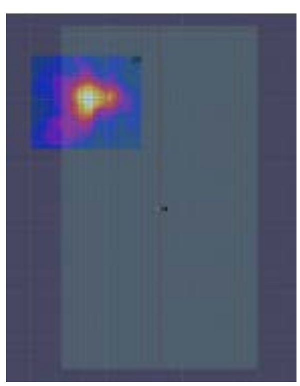
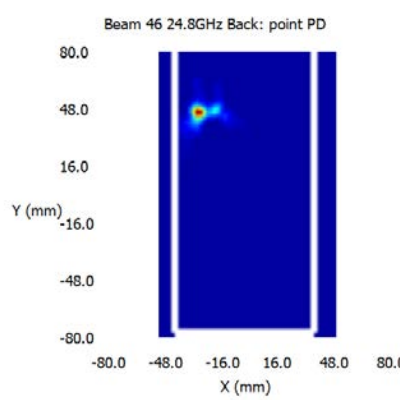
Table 3 - Simulated and measured n258 MPE (sPD) at 2 mm away from DUT.

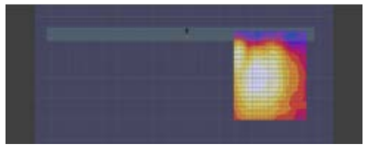
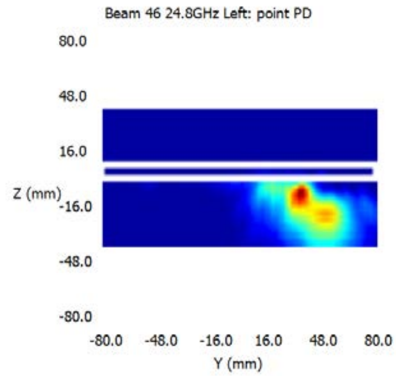
a) Side-Firing Array, n258

Beam ID	**Surface**	**Measured Point PD**	**Simulated Point PD**
170	S1		

	S2		
	S4		

b) Back-Firing Array 1, n258

Beam ID	Surface	Measured Point PD	Simulated Point PD
46	**S2**		

	S3		Beam 46 24.8GHz Left: point PD 80.0 48.0 16.0 Z (mm) -16.0 -48.0 -80.0 -80.0 -48.0 -16.0 16.0 48.0 80.0 Y (mm)

c) Back-Firing Array 2, n258

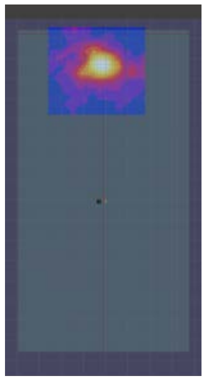
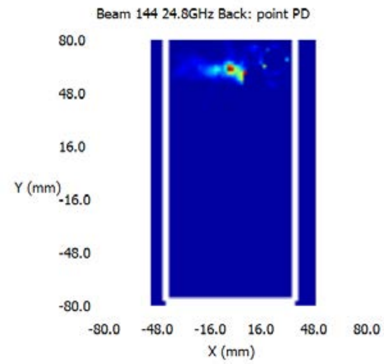
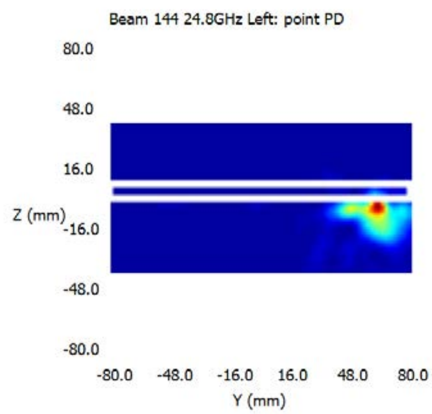
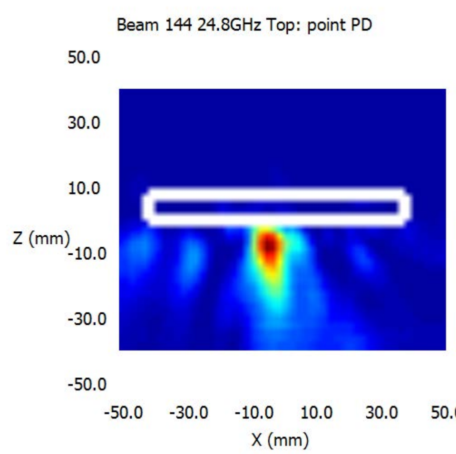
Beam ID	Surface	Measured Point PD	Simulated Point PD
144	**S2**		
	S3		
	S5		

Figure 7. *Simulated and measured point PD for different beams for n258*

Measured MPE and simulated MPE values for n261 are summarized below in Table 4, with unit W/m^2. The difference between simulated and measured MPE values is in dB. Simulated and measured point PD for different beams for n261 are shown in Figure 8.

a) Side-Firing Array, n261

Beam ID	Ant Pol	Simulation (W/m^2)	Measurement (W/m^2)	Delta = Sim – Meas. (dB)
		S4	**S4**	S4
38	V	**15.16**	**18.4**	-0.84
42	V	**14.91**	**17.4**	-0.67
50	V	**13.74**	**17.5**	-1.05
169	H	**15.72**	**16.3**	-0.16
170	H	**20.12**	**18.4**	0.39
178	H	**18.76**	**16.6**	0.53

b) Back-Firing Array 1, n261

Beam ID	Ant Pol	Simulation (W/m^2)	Measurement (W/m^2)	Delta = Sim – Meas. (dB)
		S2	**S2**	S2
36	V	**21.00**	**21.8**	-0.16
37	V	**23.68**	**19.1**	0.93
46	V	**23.11**	**21.6**	0.29
161	H	**24.37**	**15.7**	1.91
171	H	**25.03**	**18.4**	1.34
174	H	**21.29**	**17.9**	0.75

c) Back-Firing Array 2, n261

Beam ID	Ant Pol	Simulation (W/m^2)	Measurement (W/m^2)	Delta = Sim – Meas. (dB)
		S2	**S2**	S2
17	V	**6.05**	**3.21**	2.75
19	V	**6.42**	**2.08**	4.89
27	V	**5.97**	**2.34**	4.07
145	H	**8.04**	**4.73**	2.30
147	H	**7.80**	**4.81**	2.10
155	H	**7.96**	**4.77**	2.22

Table 4 - Simulated and measured n261 MPE (sPD) at 2 mm away from DUT.

a) Side-Firing Array, n261

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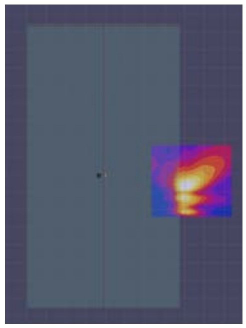
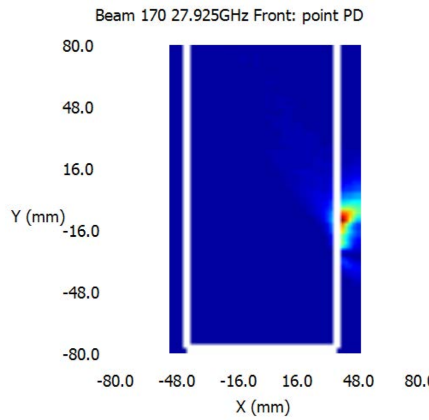
<tr><td rowspan="3">170</td><td>S1</td><td></td><td>
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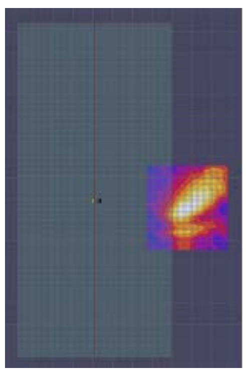
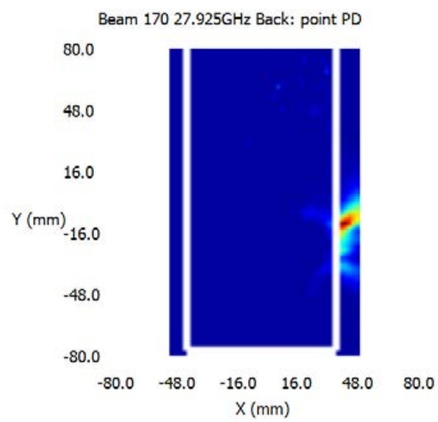
<tr><td>S2</td><td></td><td>
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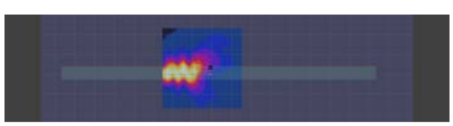
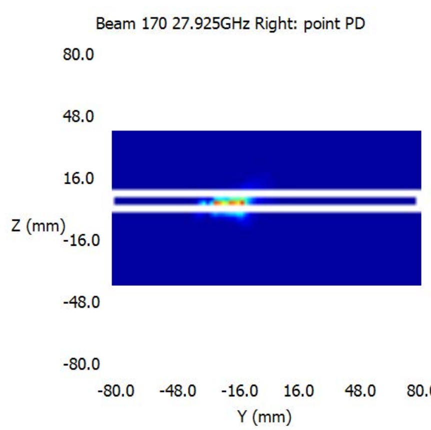
<tr><td>S4</td><td></td><td>
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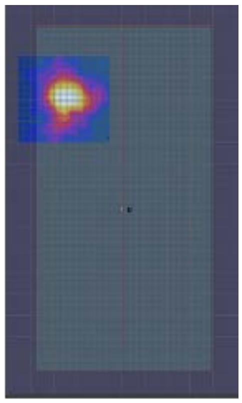
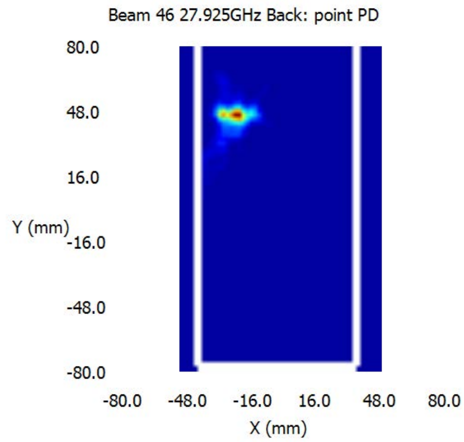
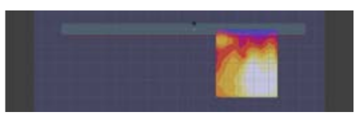
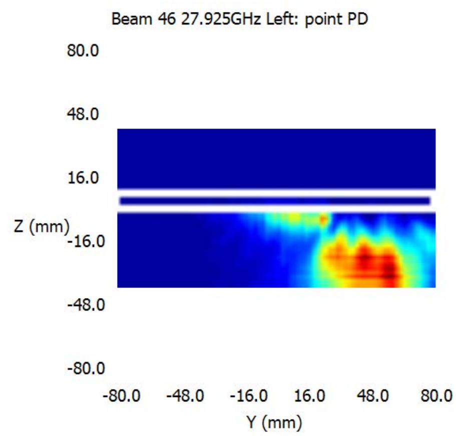
b) Back-Firing Array 1, n261

Beam ID	Surface	Measured Point PD	Simulated Point PD
46	**S2**		
	S3		

c) Back-Firing Array 2, n261

Beam ID	Surface	Measured Point PD	Simulated Point PD

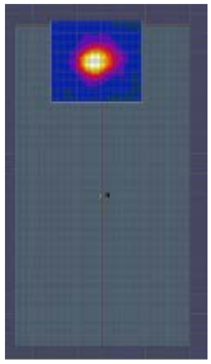
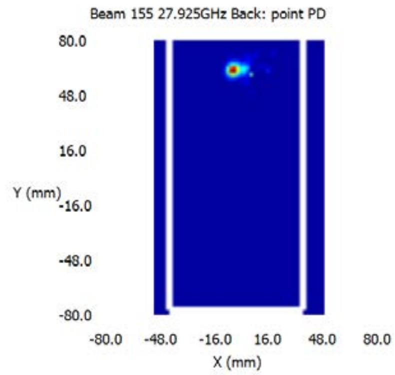
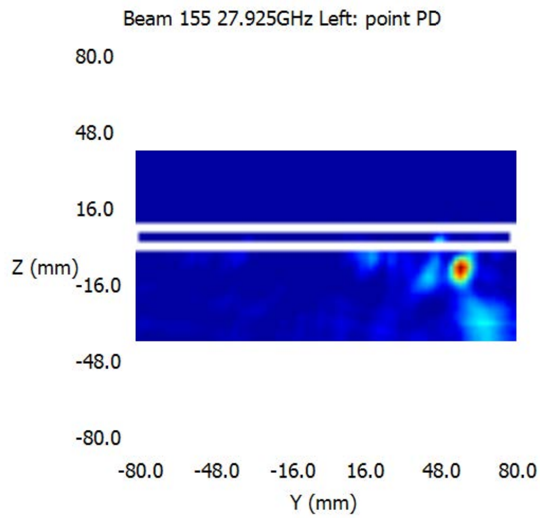
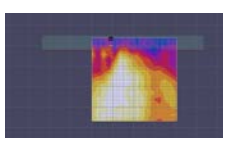
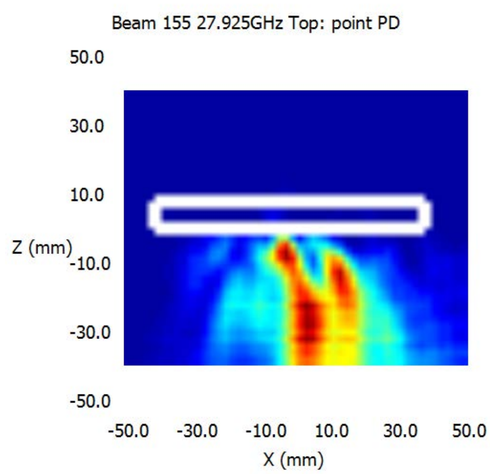
155	**S2**		
	S3		
	S5		

Figure 8. Simulated and measured point PD for different beams for n261.

Measured MPE and simulated MPE values for n260 are summarized below in Table 5, with unit W/m^2. The difference between simulated and measured MPE values is in dB. Simulated and measured point PD for different beams for n260 are shown in Figure 9.

a) Side-Firing Array, n260

Beam ID	Ant Pol	Simulation (W/m^2)	Measurement (W/m^2)	Delta = Sim – Meas. (dB)
		S4	**S4**	S4
41	V	**12.19**	**16.1**	-1.21
48	V	**10.23**	**9.13**	0.49
50	V	**13.20**	**17.6**	-1.25
169	H	**9.73**	**14.5**	-1.73
170	H	**14.99**	**9.56**	1.95
178	H	**13.20**	**13**	0.07

b) Back-Firing Array 1, n260

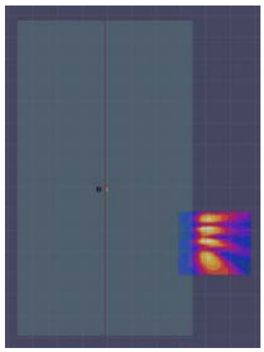
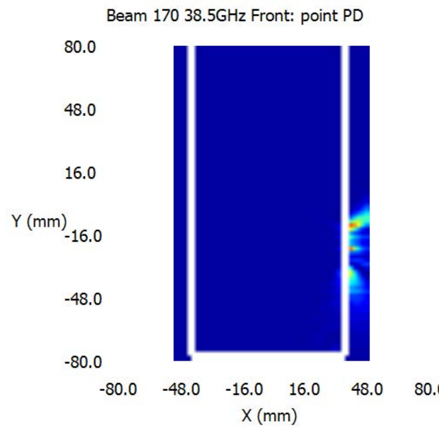
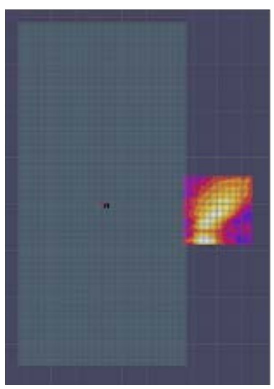
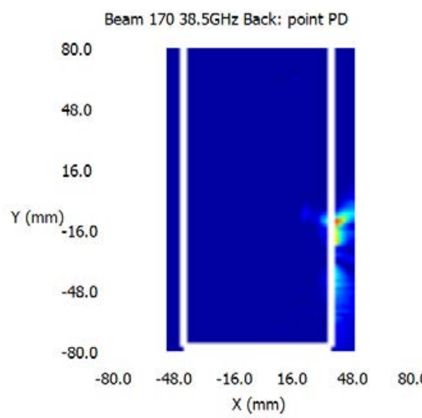
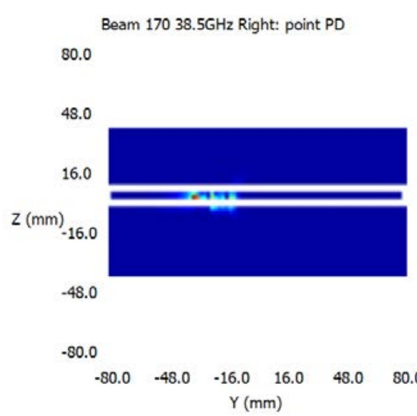
Beam ID	Ant Pol	Simulation (W/m^2)	Measurement (W/m^2)	Delta = Sim – Meas. (dB)
		S2	**S2**	S2
34	V	**14.82**	**10.1**	1.67
36	V	**15.48**	**10.1**	1.85
43	V	**13.40**	**9.13**	1.67
163	H	**15.01**	**11.8**	1.04
172	H	**14.40**	**11.2**	1.09
174	H	**14.80**	**10.5**	1.49

c) Back-Firing Array 2, n260

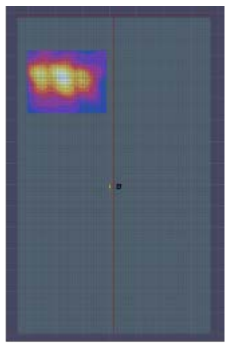
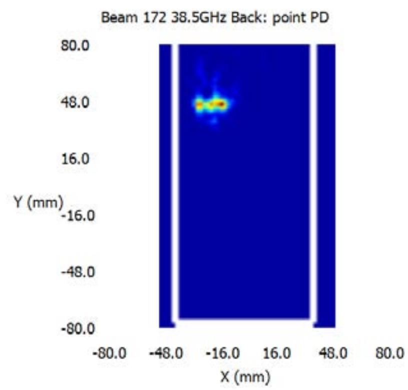
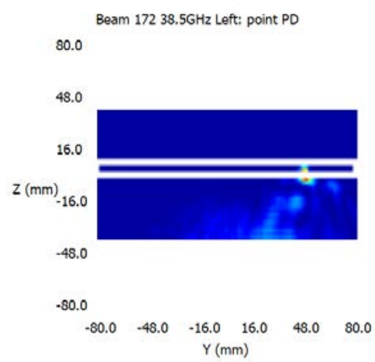
Beam ID	Ant Pol	Simulation (W/m^2)	Measurement (W/m^2)	Delta = Sim – Meas. (dB)
		S2	**S2**	S2
18	V	**4.64**	**2.76**	2.26
19	V	**4.33**	**2.12**	3.10
27	V	**4.56**	**2.86**	2.03
144	H	**3.79**	**2.56**	1.70
147	H	**3.38**	**2.76**	0.88
157	H	**3.69**	**2.82**	1.17

Table 5 – Simulated and measured n260 MPE (sPD) at 2 mm away from DUT.

a) Side-Firing Array, n260

<table>
<tr><th>Beam ID</th><th>Surface</th><th>Measured Point PD</th><th>Simulated Point PD</th></tr>
<tr><td rowspan="3">170</td><td>S1</td><td></td><td>
</td></tr>
<tr><td>S2</td><td></td><td>
</td></tr>
<tr><td>S4</td><td></td><td>
</td></tr>
</table>

b) Back-Firing Array 1, n260

Beam ID	Surface	Measured Point PD	Simulated Point PD
172	**S2**		
	S3		

c) Back-Firing Array 2, n260

Beam ID	Surface	Measured Point PD	Simulated Point PD

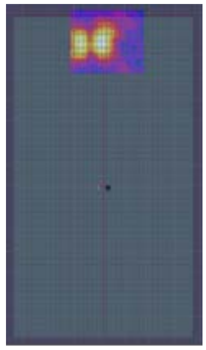
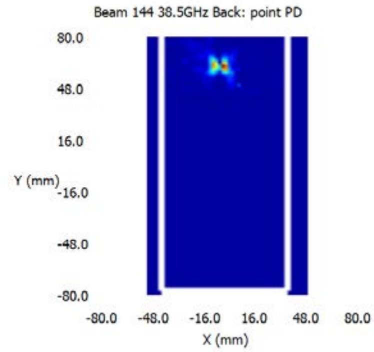
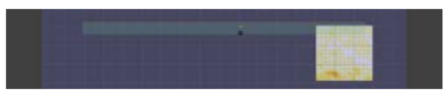
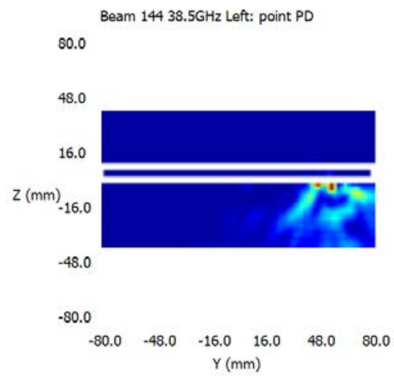
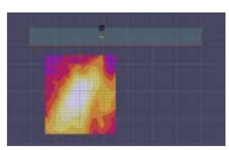
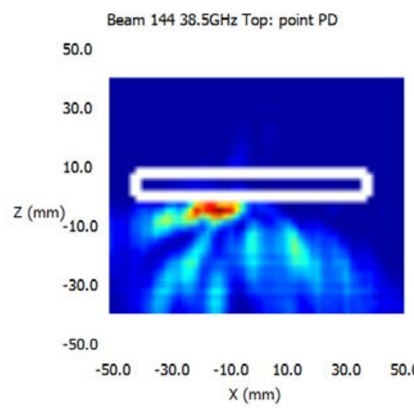
144	**S2**		
	S3		
	S5		

Figure 9. Simulated and measured point PD for different beams for n260.

Appendix A: Worst Phase Derivation for Beam Pair

For beam pairs, since the relative phase between two beams in unknown, so finding the worst-case PD by sweeping the relative phase for all possible angles is required for conservative assessments.

Assuming E-field and H-field for beam ID a are {Ex_a, Ey_a, Ez_a} and {Hx_a, Hy_a,Hz_a}, respectively; for beam pair which is ID b is {Ex_b,Ey_b,Ez_b} and {Hx_b,Hy_b,Hz_b}, respectively. The relative phase between beam a and b is θ, the combined E and H field after beam pairing is:

$$Ex\_pair\_i(\theta) = Ex\_a + Ex\_b \times e^{-j\omega\theta}$$
$$Ey\_pair\_i(\theta) = Ey\_a + Ey\_b \times e^{-j\omega\theta}$$
$$Ez\_pair\_i(\theta) = Ez\_a + Ez\_b \times e^{-j\omega\theta}$$

$$Hx\_pair\_i(\theta) = Hx\_a + Hx\_b \times e^{-j\omega\theta}$$
$$Hy\_pair\_i(\theta) = Hy\_a + Hy\_b \times e^{-j\omega\theta}$$
$$Hz\_pair\_i(\theta) = Hz\_a + Hz\_b \times e^{-j\omega\theta}$$

The combined PD can be calculated as:

$$PDx\_pair\_i(\theta) = Ey\_pair\_i(\theta)\times Hz\_pair\_i(\theta)^* - Ez\_pair\_i(\theta)\times Hy\_pair\_i(\theta)^*$$
$$PDy\_pair\_i(\theta) = Ez\_pair\_i(\theta)\times Hx\_pair\_i(\theta)^* - Ex\_pair\_i(\theta)\times Hz\_pair\_i(\theta)^*$$
$$PDz\_pair\_i(\theta) = Ex\_pair\_i(\theta)\times Hy\_pair\_i(\theta)^* - Ey\_pair\_i(\theta)\times Hx\_pair\_i(\theta)^*$$
$$PD(\theta) = \tfrac{1}{2}[(Re(PDx\_pair\_i(\theta)))^2 + (Re(PDy\_pair\_i(\theta)))^2 + (Re(PDz\_pair\_i(\theta)))^2]^{1/2}$$

Sweep θ from 0 degree to 360 degree to find the worst case beam pair.

Appendix B: 4 cm² Averaging PD and Scaling Factor

4 cm² Averaging PD: The following tables show the simulated sPD results for all three different arrays, at both band n258, n261 and band n260. Table a), b), and c) show the results for n258, for side array, back array 1, and back array 2, respectively; table d), e), and f) show the results for n261, for side array, back array 1, and back array 2, respectively; table g), h) and i) show the results for n260, for side array, back array 1, and back array 2, respectively.

a) *Simulated sPD (W/m²) at 4 cm² averaging for side array at n258.*

			4 cm² sPD (W/m²) at 6 dBm per port, n258								
Module ID	Beam ID 1	Beam ID 2	LB			MB			HB		
1			S1	S2	**S4**	S1	S2	**S4**	S1	S2	**S4**
Side Array	2		0.88	0.65	**2.95**	0.84	0.49	**2.5**	0.94	0.66	**2.98**
	5		1.41	1.08	**4.28**	1.37	1.02	**4.12**	1.21	0.85	**3.62**
	7		0.97	0.87	**3.64**	0.81	0.9	**3.3**	0.67	0.86	**2.98**
	9		0.76	0.91	**3.42**	0.85	0.96	**3.45**	0.99	1	**3.76**
	11		0.86	0.71	**3.02**	0.86	0.62	**2.8**	0.66	0.52	**2.34**

	20		2.64	1.55	**7.47**	2.29	1.45	**6.51**	1.89	1.28	**5.62**
	21		3.2	1.59	**7.78**	3.04	1.66	**7.62**	3	1.8	**7.79**
	22		2.4	2.18	**7.88**	2.4	2.16	**7.74**	2.21	2.22	**7.58**
	23		1.45	1.94	**5.94**	1.49	1.43	**5.2**	1.45	1.35	**5.12**
	30		3.2	1.55	**7.83**	3.06	1.64	**7.65**	3.04	1.77	**7.83**
	31		3.03	1.66	**7.43**	2.82	1.65	**7.24**	2.69	1.79	**7.36**
	32		2.36	2.51	**8.41**	2.07	2.65	**7.9**	1.95	2.67	**7.75**
	38		5.86	2.66	**14.88**	5.7	2.9	**14.24**	6.21	3.12	**15.21**
	39		5.64	4.03	**14.88**	5.97	3.74	**15.31**	6.25	3.93	**16.16**
	40		4.48	3.57	**13.76**	4.46	3.65	**13.9**	4.05	3.24	**13.21**
	41		5.47	4.34	**16.05**	5.36	4.61	**16.01**	4.73	4.58	**15.22**
	42		5.19	6.83	**19.52**	4.68	7.1	**19.25**	4.74	7.17	**19.43**
	47		6.73	3.38	**16.37**	6.57	3.35	**15.77**	6.87	3.6	**16.91**
	48		4.89	4.09	**14.46**	5.24	4.01	**14.89**	5.14	3.91	**14.8**
	49		4.86	3.77	**14.54**	4.67	3.68	**14.22**	4.19	3.53	**13.71**
	50		5.75	5.54	**17.83**	5.4	5.93	**17.68**	5.01	5.99	**17.11**
	130		1.16	1.12	**4.2**	1.23	1.16	**4.47**	1.27	1.12	**4.62**
	133		0.92	0.79	**3.14**	0.9	0.68	**2.79**	0.9	0.72	**2.82**
	135		1.02	0.54	**2.95**	1.15	0.71	**3.49**	1.12	0.79	**3.71**
	137		0.85	0.69	**3.24**	0.82	0.66	**3.21**	0.72	0.58	**2.92**
	139		0.76	0.72	**3.04**	0.71	0.7	**2.69**	0.75	0.73	**2.78**
	148		0.77	1.1	**4.41**	0.78	1.15	**4.32**	0.78	1.21	**4.37**
	149		2.48	2.73	**8.45**	2.37	2.68	**8.13**	2.33	2.57	**7.99**
	150		2.43	1.49	**6.47**	2.83	1.75	**7.5**	2.77	1.83	**7.6**
	151		1.73	1.15	**5.74**	1.92	1.05	**6**	2.05	1.11	**6.45**
	158		2.18	2.8	**7.91**	1.99	2.55	**7.33**	1.9	2.36	**7.08**
	159		2.51	2.35	**8.14**	2.55	2.4	**8.18**	2.6	2.41	**8.28**
	160		1.99	1.17	**6.13**	2.21	1.15	**6.48**	2.35	1.3	**6.95**
	166		3.32	4.92	**14.39**	3.35	5.9	**15.68**	3.39	6.44	**16.51**
	167		5.28	4.95	**15.78**	4.9	5.32	**15.75**	4.7	5.19	**15.73**
	168		4.71	3.67	**14.42**	4.97	4.15	**15.51**	5	4.22	**15.86**
	169		5	3.6	**14.42**	5.66	3.95	**15.64**	5.9	4.17	**16.28**
	170		6.92	4.26	**17.23**	7.87	4.27	**18.89**	8.34	4.34	**19.89**
	175		5.04	6.39	**18.55**	4.41	6.67	**17.38**	4.02	6.51	**16.26**
	176		4.84	3.94	**14.34**	4.94	4.47	**15.58**	4.89	4.67	**16.13**
	177		4.76	3.54	**14.43**	5.17	3.93	**15.4**	5.4	4.05	**15.9**
	178		5.38	3.64	**14.09**	6.33	4.03	**15.8**	6.77	4.28	**16.81**
	2	130	2.95	2.58	**10.01**	3.16	2.53	**10.18**	3.23	2.61	**10.53**
	5	133	3.14	2.23	**8.58**	2.87	2.13	**8.17**	2.7	1.97	**8.05**
	7	135	2.94	1.74	**7.68**	2.76	2.14	**8.12**	2.36	2.31	**7.8**
	9	137	2.07	2.1	**7.47**	2.06	2.14	**8.07**	2.24	2.01	**8.39**
	11	139	2.3	1.9	**7.78**	2.08	1.62	**6.71**	1.9	1.52	**6.44**
	20	148	4.17	3.95	**11.19**	3.71	3.83	**11.18**	2.99	3.68	**10.58**
	21	149	8.6	6.25	**20.68**	8.01	6.35	**20.62**	7.9	6.37	**20.64**
	22	150	6.39	4.61	**16.32**	6.25	5.24	**17.19**	6.19	5.46	**17.81**
	23	151	4.52	4.26	**13.56**	5.16	3.4	**14.31**	5.48	3.66	**14.97**
	30	158	8.41	6.42	**20.12**	7.8	6.21	**19.68**	7.64	6.07	**19.24**
	31	159	8.08	5.39	**19.89**	7.86	5.59	**20.22**	7.68	5.82	**20.54**
	32	160	6.12	3.98	**14.73**	5.73	4	**14.23**	5.52	4.18	**14.45**

	38	166	14.58	10.92	**34.19**	13.67	12.92	**33.36**	14.51	14.39	**35.22**
	39	167	14.81	14.15	**36.3**	15.12	13.99	**36.66**	15.78	13.86	**38.96**
	40	168	12.62	8.85	**34.21**	12.54	9.92	**36.03**	11.63	9.75	**35.4**
	41	169	15.87	11.29	**39.74**	17.34	12.25	**42.35**	16.65	12.83	**41.59**
	42	170	20.02	17.65	**45.8**	20.93	17.71	**48.04**	21.89	18.07	**50.56**
	47	175	16.78	15.41	**41.19**	15.36	15.81	**38.66**	16.04	16.01	**39.92**
	48	176	13.73	11.35	**35.67**	14.21	12.06	**37.71**	14.09	12.2	**38.23**
	49	177	13.89	9.56	**36.96**	14.31	10.01	**38.08**	13.63	10.15	**37.73**
	50	178	18.12	13.85	**41.07**	19.42	14.84	**43.6**	19.38	15.67	**44.13**

b) Simulated sPD (W/m^2) at 4 cm^2 averaging for back array 1 at n258.

			4 cm^2 sPD (W/m^2) at 6 dBm per port, n258								
Module ID	Beam ID 1	Beam ID 2	LB			MB			HB		
0			S1	**S2**	S3	S1	**S2**	S3	S1	**S2**	S3
Back Array 1	0		x	**4.56**	0.1	x	**4.69**	0.12	x	**4.12**	0.18
	3		x	**3.09**	0.44	x	**2.92**	0.55	x	**3.79**	0.45
	6		x	**2.76**	0.25	x	**2.87**	0.49	x	**3.23**	0.54
	8		x	**3.96**	1	x	**4.66**	1.04	x	**4.78**	0.88
	10		x	**3.16**	0.16	x	**4.32**	0.29	x	**5.03**	0.48
	12		x	**8.58**	0.21	x	**6.49**	0.33	x	**7.2**	0.24
	13		x	**5.4**	0.9	x	**6.88**	1.22	x	**7.66**	1.38
	14		x	**5.86**	0.86	x	**7.48**	0.94	x	**8.76**	0.86
	15		x	**5.68**	0.6	x	**4.82**	0.77	x	**4.73**	0.75
	24		x	**8.69**	0.28	x	**7.77**	0.39	x	**9.13**	0.25
	25		x	**8.04**	0.57	x	**8.9**	0.65	x	**10.8**	0.51
	26		x	**5.36**	0.84	x	**6.63**	0.94	x	**7.56**	0.88
	33		x	**16.13**	1.21	x	**13.92**	2.17	x	**17.05**	1.66
	34		x	**20.31**	2.02	x	**19.61**	1.96	x	**23.54**	1.48
	35		x	**19.55**	1.54	x	**22.75**	1.5	x	**24.69**	1.52
	36		x	**17.14**	2.65	x	**22.38**	4.29	x	**25.98**	5.39
	37		x	**11.67**	3.6	x	**16.26**	5.93	x	**18.99**	6.49
	43		x	**17.79**	2	x	**17.01**	2.75	x	**20.76**	2.22
	44		x	**20.63**	1.73	x	**20.76**	1.69	x	**23.78**	1.39
	45		x	**18.1**	1.58	x	**22.96**	1.58	x	**25.37**	1.93
	46		x	**15.62**	2.8	x	**21.3**	4.83	x	**25.39**	6.15
	128		x	**4.15**	0.55	x	**4.48**	0.65	x	**4.44**	0.81
	131		x	**3.39**	0.18	x	**4.03**	0.35	x	**4.82**	0.34
	134		x	**2.69**	0.19	x	**3.41**	0.38	x	**3.99**	0.57
	136		x	**3.21**	0.3	x	**4.16**	0.35	x	**5.17**	0.36
	138		x	**4.71**	0.22	x	**4.82**	0.23	x	**4.61**	0.23
	140		x	**6.54**	0.48	x	**8.01**	0.81	x	**9.83**	1.13
	141		x	**8.92**	0.36	x	**9.49**	0.41	x	**9.87**	0.5
	142		x	**5.47**	0.33	x	**7.24**	0.42	x	**8.34**	0.82

	143		x	**6.43**	1.25	x	**6.98**	1.64	x	**8.09**	1.93
	152		x	**5.99**	0.47	x	**6.82**	1.08	x	**8.58**	1.42
	153		x	**4.79**	0.31	x	**5.84**	0.48	x	**6.73**	0.53
	154		x	**7.65**	1.17	x	**7.86**	1.5	x	**8.79**	1.8
	161		x	**15.83**	0.55	x	**18.74**	0.52	x	**21.9**	0.5
	162		x	**21.2**	0.63	x	**21.13**	0.58	x	**22.46**	0.5
	163		x	**21.86**	0.7	x	**23.3**	0.41	x	**24.26**	0.69
	164		x	**22.53**	3.67	x	**25.37**	4.28	x	**26.74**	5.1
	165		x	**16.8**	3.73	x	**21.39**	4.89	x	**24.22**	5.96
	171		x	**20**	0.56	x	**20.6**	0.58	x	**22.73**	0.44
	172		x	**21.74**	0.69	x	**23.39**	0.56	x	**24.04**	0.55
	173		x	**22.44**	2.33	x	**24.3**	1.99	x	**25.71**	2.66
	174		x	**21.07**	3.96	x	**24.53**	4.48	x	**26.43**	5.36
	0	128	x	**7.84**	0.94	x	**8.11**	0.91	x	**7.35**	1.28
	3	131	x	**7.59**	0.87	x	**8.25**	1.43	x	**9.81**	1.24
	6	134	x	**7.39**	0.62	x	**7.76**	1.42	x	**8.88**	1.72
	8	136	x	**7.21**	1.92	x	**8.22**	1.96	x	**9.17**	1.71
	10	138	x	**9.87**	0.56	x	**9.72**	0.7	x	**10.59**	0.81
	12	140	x	**14.83**	0.97	x	**16.47**	1.77	x	**17.66**	1.87
	13	141	x	**14.28**	1.79	x	**16.77**	2.21	x	**17.78**	2.31
	14	142	x	**13.68**	1.77	x	**15.64**	1.75	x	**19.14**	1.97
	15	143	x	**13.53**	2.8	x	**12.99**	3.31	x	**13.38**	3.39
	24	152	x	**15.19**	1.16	x	**15.55**	2.21	x	**17.15**	2.34
	25	153	x	**13.86**	1.16	x	**15.39**	1.65	x	**17.4**	1.57
	26	154	x	**13.99**	3.22	x	**16.25**	3.6	x	**17.04**	3.48
	33	161	x	**34.24**	2.42	x	**35.34**	3.76	x	**42.81**	2.34
	34	162	x	**45.15**	4.35	x	**43.5**	3.47	x	**49.81**	2.98
	35	163	x	**44.63**	2.56	x	**50.02**	2.45	x	**50.86**	2.78
	36	164	x	**43.7**	8.75	x	**50.31**	11.82	x	**56.27**	13.92
	37	165	x	**34.35**	11.01	x	**41.9**	14.26	x	**50.49**	17.31
	43	171	x	**39.38**	4.05	x	**39.59**	4.86	x	**48**	4.05
	44	172	x	**44.85**	3.96	x	**46.82**	2.96	x	**51.35**	2.84
	45	173	x	**43.17**	4.29	x	**49.84**	5.42	x	**54.82**	6.56
	46	174	x	**43.06**	9.49	x	**50.66**	13.14	x	**58.46**	16.29

c) Simulated sPD (W/m^2) at 4 cm^2 averaging for back array 2 at n258.

			4 cm^2 sPD (W/m^2) at 6 dBm per port, n258								
Module ID	Beam ID 1	Beam ID 2	LB			MB			HB		
0			**S2**	S3	S5	**S2**	S3	S5	**S2**	S3	S5
Back Array 2	1		**3.05**	0.06	0.29	**2.86**	0.11	0.29	**2.83**	0.07	0.25
	4		**2.01**	0.07	0.12	**2.06**	0.07	0.16	**2.7**	0.1	0.28
	16		**3.41**	0.18	0.25	**4.08**	0.24	0.36	**4.39**	0.25	0.33
	17		**4.72**	0.13	0.35	**5.8**	0.15	0.55	**5.72**	0.13	0.64
	18		**6.42**	0.11	0.58	**5.82**	0.13	0.72	**6.13**	0.08	0.75

	19		**4.1**	0.13	0.39	**3.13**	0.22	0.39	**4.27**	0.24	0.64
	27		**3.53**	0.17	0.25	**4.38**	0.23	0.4	**4.57**	0.23	0.38
	28		**6.42**	0.12	0.59	**5.59**	0.13	0.72	**6**	0.09	0.74
	29		**5.86**	0.14	0.56	**4.4**	0.12	0.64	**5.27**	0.14	0.79
	129		**3.13**	0.15	0.2	**3.86**	0.15	0.23	**4.22**	0.19	0.28
	132		**3.56**	0.38	0.29	**3.33**	0.27	0.25	**3.27**	0.19	0.22
	144		**4.85**	0.58	0.39	**6.51**	0.57	0.46	**7.7**	0.45	0.55
	145		**5.68**	0.21	0.57	**7.35**	0.26	0.61	**8.69**	0.18	0.64
	146		**7.42**	0.2	0.72	**7.54**	0.19	0.69	**7.83**	0.24	0.57
	147		**8.67**	0.62	0.63	**7.8**	0.38	0.55	**7.3**	0.43	0.45
	155		**5.95**	0.16	0.61	**7.47**	0.2	0.64	**8.71**	0.17	0.64
	156		**6.21**	0.12	0.64	**7.55**	0.15	0.67	**8.67**	0.18	0.65
	157		**8.39**	0.46	0.66	**7.71**	0.27	0.59	**7.43**	0.32	0.47
	1	129	**6.82**	0.3	0.52	**8.17**	0.45	0.69	**7.77**	0.39	0.58
	4	132	**7.95**	0.54	0.58	**6.33**	0.4	0.48	**6.33**	0.32	0.58
	16	144	**11.89**	1.07	0.83	**14.66**	1.35	1.24	**14.16**	0.94	1.26
	17	145	**13.95**	0.51	1.02	**16.08**	0.73	1.48	**15.32**	0.44	1.51
	18	146	**16.7**	0.38	1.65	**15.32**	0.5	1.59	**17.04**	0.41	1.55
	19	147	**14.46**	1	1.28	**12.55**	0.87	1.17	**13.02**	0.84	1.31
	27	155	**12.92**	0.5	1.06	**14.87**	0.75	1.35	**13.92**	0.56	1.25
	28	156	**16.26**	0.26	1.58	**14.65**	0.38	1.63	**17.45**	0.34	1.61
	29	157	**16.07**	0.64	1.56	**14.22**	0.6	1.46	**14.9**	0.53	1.54

d) Simulated sPD (W/m²) at 4 cm² averaging for side array at n261.

			4 cm² sPD (W/m²) at 6 dBm per port, n261								
Module ID	Beam ID 1	Beam ID 2	LB			MB			HB		
1			S1	S2	**S4**	S1	S2	**S4**	S1	S2	**S4**
Side Array	2		1.06	1.05	**4.13**	1.06	1.11	**4.12**	1.09	1.2	**4.33**
	5		0.6	0.8	**2.46**	0.64	0.74	**2.41**	0.62	0.72	**2.29**
	7		0.88	0.77	**3.18**	0.76	0.7	**2.88**	0.67	0.76	**2.79**
	9		0.51	0.61	**2.32**	0.51	0.6	**2.28**	0.49	0.62	**2.27**
	11		0.87	0.69	**3.1**	0.96	0.72	**3.45**	0.93	0.78	**3.53**
	20		1.88	1.16	**5.35**	2.34	1.36	**6.34**	2.28	1.43	**6.48**
	21		2.14	1.5	**6.25**	1.77	1.73	**5.82**	1.68	1.8	**5.86**
	22		1.69	1.75	**5.52**	1.27	1.82	**5.43**	1.09	1.85	**5.11**
	23		1.3	2.15	**6.81**	1.38	2.02	**6.84**	1.47	2.07	**6.9**
	30		2.15	1.47	**6.29**	2.01	1.03	**6.04**	2.03	0.98	**5.93**
	31		1.98	1.63	**6.17**	1.33	2.29	**6.41**	1.27	2.27	**6.3**
	32		1.23	2.02	**6.26**	1.25	2.21	**6.88**	1.31	2.24	**6.87**
	38		6.31	3.26	**14.26**	6.77	3.13	**15.16**	6.16	3.31	**14.63**
	39		4.52	2.72	**12.37**	4.84	2.91	**13.14**	4.53	3	**13.05**
	40		3.41	2.81	**11.56**	3.55	3.85	**12.34**	3.01	3.58	**11.05**
	41		3.04	5.12	**13.38**	2.95	4.41	**12.81**	2.9	4.16	**12.24**
	42		3.25	6.99	**16.55**	2.97	6.66	**14.91**	3.03	7.23	**15.94**

	47		5.22	2.94	**12.62**	5.21	2.99	**13.22**	4.87	3.14	**13.1**
	48		4.36	2.87	**13.31**	4.83	3.28	**13.85**	4.3	3.13	**12.88**
	49		3.02	3.64	**11.53**	2.87	3.95	**11.82**	2.56	3.79	**11.17**
	50		3.44	6.45	**15.21**	3.13	5.71	**13.74**	3.12	5.73	**13.65**
	130		0.85	0.72	**3**	0.91	0.78	**3.34**	0.95	0.89	**3.53**
	133		1.05	0.83	**3.29**	1.02	0.76	**3.08**	0.93	0.69	**2.94**
	135		1.07	0.48	**2.75**	1.08	0.6	**2.87**	1.05	0.62	**2.87**
	137		0.6	0.83	**3.23**	0.51	0.79	**2.89**	0.51	0.74	**2.76**
	139		0.67	0.6	**2.56**	0.69	0.65	**2.76**	0.77	0.75	**3.06**
	148		0.85	1.68	**5.49**	1.33	1.77	**5.7**	1.36	1.95	**5.99**
	149		1.85	1.51	**5.61**	2.15	1.54	**6.19**	2.15	1.68	**6.39**
	150		2.46	1.75	**7.03**	2.71	1.37	**7.14**	2.61	1.28	**6.9**
	151		1.82	1.58	**6.44**	1.8	1.38	**6.28**	1.64	1.26	**6.04**
	158		1.43	1.77	**5.58**	1.55	1.75	**5.75**	1.56	1.94	**6.07**
	159		2.33	1.34	**6.14**	2.49	1.45	**6.65**	2.46	1.49	**6.7**
	160		2.16	1.46	**6.73**	2.16	1.33	**6.62**	2.01	1.18	**6.32**
	166		2.75	4.78	**11.7**	2.42	4.66	**11.18**	2.67	5.12	**12.63**
	167		2.91	3.84	**11.49**	2.56	2.97	**9.5**	2.24	2.73	**8.73**
	168		4.21	3.35	**12.4**	2.81	2.98	**10.7**	2.54	2.83	**10.39**
	169		5.61	3.36	**14.15**	6.06	3.83	**15.72**	5.79	3.58	**14.91**
	170		7.14	3.87	**18.71**	7.66	4.39	**20.12**	8	4.22	**20.15**
	175		2.84	4.14	**11.17**	2.33	3.44	**9.16**	2.09	3.27	**8.68**
	176		3.22	3.53	**11.56**	2.46	3.17	**10.03**	2.14	3.06	**9.44**
	177		4.8	3.26	**13.08**	4.15	3.06	**12.71**	3.82	2.95	**12**
	178		6.46	3.7	**15.66**	7.58	4.67	**18.76**	7.58	4.47	**18.46**
	2	130	2.06	2.06	**7.87**	2.32	2.22	**8.09**	2.46	2.51	**8.25**
	5	133	2.09	2.16	**6.89**	2.15	2.03	**6.59**	2.02	1.94	**6.26**
	7	135	2.44	1.88	**6.31**	2.33	1.99	**5.85**	2.25	2.14	**6.02**
	9	137	1.36	1.91	**6.35**	1.29	1.7	**5.91**	1.29	1.54	**5.49**
	11	139	1.94	1.68	**6.96**	2.01	1.58	**6.6**	2.16	1.66	**7.72**
	20	148	3.14	3.95	**11.52**	5.35	4.56	**13.8**	5.36	4.93	**14.08**
	21	149	5.08	4.05	**12.85**	4.74	4.41	**14.48**	4.5	4.85	**14.77**
	22	150	4.72	5.37	**14.23**	4.89	3.09	**13.2**	4.61	3.17	**12.54**
	23	151	4.67	5.08	**15.6**	4.12	4.77	**14.29**	3.87	4.65	**13.82**
	30	158	4.9	4.78	**12.82**	4.14	2.53	**11.51**	4.21	2.62	**12**
	31	159	4.63	3.67	**13.17**	4.98	5.25	**15.19**	4.86	5.29	**15.26**
	32	160	4.7	3.25	**12.97**	4.81	5.34	**14.84**	4.54	5.15	**14.06**
	38	166	14.01	12.57	**28.43**	14.17	11.66	**28.6**	13.55	12.97	**29.39**
	39	167	10.21	9.06	**26.82**	10.21	8.03	**25.61**	8.26	8.3	**23.95**
	40	168	8.56	7.6	**27.45**	8.14	9.35	**29.39**	6.73	9.03	**26.72**
	41	169	12.78	13.14	**34.06**	13.21	12.67	**34.5**	12.88	11.43	**31.23**
	42	170	16.29	17.94	**39.86**	16.22	18.51	**39.16**	17.16	19.07	**39.7**
	47	175	11.86	10.37	**26.86**	11.32	9.09	**25.77**	9.69	9.48	**24.38**
	48	176	9.69	8.56	**28.08**	10.1	8.62	**27.62**	8.21	8.44	**25.45**
	49	177	9.57	9.75	**29.6**	9.39	10.46	**31.08**	8.69	9.68	**28.19**
	50	178	15.54	16.45	**37.34**	16.47	16.67	**37.47**	16.76	16.34	**35.28**

e) Simulated sPD (W/m^2) at 4 cm^2 averaging for back array 1 at n261.

			4 cm^2 sPD (W/m^2) at 6 dBm per port, n261

Module ID	Beam ID 1	Beam ID 2	LB			MB			HB		
0			S1	**S2**	S3	S1	**S2**	S3	S1	**S2**	S3
Back Array 1	0		x	**4.91**	0.36	x	**4.52**	0.34	x	**4.07**	0.28
	3		x	**3.91**	0.54	x	**3.83**	0.59	x	**4.19**	0.59
	6		x	**3.88**	0.51	x	**3.76**	0.4	x	**3.88**	0.49
	8		x	**3.56**	0.57	x	**3.54**	0.5	x	**3.57**	0.6
	10		x	**4.89**	0.36	x	**4.53**	0.31	x	**4.31**	0.26
	12		x	**9.76**	0.45	x	**7.41**	0.34	x	**7.64**	0.51
	13		x	**6.71**	0.95	x	**8.32**	0.53	x	**8.46**	0.45
	14		x	**9.26**	1.22	x	**8.93**	0.95	x	**9.24**	0.92
	15		x	**7.83**	1.61	x	**6.9**	1.64	x	**7.3**	1.98
	24		x	**9.9**	0.16	x	**8.37**	0.28	x	**8.09**	0.21
	25		x	**9.23**	0.53	x	**8.43**	0.71	x	**8.71**	0.61
	26		x	**9.02**	1.44	x	**9.18**	1.19	x	**9.34**	1.18
	33		x	**23.9**	0.44	x	**22.23**	0.49	x	**22.06**	0.49
	34		x	**19.94**	0.39	x	**18.42**	0.45	x	**19.1**	0.52
	35		x	**20.42**	1.22	x	**17.92**	0.7	x	**17.83**	0.73
	36		x	**25.43**	5.41	x	**21**	2.27	x	**20.86**	2.42
	37		x	**25.88**	8.52	x	**23.68**	5.29	x	**22.7**	5.33
	43		x	**21.46**	0.32	x	**19.15**	0.49	x	**20.21**	0.45
	44		x	**20.39**	0.81	x	**17.65**	0.6	x	**17.99**	0.68
	45		x	**21.51**	2.28	x	**19.16**	0.81	x	**19.03**	0.9
	46		x	**28.07**	6.53	x	**23.11**	4.54	x	**22.39**	4.53
	128		x	**4.66**	0.67	x	**4.54**	0.5	x	**4.14**	0.37
	131		x	**4.24**	0.27	x	**3.59**	0.19	x	**3.62**	0.27
	134		x	**4.4**	0.71	x	**4.44**	0.75	x	**4.06**	0.59
	136		x	**4.8**	0.42	x	**4.62**	0.31	x	**4.77**	0.29
	138		x	**4.85**	0.26	x	**4.81**	0.3	x	**4.76**	0.35
	140		x	**8.42**	1.54	x	**8.52**	0.54	x	**8.72**	0.55
	141		x	**9.5**	0.51	x	**8.98**	0.37	x	**8.45**	0.39
	142		x	**8.69**	0.89	x	**8.09**	1.02	x	**8.16**	1.09
	143		x	**8.15**	1.67	x	**6.15**	1.1	x	**6.24**	1.06
	152		x	**7.62**	1.46	x	**8.9**	0.25	x	**8.17**	0.23
	153		x	**7.89**	0.59	x	**8.95**	0.66	x	**8.74**	0.77
	154		x	**9.16**	1.62	x	**9.49**	0.92	x	**9.96**	1.01
	161		x	**25.26**	0.9	x	**24.37**	1.03	x	**22**	0.57
	162		x	**22.14**	0.46	x	**22.17**	0.82	x	**21.72**	0.81
	163		x	**21.28**	1.04	x	**21.21**	0.85	x	**20.53**	0.91
	164		x	**24.04**	4.57	x	**20.58**	1.43	x	**20.72**	1.44
	165		x	**24.4**	8.07	x	**21.92**	4.6	x	**22.34**	4.76
	171		x	**23.54**	0.8	x	**25.03**	0.77	x	**22.83**	0.57
	172		x	**22.86**	0.74	x	**21.28**	0.56	x	**21.06**	0.6

	173		x	**20.88**	2.55	x	**20.52**	0.98	x	**20.19**	1
	174		x	**25.59**	6.19	x	**21.29**	3.86	x	**21.76**	3.66
	0	128	x	**9.65**	1.39	x	**8.48**	1.08	x	**7.84**	0.88
	3	131	x	**8.62**	1.27	x	**8.47**	1.24	x	**8.51**	1.32
	6	134	x	**8.76**	1.68	x	**8.34**	1.52	x	**8.19**	1.38
	8	136	x	**7.34**	1.41	x	**7.24**	1.03	x	**7.65**	1.08
	10	138	x	**10.86**	0.96	x	**10.41**	0.84	x	**10.35**	0.74
	12	140	x	**17.59**	2.94	x	**14.59**	1.39	x	**15.06**	1.65
	13	141	x	**17.04**	1.6	x	**19.62**	0.91	x	**19.36**	0.9
	14	142	x	**18.91**	3.09	x	**17.29**	3.06	x	**19.21**	2.86
	15	143	x	**17.75**	5.03	x	**14.43**	3.98	x	**15.15**	4.31
	24	152	x	**16.63**	2.08	x	**20.32**	0.79	x	**18.95**	0.48
	25	153	x	**17.94**	1.21	x	**18.64**	1.7	x	**19.46**	1.58
	26	154	x	**20.79**	4.76	x	**21.9**	3.28	x	**22.15**	3.05
	33	161	x	**53.28**	1.81	x	**54.51**	1.53	x	**47.03**	1.57
	34	162	x	**46.38**	1.2	x	**42.96**	1.94	x	**47.23**	2.23
	35	163	x	**47.22**	2.89	x	**44.97**	1.62	x	**44.3**	2.01
	36	164	x	**52.44**	11.88	x	**46.45**	4.6	x	**47.35**	4.44
	37	165	x	**68.58**	25.33	x	**48.92**	12.5	x	**49.71**	12.13
	43	171	x	**47.01**	1.71	x	**44.51**	1.72	x	**46.03**	1.52
	44	172	x	**49.45**	1.65	x	**43.4**	1.51	x	**45.81**	1.69
	45	173	x	**45.42**	5.51	x	**45.36**	2.84	x	**45.04**	2.52
	46	174	x	**59.22**	17.91	x	**48.05**	10.16	x	**49.99**	9.46

f) Simulated sPD (W/m^2) at 4 cm^2 averaging for back array 2 at n261.

			4 cm^2 sPD (W/m^2) at 6 dBm per port, n261								
Module ID	Beam ID 1	Beam ID 2	LB			MB			HB		
0			**S2**	S3	S5	**S2**	S3	S5	**S2**	S3	S5
Back Array 2	1		**3.44**	0.13	0.56	**3.9**	0.16	0.52	**4.08**	0.16	0.56
	4		**3.01**	0.07	0.3	**2.49**	0.1	0.23	**2.43**	0.12	0.25
	16		**6.18**	0.31	0.54	**6.03**	0.35	0.42	**6.42**	0.31	0.4
	17		**6.06**	0.28	0.43	**6.05**	0.26	0.44	**6.53**	0.23	0.5
	18		**6.18**	0.18	1.13	**6.25**	0.11	1.2	**6.24**	0.1	1.33
	19		**6.47**	0.19	1.15	**6.42**	0.21	0.94	**6.4**	0.21	1.01
	27		**6.13**	0.31	0.49	**5.97**	0.35	0.33	**6.5**	0.3	0.31
	28		**6.2**	0.17	1.21	**6.1**	0.16	0.79	**6.36**	0.15	0.89
	29		**6.39**	0.18	1.39	**6.45**	0.14	1.13	**6.34**	0.14	1.25
	129		**3.33**	0.19	0.2	**3.39**	0.21	0.19	**3.45**	0.24	0.2
	132		**4.16**	0.18	0.22	**3.98**	0.2	0.2	**2.73**	0.16	0.15
	144		**7.62**	0.44	0.44	**7.4**	0.55	0.48	**6**	0.52	0.36
	145		**8.43**	0.16	0.67	**8.04**	0.12	0.63	**6.31**	0.13	0.5
	146		**7.52**	0.14	0.59	**6.93**	0.26	0.55	**5.92**	0.22	0.49
	147		**7.63**	0.41	0.51	**7.8**	0.61	0.45	**6.96**	0.56	0.39
	155		**8.47**	0.11	0.69	**7.96**	0.08	0.62	**6.29**	0.09	0.49
	156		**8.43**	0.08	0.7	**7.63**	0.1	0.58	**6.17**	0.09	0.49

	157		**7.44**	0.32	0.54	**7.29**	0.35	0.54	**6.32**	0.31	0.47
	1	129	**7.81**	0.33	1.04	**7.79**	0.37	0.95	**8.45**	0.45	1.13
	4	132	**8.3**	0.43	0.68	**8.15**	0.47	0.49	**5.87**	0.41	0.47
	16	144	**16.51**	0.79	1.09	**15.98**	1.04	0.8	**13**	1.07	0.83
	17	145	**17.19**	0.48	1.35	**15.99**	0.45	1.17	**13.88**	0.49	1.23
	18	146	**15.83**	0.45	1.94	**14.51**	0.45	2.08	**13.56**	0.4	2.25
	19	147	**14.9**	0.92	1.81	**16.4**	1.14	1.62	**14.54**	1.11	1.75
	27	155	**17.29**	0.51	1.28	**15.96**	0.56	0.97	**13.5**	0.47	0.78
	28	156	**16.2**	0.3	2.25	**15.54**	0.35	1.67	**14**	0.29	1.79
	29	157	**15.46**	0.75	2.07	**15.42**	0.72	1.97	**13.29**	0.67	2.13

g) Simulated sPD (W/m^2) at 4 cm^2 averaging for side array at n260.

			4 cm^2 sPD (W/m^2) at 6 dBm per port, n260								
Module ID	Beam ID 1	Beam ID 2	LB			MB			HB		
1			S1	S2	**S4**	S1	S2	**S4**	S1	S2	**S4**
Side Array	2		0.89	0.71	**3.89**	0.66	0.47	**2.72**	0.74	0.44	**3.04**
	5		0.47	0.51	**1.91**	0.5	0.37	**1.94**	0.36	0.25	**1.38**
	7		0.53	0.45	**1.8**	0.63	0.49	**2.08**	0.51	0.35	**1.61**
	9		0.54	0.42	**2.42**	0.59	0.43	**2.56**	0.63	0.43	**2.5**
	11		0.8	0.7	**3.37**	0.64	0.54	**2.72**	0.7	0.55	**2.74**
	20		1.44	1.3	**6.47**	1.13	0.67	**4.65**	1.11	0.64	**5.16**
	21		1.1	1.02	**3.98**	1.11	0.92	**4.39**	1.09	0.8	**3.71**
	22		1.27	1.11	**4.67**	1.19	0.98	**4.19**	1.05	0.73	**3.52**
	23		1.54	1.25	**6.84**	1.29	0.97	**5.6**	1.53	1.12	**6.32**
	30		1.11	0.97	**5.07**	1.14	0.95	**5.14**	1.19	0.87	**4.68**
	31		1.24	1.07	**4.09**	1.16	0.9	**4.21**	1.16	0.86	**4.08**
	32		0.75	0.55	**2.88**	0.81	0.62	**3.26**	0.65	0.45	**2.52**
	38		2.27	2.17	**9.3**	1.5	1.3	**6.85**	1.51	1.07	**6.33**
	39		2.5	2.8	**10.36**	2.47	1.66	**8.34**	2.18	1.36	**7.23**
	40		3.43	3	**11.25**	3.37	2.67	**10.93**	3.01	2.1	**9.55**
	41		3.63	2.9	**12.85**	3.38	2.77	**12.19**	3.14	2.3	**11.46**
	42		2.97	1.99	**9.88**	2.63	2.03	**10.63**	2.79	1.95	**11.01**
	47		2.32	2.18	**9.41**	1.63	1.2	**6.92**	1.62	1.14	**6.39**
	48		3.19	3.27	**11.39**	3.18	2.37	**10.23**	2.77	1.74	**8.9**
	49		2.77	2.51	**9.7**	2.7	2.13	**9.35**	2.57	1.8	**8.67**
	50		3.95	2.83	**13.98**	3.49	2.68	**13.2**	3.22	2.33	**12.48**
	130		1.1	0.44	**2.92**	1.04	0.67	**3.6**	0.88	0.51	**2.98**
	133		1.15	0.51	**2.79**	0.54	0.53	**2.15**	0.54	0.42	**2.09**
	135		1.02	0.33	**2.51**	0.45	0.48	**1.95**	0.39	0.32	**1.59**
	137		0.79	0.31	**2.84**	0.76	0.49	**3.12**	0.43	0.41	**2.32**
	139		1.01	0.4	**3.16**	1.1	0.35	**3.12**	0.76	0.34	**2.46**
	148		2.32	0.82	**6.13**	2.15	1.1	**7.38**	1.68	0.91	**6.36**
	149		1.89	0.82	**4.91**	1.58	0.82	**4.99**	1.06	0.72	**3.66**
	150		1.82	0.83	**4.45**	1.01	0.83	**3.47**	0.69	0.53	**2.59**
	151		2.51	0.82	**6.54**	2.14	1.15	**7.41**	1.72	0.99	**6.4**
	158		1.85	0.94	**4.82**	1.63	1.12	**5.72**	1.34	0.82	**4.9**

	159		2.15	1.02	**5.19**	1.08	1.26	**4.19**	1.21	0.95	**3.9**
	160		1.69	0.63	**6.33**	2.19	0.68	**7.04**	1.43	0.74	**5.5**
	166		4.56	1.72	**12.19**	3.86	2.74	**12.99**	2.75	2.51	**12.01**
	167		3.16	0.81	**6.98**	2.32	1.31	**7.14**	1.94	1.08	**5.87**
	168		5.16	2.76	**12.51**	3.06	3.22	**10.47**	2.71	2.18	**8.59**
	169		6.03	1.67	**13.29**	3.54	1.54	**9.73**	2.71	1.68	**8.56**
	170		4.68	1.49	**14.14**	4.45	3.17	**14.99**	2.69	2.69	**12.76**
	175		3.79	1.29	**9.39**	3.37	2.09	**10.49**	2.75	1.82	**9.13**
	176		3.47	1.93	**8.76**	2.4	2.2	**8.35**	1.76	1.41	**6.19**
	177		5.39	2.55	**12.64**	3.27	3	**10.81**	2.85	1.85	**8.59**
	178		5.51	1.4	**13.11**	4.06	2.33	**13.2**	2.86	2.15	**11.28**
	2	130	2.69	1.6	**7.95**	2.04	1.5	**7.04**	1.91	1.06	**6.81**
	5	133	2	1.48	**5.55**	1.47	1.07	**4.71**	1.01	0.73	**3.86**
	7	135	1.78	1.03	**4.67**	1.28	1	**4.21**	0.96	0.78	**3.44**
	9	137	1.64	1.05	**6.16**	1.83	1.08	**6.38**	1.24	0.9	**5.06**
	11	139	2.64	1.43	**7.84**	2.19	1.15	**6.32**	1.88	1.2	**5.46**
	20	148	4.55	3.23	**13.58**	4.13	2.39	**13.81**	3.33	1.9	**14.38**
	21	149	4.75	2.65	**11.3**	3.38	1.97	**10.16**	2.78	1.65	**8.22**
	22	150	3.36	1.94	**9.32**	2.66	2.04	**9.05**	1.87	1.4	**6.56**
	23	151	3.43	1.88	**10.9**	2.99	1.9	**10.07**	2.56	2.16	**10.38**
	30	158	3.12	2.36	**8.85**	2.4	2.04	**8.93**	2.18	1.52	**7.73**
	31	159	3.7	2.24	**8.86**	2.27	2.1	**7.91**	2.34	1.66	**7.65**
	32	160	2.38	1.26	**8.83**	2.9	1.39	**9.6**	2.05	1.17	**7.21**
	38	166	9.39	6.1	**26.38**	7.08	5.03	**24.19**	5.42	3.78	**22**
	39	167	7.13	5.1	**19.97**	7.21	3.92	**20.82**	5.34	2.6	**15.01**
	40	168	10.38	8.06	**27.07**	8.4	6.62	**25.07**	6.93	4.91	**20.57**
	41	169	10.62	6.12	**30.96**	7.96	4.89	**24.94**	6.89	4.61	**22.94**
	42	170	11.26	4.66	**27.19**	9.76	6.65	**29.18**	7.02	5.56	**24.59**
	47	175	9.23	5.54	**23.89**	7.26	4.9	**21.81**	5.61	3.35	**17.69**
	48	176	8.84	7.53	**23.51**	7.84	5.35	**22.54**	5.9	3.55	**17.82**
	49	177	8.95	6.99	**27.14**	6.77	5.69	**21.94**	5.79	4.01	**18.21**
	50	178	12.97	5.05	**33.55**	9.82	5.34	**31.11**	7.65	4.71	**27.57**

h) Simulated sPD (W/m^2) at 4 cm^2 averaging for back array 1 at n260.

			4 cm^2 sPD (W/m^2) at 6 dBm per port, n260								
Module ID	Beam ID 1	Beam ID 2	LB			MB			HB		
0			S1	**S2**	S3	S1	**S2**	S3	S1	**S2**	S3
Back Array 1	0		x	**2.94**	0.47	x	**3.03**	0.55	x	**3.05**	0.55
	3		x	**3.11**	0.39	x	**3.01**	0.37	x	**2.86**	0.31
	6		x	**3.47**	0.34	x	**3.72**	0.38	x	**3.36**	0.38
	8		x	**3.47**	0.24	x	**3.65**	0.27	x	**3.52**	0.24
	10		x	**4.43**	0.16	x	**4.28**	0.12	x	**3.92**	0.16
	12		x	**6.72**	1.22	x	**6.48**	1.01	x	**6.12**	1.1
	13		x	**7.56**	0.72	x	**7.1**	0.73	x	**6.75**	0.8
	14		x	**6.02**	0.64	x	**6**	0.54	x	**5.34**	0.54
	15		x	**5.83**	0.72	x	**5.93**	0.48	x	**5.96**	0.35

	24		x	**6.01**	1.27	x	**6.2**	1.4	x	**5.83**	1.42
	25		x	**6.02**	0.78	x	**6.03**	1.08	x	**6.3**	1.02
	26		x	**6.5**	1.07	x	**6.2**	0.89	x	**5.55**	0.84
	33		x	**15**	5.11	x	**13.12**	4.34	x	**12.6**	4.18
	34		x	**16.29**	3.77	x	**14.82**	4.02	x	**12.96**	4.45
	35		x	**14.7**	0.82	x	**13.87**	1.32	x	**13.32**	1.29
	36		x	**15.24**	0.62	x	**15.48**	0.82	x	**15.14**	1.06
	37		x	**13.43**	1.52	x	**15.31**	0.79	x	**15.04**	0.58
	43		x	**15.92**	5.08	x	**13.4**	4.49	x	**12.62**	4.55
	44		x	**14.65**	0.93	x	**14.64**	1.35	x	**12.88**	1.82
	45		x	**15.31**	0.66	x	**14.96**	1.13	x	**14.72**	1.4
	46		x	**14.53**	0.79	x	**14.86**	0.88	x	**14.44**	0.77
	128		x	**3.04**	0.56	x	**2.98**	0.59	x	**2.52**	0.5
	131		x	**3.34**	0.39	x	**3.25**	0.35	x	**3.02**	0.37
	134		x	**3.21**	0.28	x	**3.37**	0.28	x	**3.35**	0.32
	136		x	**3.74**	0.19	x	**3.31**	0.27	x	**3.69**	0.28
	138		x	**3.44**	0.15	x	**4.17**	0.21	x	**3.53**	0.23
	140		x	**6.18**	1.55	x	**6.44**	1.41	x	**5.73**	1.38
	141		x	**7.24**	0.51	x	**7.35**	0.62	x	**7.44**	0.55
	142		x	**6.84**	0.19	x	**6.64**	0.22	x	**6.48**	0.29
	143		x	**6.29**	1.44	x	**6.62**	1.36	x	**5.76**	1.29
	152		x	**6.99**	0.8	x	**6.56**	0.92	x	**7.03**	0.91
	153		x	**5.83**	0.5	x	**4.88**	0.47	x	**4.53**	0.5
	154		x	**6.53**	0.29	x	**6.56**	0.2	x	**6.46**	0.19
	161		x	**13.94**	4.97	x	**15.36**	4.63	x	**15.82**	4.77
	162		x	**14.92**	3.67	x	**14.83**	3.87	x	**14.07**	3.66
	163		x	**16.16**	0.65	x	**15.01**	0.87	x	**14.62**	1.08
	164		x	**16.06**	0.71	x	**14.46**	0.77	x	**12.86**	0.71
	165		x	**13.48**	1.65	x	**14.44**	1.72	x	**13.19**	1.24
	171		x	**14.85**	4.42	x	**15.1**	4.56	x	**14.71**	4.25
	172		x	**16.86**	0.53	x	**14.4**	0.65	x	**13.64**	0.83
	173		x	**16.02**	0.52	x	**14.96**	0.73	x	**14.17**	0.7
	174		x	**16.57**	0.79	x	**14.8**	0.97	x	**13.05**	1.12
	0	128	x	**6.72**	1.46	x	**6.78**	1.51	x	**6.48**	1.33
	3	131	x	**7.39**	1.01	x	**7.13**	0.91	x	**7.03**	0.95
	6	134	x	**7.67**	0.89	x	**7.76**	0.89	x	**8.14**	0.88
	8	136	x	**8.33**	0.67	x	**8.32**	0.57	x	**8.5**	0.58
	10	138	x	**8.15**	0.32	x	**8.72**	0.33	x	**8.56**	0.36
	12	140	x	**14.65**	3.01	x	**15.17**	2.82	x	**14.59**	2.95
	13	141	x	**15.13**	1.46	x	**15.35**	1.64	x	**14.72**	1.66
	14	142	x	**13.84**	1.03	x	**13.46**	0.9	x	**13.73**	1.12
	15	143	x	**13.96**	2.54	x	**14.77**	1.99	x	**14**	1.81
	24	152	x	**12.1**	2.13	x	**11.76**	2.31	x	**11.13**	2.35
	25	153	x	**13.37**	1.23	x	**12.03**	2.1	x	**12.23**	1.93
	26	154	x	**15.21**	1.61	x	**14.09**	1.15	x	**14.31**	1.31
	33	161	x	**34.08**	10.8	x	**35.68**	9.8	x	**37.37**	10.21
	34	162	x	**33.42**	6.91	x	**33.65**	8.02	x	**32.83**	8.61
	35	163	x	**32.53**	2.31	x	**31.29**	3.51	x	**31.63**	4.19
	36	164	x	**35.36**	1.57	x	**33.39**	2.55	x	**33.39**	2.74

	37	165	x	**32.99**	4.89	x	**34.52**	3.56	x	**35.18**	2.11
	43	171	x	**33.67**	9.12	x	**32.6**	9.47	x	**32.54**	9.45
	44	172	x	**33.09**	1.95	x	**32.11**	2.32	x	**31.7**	2.62
	45	173	x	**33.85**	1.37	x	**32.18**	2.59	x	**32.3**	3.31
	46	174	x	**34.46**	2.01	x	**33.44**	2.47	x	**33.09**	2.78

i) *Simulated sPD (W/m^2) at 4 cm^2 averaging for back array 2 at n260.*

			4 cm^2 sPD (W/m^2) at 6 dBm per port, n260								
Module ID	Beam ID 1	Beam ID 2	LB			MB			HB		
0			**S2**	S3	S5	**S2**	S3	S5	**S2**	S3	S5
Back Array 2	1		**2.78**	0.13	0.28	**2.83**	0.12	0.26	**1.62**	0.05	0.12
	4		**1.66**	0.05	0.18	**1.7**	0.06	0.15	**1.9**	0.07	0.19
	16		**4.39**	0.15	0.39	**4.38**	0.15	0.37	**4.08**	0.12	0.37
	17		**3.98**	0.1	0.37	**4.5**	0.1	0.46	**3.9**	0.09	0.39
	18		**3.81**	0.11	0.5	**4.64**	0.12	0.61	**3.19**	0.06	0.38
	19		**4.91**	0.24	0.48	**4.33**	0.29	0.36	**3.16**	0.15	0.23
	27		**3.82**	0.09	0.39	**4.56**	0.1	0.52	**3.7**	0.08	0.39
	28		**3.99**	0.13	0.54	**4.64**	0.15	0.62	**3.04**	0.08	0.36
	29		**4.46**	0.18	0.55	**4.55**	0.23	0.54	**2.92**	0.11	0.28
	129		**2.09**	0.11	0.18	**1.58**	0.07	0.17	**1.61**	0.05	0.25
	132		**2.62**	0.06	0.23	**1.98**	0.04	0.17	**1.84**	0.05	0.18
	144		**5.17**	0.27	0.31	**3.79**	0.15	0.27	**3.35**	0.14	0.36
	145		**3.91**	0.05	0.63	**3.19**	0.07	0.46	**3.61**	0.07	0.49
	146		**4.1**	0.06	0.59	**3.39**	0.08	0.43	**3.7**	0.07	0.45
	147		**4.72**	0.25	0.45	**3.38**	0.18	0.35	**2.94**	0.14	0.5
	155		**4.01**	0.15	0.56	**2.96**	0.14	0.46	**2.97**	0.1	0.56
	156		**3.77**	0.07	0.63	**3.01**	0.08	0.48	**3.46**	0.06	0.52
	157		**4.58**	0.13	0.47	**3.69**	0.1	0.37	**3.74**	0.09	0.45
	1	129	**5.71**	0.26	0.45	**4.66**	0.25	0.53	**3.49**	0.12	0.49
	4	132	**4.94**	0.16	0.46	**4.45**	0.15	0.39	**4.68**	0.14	0.46
	16	144	**11.35**	0.44	0.82	**9.22**	0.37	0.74	**8.89**	0.3	0.86
	17	145	**8.01**	0.21	1.05	**7.99**	0.23	1.17	**8.3**	0.18	1.25
	18	146	**8.56**	0.23	1.13	**8.87**	0.23	1.28	**7.62**	0.16	1.27
	19	147	**10.26**	0.55	0.75	**8.55**	0.51	0.76	**6.67**	0.38	0.77
	27	155	**8.86**	0.34	1.18	**7.96**	0.32	1.15	**7.26**	0.21	1.16
	28	156	**8.77**	0.26	1.17	**8.27**	0.32	1.19	**7.07**	0.17	1.14
	29	157	**10.28**	0.43	1.19	**9.58**	0.36	1.21	**7.74**	0.25	1.14

Scaling factor calculation: The following tables show the scaling factor results for all three different modules, at both band n258, n261 and band n260. The scaling factor is defined as the MPE internal design limit (5 W/m^2) divided by the simulated averaged power density. Table a), b), and c) show the results for n258, for side, back, and front modules, respectively; table d), e), and f) show the results for n261, for side, back, and front modules, respectively; table g), h) and i) show the results for n260, for side, back, and front modules, respectively.

a) Scaling factor for side array n258

Beam ID 1	Beam ID 2	S_LB	S_MB	S_HB	S
2		1.69	2.00	1.68	1.68
5		1.17	1.21	1.38	1.17
7		1.37	1.52	1.68	1.37
9		1.46	1.45	1.33	1.33
11		1.66	1.79	2.14	1.66
20		0.67	0.77	0.89	0.67
21		0.64	0.66	0.64	0.64
22		0.63	0.65	0.66	0.63
23		0.84	0.96	0.98	0.84
30		0.64	0.65	0.64	0.64
31		0.67	0.69	0.68	0.67
32		0.59	0.63	0.65	0.59
38		0.34	0.35	0.33	0.33
39		0.34	0.33	0.31	0.31
40		0.36	0.36	0.38	0.36
41		0.31	0.31	0.33	0.31
42		0.26	0.26	0.26	0.26
47		0.31	0.32	0.30	0.30
48		0.35	0.34	0.34	0.34
49		0.34	0.35	0.36	0.34
50		0.28	0.28	0.29	0.28
130		1.19	1.12	1.08	1.08
133		1.59	1.79	1.77	1.59
135		1.69	1.43	1.35	1.35
137		1.54	1.56	1.71	1.54
139		1.64	1.86	1.80	1.64
148		1.13	1.16	1.14	1.13
149		0.59	0.62	0.63	0.59
150		0.77	0.67	0.66	0.66
151		0.87	0.83	0.78	0.78
158		0.63	0.68	0.71	0.63
159		0.61	0.61	0.60	0.60
160		0.82	0.77	0.72	0.72
166		0.35	0.32	0.30	0.30
167		0.32	0.32	0.32	0.32
168		0.35	0.32	0.32	0.32
169		0.35	0.32	0.31	0.31
170		0.29	0.26	0.25	0.25
175		0.27	0.29	0.31	0.27
176		0.35	0.32	0.31	0.31
177		0.35	0.32	0.31	0.31
178		0.35	0.32	0.30	0.30
2	130	0.50	0.49	0.47	0.47
5	133	0.58	0.61	0.62	0.58
7	135	0.65	0.62	0.64	0.62
9	137	0.67	0.62	0.60	0.60

11	139	0.64	0.75	0.78	0.64
20	148	0.45	0.45	0.47	0.45
21	149	0.24	0.24	0.24	0.24
22	150	0.31	0.29	0.28	0.28
23	151	0.37	0.35	0.33	0.33
30	158	0.25	0.25	0.26	0.25
31	159	0.25	0.25	0.24	0.24
32	160	0.34	0.35	0.35	0.34
38	166	0.15	0.15	0.14	0.14
39	167	0.14	0.14	0.13	0.13
40	168	0.15	0.14	0.14	0.14
41	169	0.13	0.12	0.12	0.12
42	170	0.11	0.10	0.10	0.10
47	175	0.12	0.13	0.13	0.12
48	176	0.14	0.13	0.13	0.13
49	177	0.14	0.13	0.13	0.13
50	178	0.12	0.11	0.11	0.11

b) *Scaling factor for back array 1 n258*

Beam ID 1	Beam ID 2	S_LB	S_MB	S_HB	S
0		1.10	1.07	1.21	1.07
3		1.62	1.71	1.32	1.32
6		1.81	1.74	1.55	1.55
8		1.26	1.07	1.05	1.05
10		1.58	1.16	0.99	0.99
12		0.58	0.77	0.69	0.58
13		0.93	0.73	0.65	0.65
14		0.85	0.67	0.57	0.57
15		0.88	1.04	1.06	0.88
24		0.58	0.64	0.55	0.55
25		0.62	0.56	0.46	0.46
26		0.93	0.75	0.66	0.66
33		0.31	0.36	0.29	0.29
34		0.25	0.25	0.21	0.21
35		0.26	0.22	0.20	0.20
36		0.29	0.22	0.19	0.19
37		0.43	0.31	0.26	0.26
43		0.28	0.29	0.24	0.24
44		0.24	0.24	0.21	0.21
45		0.28	0.22	0.20	0.20
46		0.32	0.23	0.20	0.20
128		1.20	1.12	1.13	1.12
131		1.47	1.24	1.04	1.04
134		1.86	1.47	1.25	1.25
136		1.56	1.20	0.97	0.97
138		1.06	1.04	1.08	1.04
140		0.76	0.62	0.51	0.51
141		0.56	0.53	0.51	0.51

142		0.91	0.69	0.60	0.60
143		0.78	0.72	0.62	0.62
152		0.83	0.73	0.58	0.58
153		1.04	0.86	0.74	0.74
154		0.65	0.64	0.57	0.57
161		0.32	0.27	0.23	0.23
162		0.24	0.24	0.22	0.22
163		0.23	0.21	0.21	0.21
164		0.22	0.20	0.19	0.19
165		0.30	0.23	0.21	0.21
171		0.25	0.24	0.22	0.22
172		0.23	0.21	0.21	0.21
173		0.22	0.21	0.19	0.19
174		0.24	0.20	0.19	0.19
0	128	0.64	0.62	0.68	0.62
3	131	0.66	0.61	0.51	0.51
6	134	0.68	0.64	0.56	0.56
8	136	0.69	0.61	0.55	0.55
10	138	0.51	0.51	0.47	0.47
12	140	0.34	0.30	0.28	0.28
13	141	0.35	0.30	0.28	0.28
14	142	0.37	0.32	0.26	0.26
15	143	0.37	0.38	0.37	0.37
24	152	0.33	0.32	0.29	0.29
25	153	0.36	0.32	0.29	0.29
26	154	0.36	0.31	0.29	0.29
33	161	0.15	0.14	0.12	0.12
34	162	0.11	0.11	0.10	0.10
35	163	0.11	0.10	0.10	0.10
36	164	0.11	0.10	0.09	0.09
37	165	0.15	0.12	0.10	0.10
43	171	0.13	0.13	0.10	0.10
44	172	0.11	0.11	0.10	0.10
45	173	0.12	0.10	0.09	0.09
46	174	0.12	0.10	0.09	0.09

c) *Scaling factor for back array 2 n258*

Beam ID 1	Beam ID 2	S_LB	S_MB	S_HB	S
1		1.64	1.75	1.77	1.64
4		2.49	2.43	1.85	1.85
16		1.47	1.23	1.14	1.14
17		1.06	0.86	0.87	0.86
18		0.78	0.86	0.82	0.78
19		1.22	1.60	1.17	1.17
27		1.42	1.14	1.09	1.09
28		0.78	0.89	0.83	0.78
29		0.85	1.14	0.95	0.85
129		1.60	1.30	1.18	1.18

132		1.40	1.50	1.53	1.40
144		1.03	0.77	0.65	0.65
145		0.88	0.68	0.58	0.58
146		0.67	0.66	0.64	0.64
147		0.58	0.64	0.68	0.58
155		0.84	0.67	0.57	0.57
156		0.81	0.66	0.58	0.58
157		0.60	0.65	0.67	0.60
1	129	0.73	0.61	0.64	0.61
4	132	0.63	0.79	0.79	0.63
16	144	0.42	0.34	0.35	0.34
17	145	0.36	0.31	0.33	0.31
18	146	0.30	0.33	0.29	0.29
19	147	0.35	0.40	0.38	0.35
27	155	0.39	0.34	0.36	0.34
28	156	0.31	0.34	0.29	0.29
29	157	0.31	0.35	0.34	0.31

d) *Scaling factor for side array n261*

Beam ID 1	Beam ID 2	S_LB	S_MB	S_HB	S
2		1.21	1.21	1.15	1.15
5		2.03	2.07	2.18	2.03
7		1.57	1.74	1.79	1.57
9		2.16	2.19	2.20	2.16
11		1.61	1.45	1.42	1.42
20		0.93	0.79	0.77	0.77
21		0.80	0.86	0.85	0.80
22		0.91	0.92	0.98	0.91
23		0.73	0.73	0.72	0.72
30		0.79	0.83	0.84	0.79
31		0.81	0.78	0.79	0.78
32		0.80	0.73	0.73	0.73
38		0.35	0.33	0.34	0.33
39		0.40	0.38	0.38	0.38
40		0.43	0.41	0.45	0.41
41		0.37	0.39	0.41	0.37
42		0.30	0.34	0.31	0.30
47		0.40	0.38	0.38	0.38
48		0.38	0.36	0.39	0.36
49		0.43	0.42	0.45	0.42
50		0.33	0.36	0.37	0.33
130		1.67	1.50	1.42	1.42
133		1.52	1.62	1.70	1.52
135		1.82	1.74	1.74	1.74
137		1.55	1.73	1.81	1.55
139		1.95	1.81	1.63	1.63
148		0.91	0.88	0.83	0.83

149		0.89	0.81	0.78	0.78
150		0.71	0.70	0.72	0.70
151		0.78	0.80	0.83	0.78
158		0.90	0.87	0.82	0.82
159		0.81	0.75	0.75	0.75
160		0.74	0.76	0.79	0.74
166		0.43	0.45	0.40	0.40
167		0.44	0.53	0.57	0.44
168		0.40	0.47	0.48	0.40
169		0.35	0.32	0.34	0.32
170		0.27	0.25	0.25	0.25
175		0.45	0.55	0.58	0.45
176		0.43	0.50	0.53	0.43
177		0.38	0.39	0.42	0.38
178		0.32	0.27	0.27	0.27
2	130	0.64	0.62	0.61	0.61
5	133	0.73	0.76	0.80	0.73
7	135	0.79	0.85	0.83	0.79
9	137	0.79	0.85	0.91	0.79
11	139	0.72	0.76	0.65	0.65
20	148	0.43	0.36	0.36	0.36
21	149	0.39	0.35	0.34	0.34
22	150	0.35	0.38	0.40	0.35
23	151	0.32	0.35	0.36	0.32
30	158	0.39	0.43	0.42	0.39
31	159	0.38	0.33	0.33	0.33
32	160	0.39	0.34	0.36	0.34
38	166	0.18	0.17	0.17	0.17
39	167	0.19	0.20	0.21	0.19
40	168	0.18	0.17	0.19	0.17
41	169	0.15	0.14	0.16	0.14
42	170	0.13	0.13	0.13	0.13
47	175	0.19	0.19	0.21	0.19
48	176	0.18	0.18	0.20	0.18
49	177	0.17	0.16	0.18	0.16
50	178	0.13	0.13	0.14	0.13

e) *Scaling factor for back array 1 n261*

Beam ID 1	Beam ID 2	S_LB	S_MB	S_HB	S
0		1.02	1.11	1.23	1.02
3		1.28	1.31	1.19	1.19
6		1.29	1.33	1.29	1.29
8		1.40	1.41	1.40	1.40
10		1.02	1.10	1.16	1.02
12		0.51	0.67	0.65	0.51
13		0.75	0.60	0.59	0.59
14		0.54	0.56	0.54	0.54
15		0.64	0.72	0.68	0.64

24		0.51	0.60	0.62	0.51
25		0.54	0.59	0.57	0.54
26		0.55	0.54	0.54	0.54
33		0.21	0.22	0.23	0.21
34		0.25	0.27	0.26	0.25
35		0.24	0.28	0.28	0.24
36		0.20	0.24	0.24	0.20
37		0.19	0.21	0.22	0.19
43		0.23	0.26	0.25	0.23
44		0.25	0.28	0.28	0.25
45		0.23	0.26	0.26	0.23
46		0.18	0.22	0.22	0.18
128		1.07	1.10	1.21	1.07
131		1.18	1.39	1.38	1.18
134		1.14	1.13	1.23	1.13
136		1.04	1.08	1.05	1.04
138		1.03	1.04	1.05	1.03
140		0.59	0.59	0.57	0.57
141		0.53	0.56	0.59	0.53
142		0.58	0.62	0.61	0.58
143		0.61	0.81	0.80	0.61
152		0.66	0.56	0.61	0.56
153		0.63	0.56	0.57	0.56
154		0.55	0.53	0.50	0.50
161		0.20	0.21	0.23	0.20
162		0.23	0.23	0.23	0.23
163		0.23	0.24	0.24	0.23
164		0.21	0.24	0.24	0.21
165		0.20	0.23	0.22	0.20
171		0.21	0.20	0.22	0.20
172		0.22	0.23	0.24	0.22
173		0.24	0.24	0.25	0.24
174		0.20	0.23	0.23	0.20
0	128	0.52	0.59	0.64	0.52
3	131	0.58	0.59	0.59	0.58
6	134	0.57	0.60	0.61	0.57
8	136	0.68	0.69	0.65	0.65
10	138	0.46	0.48	0.48	0.46
12	140	0.28	0.34	0.33	0.28
13	141	0.29	0.25	0.26	0.25
14	142	0.26	0.29	0.26	0.26
15	143	0.28	0.35	0.33	0.28
24	152	0.30	0.25	0.26	0.25
25	153	0.28	0.27	0.26	0.26
26	154	0.24	0.23	0.23	0.23
33	161	0.09	0.09	0.11	0.09
34	162	0.11	0.12	0.11	0.11
35	163	0.11	0.11	0.11	0.11

36	164	0.10	0.11	0.11	0.10
37	165	0.07	0.10	0.10	0.07
43	171	0.11	0.11	0.11	0.11
44	172	0.10	0.12	0.11	0.10
45	173	0.11	0.11	0.11	0.11
46	174	0.08	0.10	0.10	0.08

f) *Scaling factor for back array 2 n261*

Beam ID 1	Beam ID 2	S_LB	S_MB	S_HB	S
1		1.45	1.28	1.23	1.23
4		1.66	2.01	2.06	1.66
16		0.81	0.83	0.78	0.78
17		0.83	0.83	0.77	0.77
18		0.81	0.80	0.80	0.80
19		0.77	0.78	0.78	0.77
27		0.82	0.84	0.77	0.77
28		0.81	0.82	0.79	0.79
29		0.78	0.78	0.79	0.78
129		1.50	1.47	1.45	1.45
132		1.20	1.26	1.83	1.20
144		0.66	0.68	0.83	0.66
145		0.59	0.62	0.79	0.59
146		0.66	0.72	0.84	0.66
147		0.66	0.64	0.72	0.64
155		0.59	0.63	0.79	0.59
156		0.59	0.66	0.81	0.59
157		0.67	0.69	0.79	0.67
1	129	0.64	0.64	0.59	0.59
4	132	0.60	0.61	0.85	0.60
16	144	0.30	0.31	0.38	0.30
17	145	0.29	0.31	0.36	0.29
18	146	0.32	0.34	0.37	0.32
19	147	0.34	0.30	0.34	0.30
27	155	0.29	0.31	0.37	0.29
28	156	0.31	0.32	0.36	0.31
29	157	0.32	0.32	0.38	0.32

g) *Scaling factor for side array n260*

Beam ID 1	Beam ID 2	S_LB	S_MB	S_HB	S
2		1.29	1.84	1.64	1.29
5		2.62	2.58	3.62	2.58
7		2.78	2.40	3.11	2.40
9		2.07	1.95	2.00	1.95
11		1.48	1.84	1.82	1.48
20		0.77	1.08	0.97	0.77
21		1.26	1.14	1.35	1.14
22		1.07	1.19	1.42	1.07
23		0.73	0.89	0.79	0.73

30		0.99	0.97	1.07	0.97
31		1.22	1.19	1.23	1.19
32		1.74	1.53	1.98	1.53
38		0.54	0.73	0.79	0.54
39		0.48	0.60	0.69	0.48
40		0.44	0.46	0.52	0.44
41		0.39	0.41	0.44	0.39
42		0.51	0.47	0.45	0.45
47		0.53	0.72	0.78	0.53
48		0.44	0.49	0.56	0.44
49		0.52	0.53	0.58	0.52
50		0.36	0.38	0.40	0.36
130		1.71	1.39	1.68	1.39
133		1.79	2.33	2.39	1.79
135		1.99	2.56	3.14	1.99
137		1.76	1.60	2.16	1.60
139		1.58	1.60	2.03	1.58
148		0.82	0.68	0.79	0.68
149		1.02	1.00	1.37	1.00
150		1.12	1.44	1.93	1.12
151		0.76	0.67	0.78	0.67
158		1.04	0.87	1.02	0.87
159		0.96	1.19	1.28	0.96
160		0.79	0.71	0.91	0.71
166		0.41	0.38	0.42	0.38
167		0.72	0.70	0.85	0.70
168		0.40	0.48	0.58	0.40
169		0.38	0.51	0.58	0.38
170		0.35	0.33	0.39	0.33
175		0.53	0.48	0.55	0.48
176		0.57	0.60	0.81	0.57
177		0.40	0.46	0.58	0.40
178		0.38	0.38	0.44	0.38
2	130	0.63	0.71	0.73	0.63
5	133	0.90	1.06	1.30	0.90
7	135	1.07	1.19	1.45	1.07
9	137	0.81	0.78	0.99	0.78
11	139	0.64	0.79	0.92	0.64
20	148	0.37	0.36	0.35	0.35
21	149	0.44	0.49	0.61	0.44
22	150	0.54	0.55	0.76	0.54
23	151	0.46	0.50	0.48	0.46
30	158	0.56	0.56	0.65	0.56
31	159	0.56	0.63	0.65	0.56
32	160	0.57	0.52	0.69	0.52
38	166	0.19	0.21	0.23	0.19
39	167	0.25	0.24	0.33	0.24
40	168	0.18	0.20	0.24	0.18

41	169	0.16	0.20	0.22	0.16
42	170	0.18	0.17	0.20	0.17
47	175	0.21	0.23	0.28	0.21
48	176	0.21	0.22	0.28	0.21
49	177	0.18	0.23	0.27	0.18
50	178	0.15	0.16	0.18	0.15

h) Scaling factor for back array 1 n260

Beam ID 1	Beam ID 2	S_LB	S_MB	S_HB	S
0		1.70	1.65	1.64	1.64
3		1.61	1.66	1.75	1.61
6		1.44	1.34	1.49	1.34
8		1.44	1.37	1.42	1.37
10		1.13	1.17	1.28	1.13
12		0.74	0.77	0.82	0.74
13		0.66	0.70	0.74	0.66
14		0.83	0.83	0.94	0.83
15		0.86	0.84	0.84	0.84
24		0.83	0.81	0.86	0.81
25		0.83	0.83	0.79	0.79
26		0.77	0.81	0.90	0.77
33		0.33	0.38	0.40	0.33
34		0.31	0.34	0.39	0.31
35		0.34	0.36	0.38	0.34
36		0.33	0.32	0.33	0.32
37		0.37	0.33	0.33	0.33
43		0.31	0.37	0.40	0.31
44		0.34	0.34	0.39	0.34
45		0.33	0.33	0.34	0.33
46		0.34	0.34	0.35	0.34
128		1.64	1.68	1.98	1.64
131		1.50	1.54	1.66	1.50
134		1.56	1.48	1.49	1.48
136		1.34	1.51	1.36	1.34
138		1.45	1.20	1.42	1.20
140		0.81	0.78	0.87	0.78
141		0.69	0.68	0.67	0.67
142		0.73	0.75	0.77	0.73
143		0.79	0.76	0.87	0.76
152		0.72	0.76	0.71	0.71
153		0.86	1.02	1.10	0.86
154		0.77	0.76	0.77	0.76
161		0.36	0.33	0.32	0.32
162		0.34	0.34	0.36	0.34
163		0.31	0.33	0.34	0.31
164		0.31	0.35	0.39	0.31
165		0.37	0.35	0.38	0.35
171		0.34	0.33	0.34	0.33

172		0.30	0.35	0.37	0.30
173		0.31	0.33	0.35	0.31
174		0.30	0.34	0.38	0.30
0	128	0.74	0.74	0.77	0.74
3	131	0.68	0.70	0.71	0.68
6	134	0.65	0.64	0.61	0.61
8	136	0.60	0.60	0.59	0.59
10	138	0.61	0.57	0.58	0.57
12	140	0.34	0.33	0.34	0.33
13	141	0.33	0.33	0.34	0.33
14	142	0.36	0.37	0.36	0.36
15	143	0.36	0.34	0.36	0.34
24	152	0.41	0.43	0.45	0.41
25	153	0.37	0.42	0.41	0.37
26	154	0.33	0.35	0.35	0.33
33	161	0.15	0.14	0.13	0.13
34	162	0.15	0.15	0.15	0.15
35	163	0.15	0.16	0.16	0.15
36	164	0.14	0.15	0.15	0.14
37	165	0.15	0.14	0.14	0.14
43	171	0.15	0.15	0.15	0.15
44	172	0.15	0.16	0.16	0.15
45	173	0.15	0.16	0.15	0.15
46	174	0.15	0.15	0.15	0.15

i) *Scaling factor for back array 2 n260*

Beam ID 1	Beam ID 2	S_LB	S_MB	S_HB	S
1		1.80	1.77	3.09	1.77
4		3.01	2.94	2.63	2.63
16		1.14	1.14	1.23	1.14
17		1.26	1.11	1.28	1.11
18		1.31	1.08	1.57	1.08
19		1.02	1.15	1.58	1.02
27		1.31	1.10	1.35	1.10
28		1.25	1.08	1.64	1.08
29		1.12	1.10	1.71	1.10
129		2.39	3.16	3.11	2.39
132		1.91	2.53	2.72	1.91
144		0.97	1.32	1.49	0.97
145		1.28	1.57	1.39	1.28
146		1.22	1.47	1.35	1.22
147		1.06	1.48	1.70	1.06
155		1.25	1.69	1.68	1.25
156		1.33	1.66	1.45	1.33
157		1.09	1.36	1.34	1.09
1	129	0.88	1.07	1.43	0.88
4	132	1.01	1.12	1.07	1.01
16	144	0.44	0.54	0.56	0.44

17	145	0.62	0.63	0.60	0.60
18	146	0.58	0.56	0.66	0.56
19	147	0.49	0.58	0.75	0.49
27	155	0.56	0.63	0.69	0.56
28	156	0.57	0.60	0.71	0.57
29	157	0.49	0.52	0.65	0.49

Appendix C: MPE (sPD) Simulation Using New Guideline from Qualcomm

This document provides the changes from what we have submitted from last year, following the new guidelines from Qualcomm, that 2nd generation of Smart Transmit (Smart-Tx GEN2) is used in this year's iPhone program.

The 1st generation of Smart Transmit (GEN1) assumes all transmit antennas are co-located and RF exposure is 100% overlapped, while the 2nd generation of Smart Transmit (GEN2) operates based on pre-defined antenna groups. In this revision, the antenna grouping is based on mmW module placement.

As an example of a wireless device having three mmW antenna (i.e., back-firing antenna 1 (BF1), back-firing antenna 2 (BF2) and side-firing (SF) antenna), Figure C.1 illustrates GEN1 and GEN2 operation.

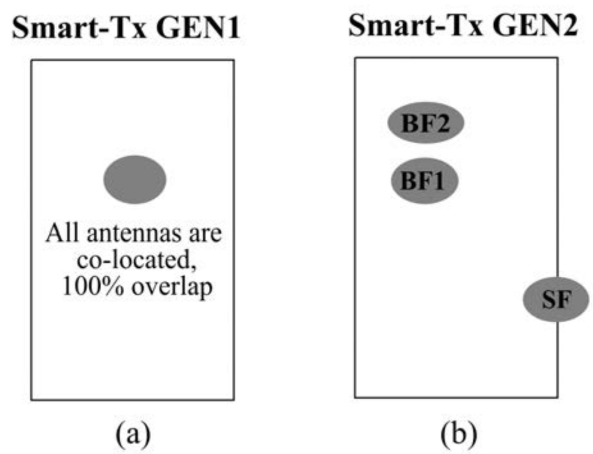


Figure C.1. Smart transmit generate illustration, (a) GEN1, and (b) GEN2

The requirement and guidelines stated for GEN1 in all previous sections apply to GEN2. The additional requirement to characterize PD for GEN2 is described in this inclusion.

- All mmW modules need to be included in each simulation model
- 2D PD plots for different surfaces are not needed for Smart-Tx GEN2

C.1 Changes in Modeling Approach Using Smart-Tx GEN2

Simulation model needs to be large enough to include all the antenna modules located inside the EUT, so that the mutual coupling can be properly calculated. Unlike GEN1, simulation of a part of the EUT (right part of Figure C.2) will not work. Instead, the entire EUT must be simulated as illustrated in the left side example in Figure C.2 for GEN2.

Additionally, the simulation domain needs to be sufficiently large for "Qualcomm MG Script" to extract valid E- and H-fields from all adjacent exposure surfaces of the EUT extended by at least 35 mm in all directions. To accomplish this, if CST is used, recommended setting for the "radiation boundary" is at least 40 mm away from EUT to well contain all adjacent exposure surfaces (S1~S6 in Figure 2).

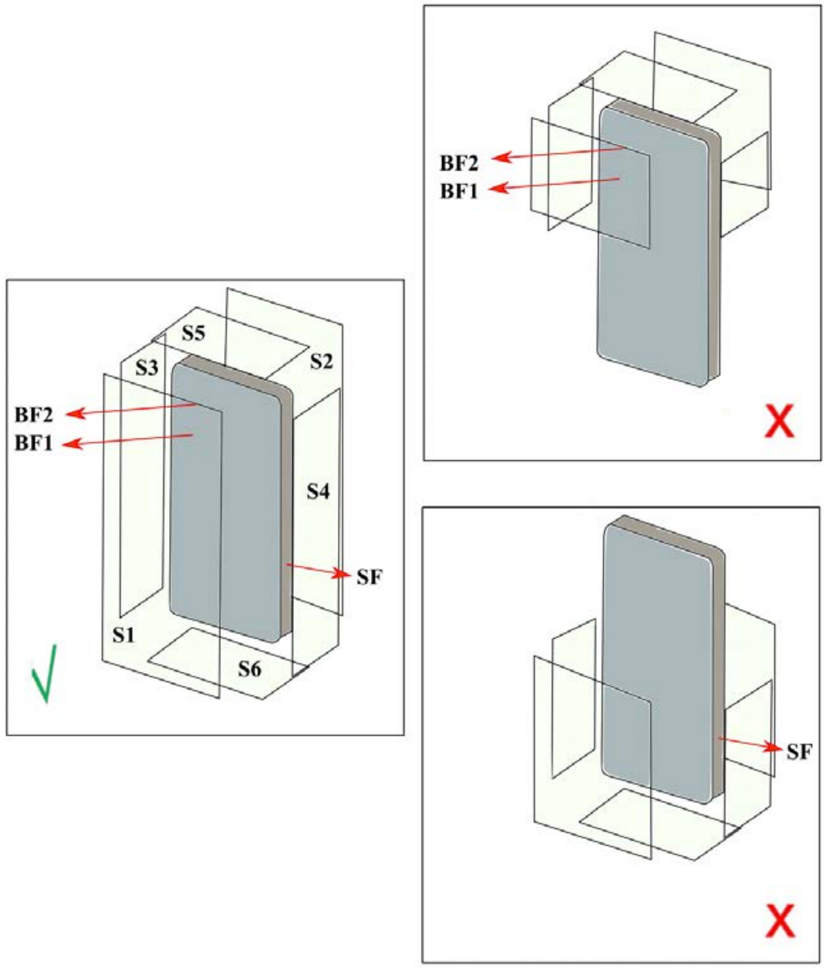


Figure C.2. Simulation model examples.

C.2 GEN2 PD Generation Using Qualcomm MG Script

Use "Qualcomm MG script" to extract E- and H-fields from the validated simulation and to assess the mutual coupling between all the mmW modules and all the beams in the codebook to determine the backoff value for each mmW module. Note the assessment and backoff value derivation are automated with "Qualcomm MG script". Once the script is done with assessment, it will provide the $sim.power_{limit}$ (backoff is already included) for all the beams for all three channels for the specified s*PD_design_target*.

C.3 Additional Verifications for GEN2

The sPD for GEN2 cannot be finalized until the additional verifications described in this section are performed and passed. The below steps are followed for verifications in the mid channel.

VERIFICATION 1: Use "Qualcomm MG script" to print the sPD plots for all the beams selected and evaluated for model validation. Compare the printed sPD plot to the corresponding simulated/measured sPD, the printed sPD distributions should match the simulated sPD distributions as shown in Table C.1 and C.4 to verify that "Qualcomm MG script" is properly used.

VERIFICATION 2: "Qualcomm MG script" identifies the worst-case 4cm^2 sPD and its location (*x,y,z*). This worst-case 4cm^2 sPD is maximum 4cm^2 sPD value out of all exposure surfaces when assuming the worst beam from each of the antenna modules are active. The script will then identify the worst beam from each module that contributes the most to the worst 4cm^2 sPD and print their contribution factor, as well as the worst surface corresponding to the worst-case 4cm^2 sPD, backoff value for each antenna module and *verification.sim.powerlimit* (before backoff) value for each identified beams.

Use CST (or other EM simulation tool) to calculate the simulated contribution factor for the identified beams. The simulated contribution factor, $c_{simulated}(i,j)$, for beam i from QTM j can be computed by

$$c_{simulated}\,(i,j) = 4cm^2\ PD\ at\ (x,y,z)\ at\ verification.sim.power\ limit\ /\ PD\_design\_target$$

Verify:

1. the printed contribution factor, $c(i,j)$, matches the simulated contribution factor, $c_{simulated}(i,j)$, obtained from CST (or other EM simulation tool) within 2% of numerical tolerance.
2. the normalized *combined sPD* does not exceed 1.0, i.e., *normalized combined sPD* = $\sum(b_j * c(i,j)) \leq 1.0$

   where *combined sPD* = sPD from current antenna module + sPD contributions from other antenna modules; b_j = backoff value for antenna module j, j = antenna module #; $c(i,j)$ = contribution factor of beam i from antenna module j to the worst 4cm^2 sPD. Both bj and $c(i,j)$ are printed from "Qualcomm MG script".

VERIFICATION 3: Measure power density for the beams identified by "Qualcomm MG script" on their corresponding worst surfaces printed from the script. Set the device in FTM mode, the sPD measurement should be performed at the reference power level with CW modulation. Scale the measured sPD to obtain 4cm^2 sPD(i,j) for beam i from antenna module j at their *input.power.limit*. Demonstrate that the *combined sPD* (i.e., $\sum[c(i,j)*sPD(i,j)]$) is less than or equal to s*PD_design_target* within the uncertainty at reference power level, i.e., *combined sPD* = $\sum[c(i,j)*measured\ 4cm^2\ sPD(i,j)] \leq$ s*PD_design_target* + uncertainty **at reference power level.**

As an example of one of the iPhone programs, which contains 2 antenna modules (i.e., Module0 (back-firing array 1 and back-firing array 2) and Module1 (side-firing array)), the following verifications are for n258, n261 and n260, respectively.

1) ***Band n258***

   "Qualcomm MG script" identifies beam *161* and *32* from Module0 and Module1, respectively. The script prints below information corresponding to the identified worst-case 4cm^2 sPD:

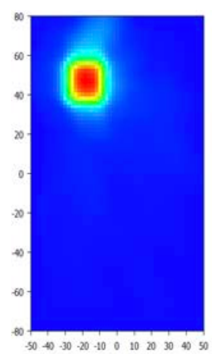
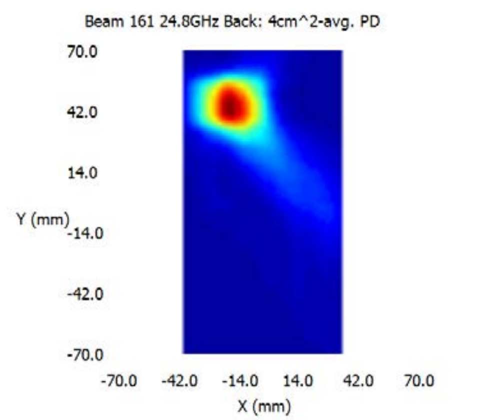
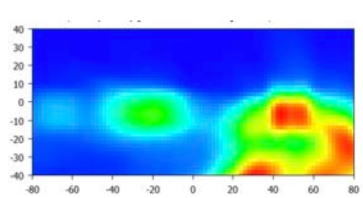
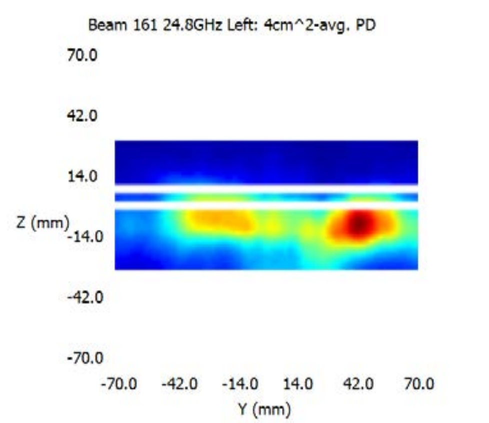
   - the backoff values (in linear) for Module0 and Module1: b_0 = 0.9772; b_1 = 0.9333

- the worst location coordinates (*x, y, z*) in meter = (0.04104, -0.01400, -0.00200)
- the worst-surface = S4 (right surface, see Figure C.2)
- the $verification.sim.power_{limit}$ (before backoff) for the beams *161* and *32* is 0.25 dBm and 4.01 dBm, respectively.
- worst surface for Module0 is S4 (Back); worst surface for Module1 is S4 (Right)
- the contribution factors *c*(*161, 0*) = 0.0493 and *c*(*32, 1*) = 1.0000 at the worst-case 4cm^2 sPD location (0.04104, -0.01400, -0.00200)

As shown in Table C.2, the printed contribution factor matches the simulated contribution factor within 2%, and the *normalized combined sPD* is less than 1.0. Thus, the verification 2 is completed for this program.

As shown in Table C.3, the *combined* measured s*PD* at the worst location ≤ s*PD_design_target* uncertainty at reference power level. Thus, the verification 3 is competed for this program.

Table C.1 - Simulated sPD distributions for selected beams.

<table>
<tr><th>Beam ID</th><th>Surface</th><th>Simulated sPD</th><th>Printed out from Qualcomm MG Script</th></tr>
<tr><td rowspan="2">161</td><td>S2</td><td></td><td>
</td></tr>
<tr><td>S3</td><td></td><td>
</td></tr>
</table>

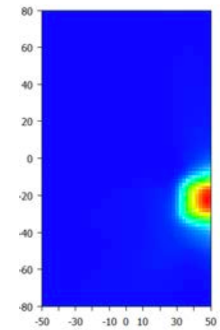
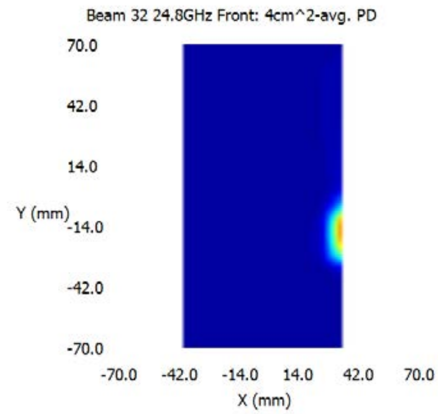
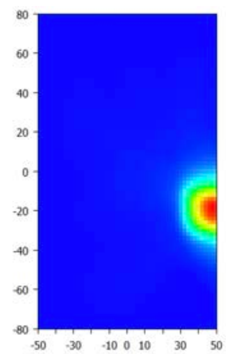
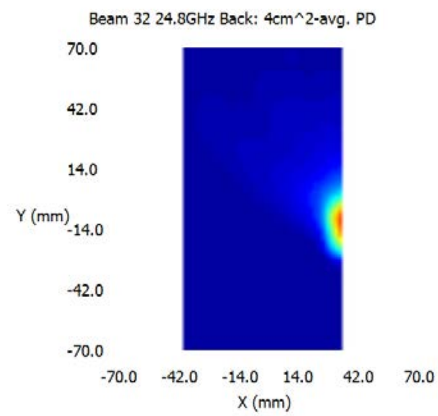
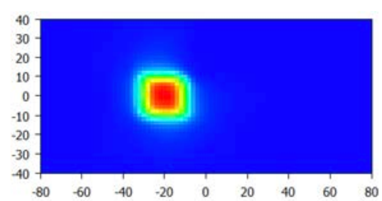
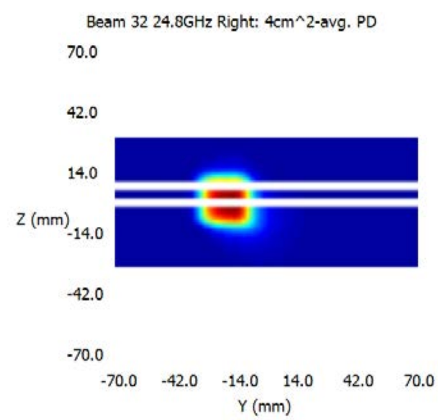
32	S1	80 60 40 20 0 -20 -40 -60 -80 -50 -30 -10 0 10 30 50	Beam 32 24.8GHz Front: 4cm^2-avg. PD 70.0 42.0 14.0 Y (mm) -14.0 -42.0 -70.0 -70.0 -42.0 -14.0 14.0 42.0 70.0 X (mm)
	S2	80 60 40 20 0 -20 -40 -60 -80 -50 -30 -10 0 10 30 50	Beam 32 24.8GHz Back: 4cm^2-avg. PD 70.0 42.0 14.0 Y (mm) -14.0 -42.0 -70.0 -70.0 -42.0 -14.0 14.0 42.0 70.0 X (mm)
	S4	40 30 20 10 0 -10 -20 -30 -40 -80 -60 -40 -20 0 20 40 60 80	Beam 32 24.8GHz Right: 4cm^2-avg. PD 70.0 42.0 14.0 Z (mm) -14.0 -42.0 -70.0 -70.0 -42.0 -14.0 14.0 42.0 70.0 Y (mm)

Table C.2 - Contribution factors from Qualcomm MG script and from CST for selected beams, and normalized *combined sPD* verification, for device with 2 antenna modules.

Worse-case surface					S4 (right surface)	
Worst-case location *(x,y,z)* in meters					(0.04104, -0.01400, -0.00200)	
sPD_design_target (W/m^2)					5	
Value printed by MG Script					Value by EM tool	
Module #	Beam ID	$c(i,j)$, i=beam ID, j=module #	Backoff factor b_j	$verification.sim.power_{limit}$ (before backoffs) [dBm]	Simulated 4cm^2 sPD at (0.04104, -0.01400, -0.00200) with $verification.sim.power_{limit}$ on S4 (W/m^2)	$c_{simulated}(i,j)$
0	161	0.0493	0.9772	0.25	0.243	0.243/5 = 0.0486
1	32	1.0000	0.9333	4.01	4.951	4.951/5 = 0.9902
Verify 1	$c(i,j)=c_{simulated}(i,j)$, i = 161, 32; j = 0, 1					
Verify 2	b_0 x $c(171,0)$ + b_1 x $c(30,1)$ = 0.9772 x 0.0493 + 0.9333 x 1.0000 = 0.9815 ≤ 1					

Table C.3: Measured 4cm^2 sPD on worst surface and *combined sPD* at worst-case location for device with 2 antenna modules.

Module#	Beam ID	Dominant Surface	Measured 4cm^2 sPD at input.power.limit on dominant surface (W/m^2)
0	161	S2 (Back)	4.832
1	32	S4 (Right)	5.134
combined sPD at the worst-case location (*x,y,z*)			$c(161,0)$xmeas.4cm^{2}sPD$(161,0)$ + $c(32,1)$xmeas.4cm^{2}sPD$(32,1)$ = 0.0493 x 4.832 + 1.0000 x 5.134 = 5.3722 W/m^2

sPD_design_target + uncertainty at reference power level of 1 dB	$= 5*10^{(+1/10)} = 6.3$ W/m^2
Verify	combined sPD < sPD_design_target + uncertainty at reference power level

Note *c(i,j)* is obtained from Table C.2.

2) Band n261

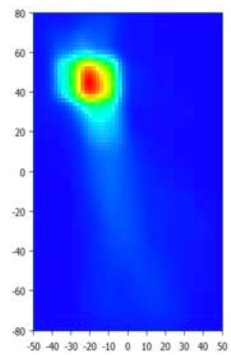
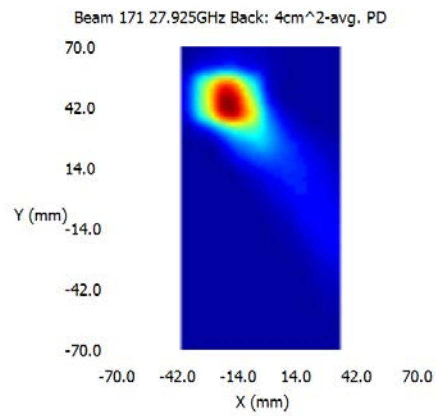
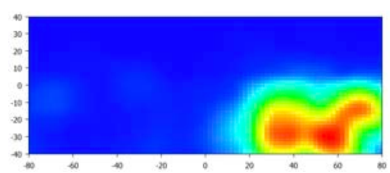
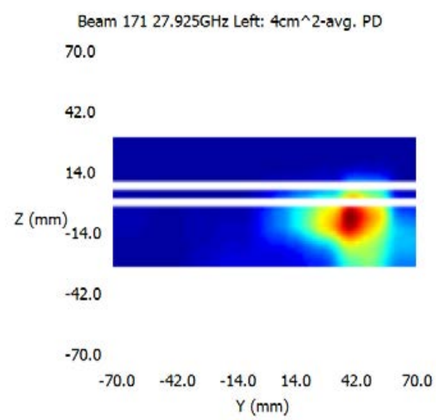
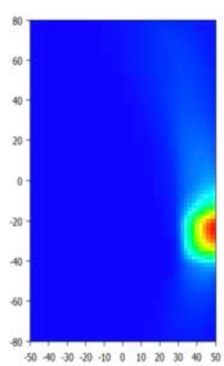
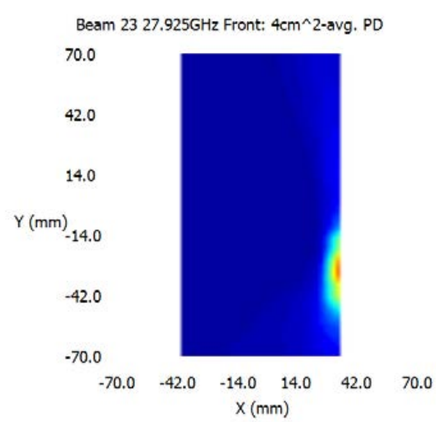
"Qualcomm MG script" identifies beam *171* and *23* from Module0 and Module1, respectively. The script prints below information corresponding to the identified worst-case 4cm^2 sPD:

- the backoff values (in linear) for Module0 and Module1: $b_0 = 0.9550$; $b_1 = 0.9333$
- the worst location coordinates (*x, y, z*) in meter = (0.04104, -0.02800, -0.00200)
- the worst-surface = S4 (right surface, see Figure C.2)
- the $verification.sim.power_{limit}$ (before backoff) for the beams *171* and *23* is -1.00 dBm and 4.63 dBm, respectively.
- worst surface for Module0 is S2 (back); worst surface for Module1 is S4 (right)
- the contribution factors *c*(*171, 0*) = 0.0442 and *c*(*23, 1*) = 1.0000 at the worst-case 4cm^2 sPD location (0.04104, -0.02800, -0.00200)

As shown in Table C.5, the printed contribution factor matches the simulated contribution factor within 2%, and the *normalized combined sPD* is less than 1.0. Thus, the verification 2 is completed for this program.

As shown in Table C.6, the *combined* measured s*PD* at the worst location ≤ s*PD_design_target* uncertainty at reference power level. Thus, the verification 3 is competed for this program.

Table C.4 - Simulated sPD distributions for selected beams.

Beam ID	Surface	Simulated sPD	Printed out from Qualcomm MG Script
171	S2		
	S3		
23	S1		

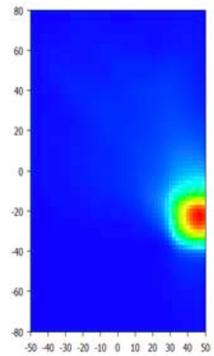
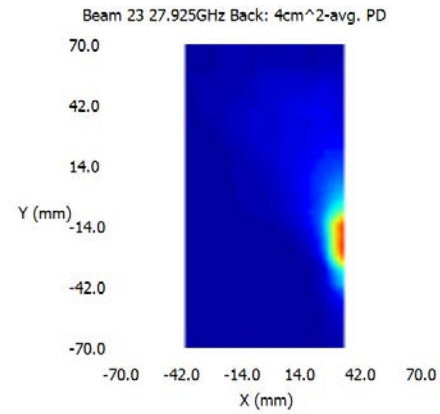
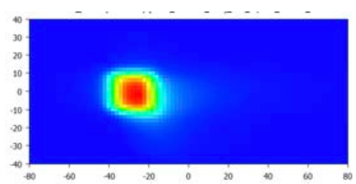
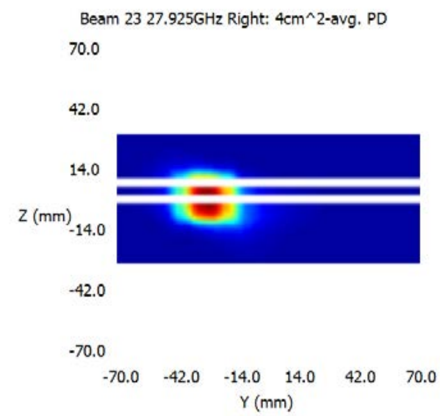
	S2		
	S4		

Table C.5 - Contribution factors from Qualcomm MG script and from CST for selected beams, and normalized *combined sPD* verification, for device with 2 antenna modules.

Worse-case surface					S4 (right surface)	
Worst-case location *(x,y,z)* in meters					(0.04104, -0.02800, -0.00200)	
sPD_design_target (W/m^2)					5	
Value printed by MG Script					Value by EM tool	
Module #	Beam ID	*c(i ,j), i*=beam ID, *j*=module #	Backoff factor b_j	$verification.sim.power_{limit}$ (before backoffs) [dBm]	Simulated 4cm^2 sPD at (0.04104, -0.02800, -0.00200) with $verification.sim.power_{limit}$ on S4 (W/m^2)	$c_{simulated}(i ,j)$

0	171	0.0442	0.9550	-1.00	0.222	0.222/5 = 0.0444
1	23	1.0000	0.9333	4.63	4.940	4.940/5 = 0.9880
Verify 1	$c(i,j) = c_{simulated}(i,j)$, i = 171, 23; j = 0, 1					
Verify 2	b_0 x $c(161,0)$ + b_1 x $c(22,1)$ = 0.9550 x 0.0442 + 0.9333 x 1.0000 = 0.9755≤ 1					

Table C.6: Measured 4cm^2 sPD on worst surface and *combined sPD* at worst-case location for device with 2 antenna modules.

Module#	Beam ID	Dominant Surface	Measured 4cm^2 sPD at input.power.limit on dominant surface (W/m^2)
0	171	S2 (Back)	4.752
1	23	S4 (Right)	4.914
combined sPD at the worst-case location (*x,y,z*)			*c(171,0)*xmeas.4cm^{2}sPD*(171,0)* + *c(23,1)*xmeas.4cm^{2}sPD*(23,1)* = 0.0442 x 4.752 + 1.0000 x 4.914 = 5.1240 W/m^2
sPD_design_target + uncertainty at reference power level of 1 dB			= 5*10$^{(+1/10)}$ = 6.3 W/m^2
Verify			combined sPD < sPD_design_target + uncertainty at reference power level

Note *c(i,j)* is obtained from Table C.5.

3) *Band n260*

"Qualcomm MG script" identifies beam *10* and *38* from Module0 and Module1, respectively. The script prints below information corresponding to the identified worst-case 4cm^2 sPD:

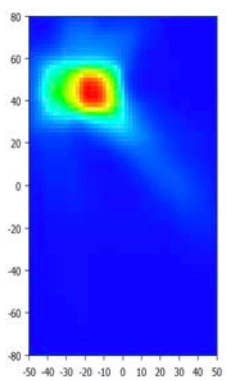
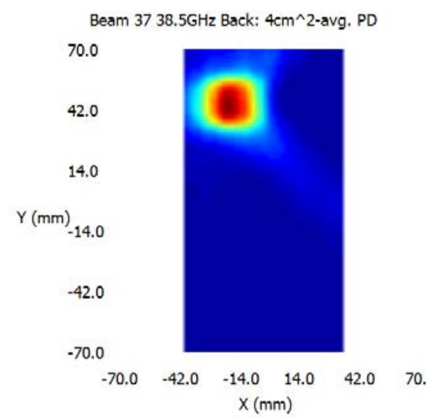
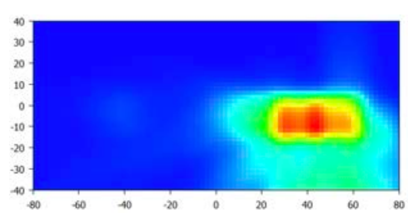
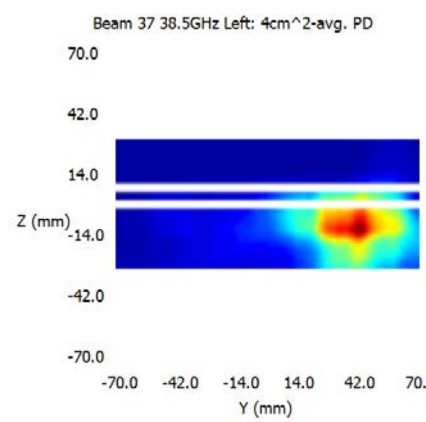
- the backoff values (in linear) for Module0 and Module1: b_0 = 0.9772; b_1 = 0.9550
- the worst location coordinates (*x, y, z*) in meter = (0.04104, -0.01200, 0.00000)
- the worst-surface = S4 (right surface, see Figure C.2)
- the *verification.sim.power$_{limit}$* (before backoff) for the beams *37* and *11* is 1.13 dBm and 8.63 dBm, respectively.
- worst surface for Module0 is S2 (back); worst surface for Module1 is S4 (right)

- the contribution factors *c*(*37, 0*) = 0.0341 and *c*(*11, 1*) = 1.0000 at the worst-case 4cm^2 sPD location (0.04104, -0.01200, 0.00000)

As shown in Table C.8, the printed contribution factor matches the simulated contribution factor within 2%, and the *normalized combined sPD* is less than 1.0. Thus, the verification 2 is completed for this program.

As shown in Table C.9, the *combined* measured s*PD* at the worst location ≤ s*PD_design_target* uncertainty at reference power level. Thus, the verification 3 is competed for this program.

Table C.7 - Simulated sPD distributions for selected beams.

<table>
<tr><th>Beam ID</th><th>Surface</th><th>Simulated sPD</th><th>Printed out from Qualcomm MG Script</th></tr>
<tr><td rowspan="2">37</td><td>S2</td><td>
</td><td>
</td></tr>
<tr><td>S3</td><td>
</td><td>
</td></tr>
</table>

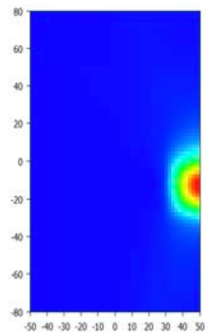
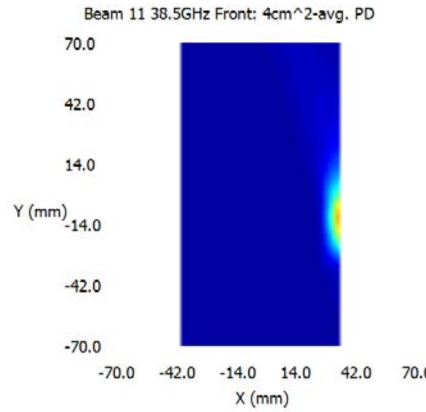
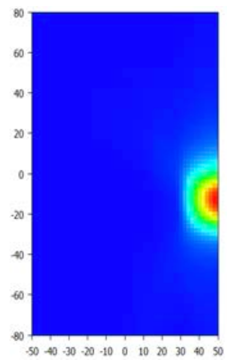
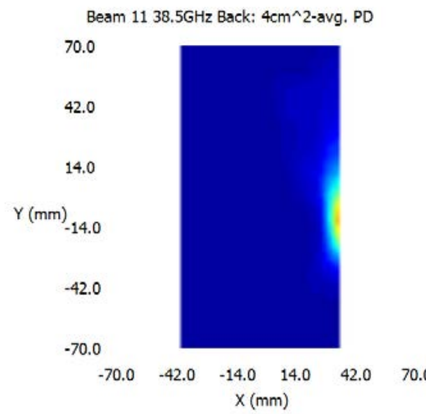
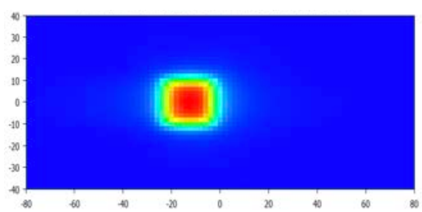
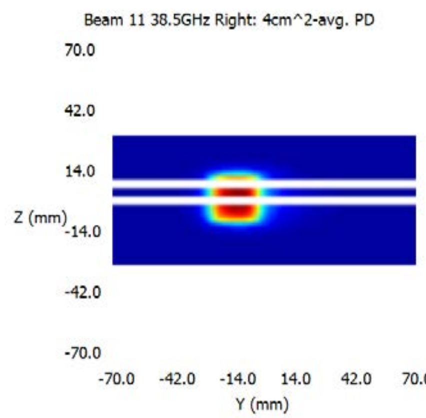
11	S1		Beam 11 38.5GHz Front: 4cm^2-avg. PD Y (mm) X (mm)
	S2		Beam 11 38.5GHz Back: 4cm^2-avg. PD Y (mm) X (mm)
	S4		Beam 11 38.5GHz Right: 4cm^2-avg. PD Z (mm) Y (mm)

Table C.8 - Contribution factors from Qualcomm MG script and from CST for selected beams, and normalized *combined sPD* verification, for device with 2 antenna modules.

Worse-case surface					S4 (right surface)	
Worst-case location *(x,y,z)* in meters					(0.04104, -0.01200, 0.00000)	
sPD_design_target (W/m^2)					5	
Value printed by MG Script					Value by EM tool	
Module #	Beam ID	*c(i ,j), i*=beam ID, *j*=module #	Backoff factor b_j	*verification.sim.power*$_{limit}$ (before backoffs) [dBm]	Simulated 4cm^2 sPD at (0.04104, -0.01200, 0.00000) with *verification.sim.power*$_{limit}$ on S4 (W/m^2)	$c_{simulated}(i ,j)$
0	37	0.0341	0.9772	1.13	0.173	0.173/5 = 0.0346
1	11	1.0000	0.9550	8.63	4.951	4.951/5 = 0.9901
Verify 1	$c(i ,j)=c_{simulated}(i ,j)$, i = 37, 11; j = 0, 1					
Verify 2	b_0 x $c(10,0)$ + b_1 x $c(38,1)$ = 0.9772 x 0.0341 + 0.9550 x 1.0000 = 0.9883 ≤ 1					

Table C.9 - Measured 4cm^2 sPD on worst surface and *combined sPD* at worst-case location for device with 2 antenna modules.

Module#	Beam ID	Dominant Surface	Measured 4cm^2 sPD at input.power.limit on dominant surface (W/m^2)
0	37	S2 (Back)	4.769
1	11	S4 (Right)	5.125
combined sPD at the worst-case location (*x,y,z*)			*c(37,0)*xmeas.4cm^2 sPD*(37,0)* + *c(11,1)*xmeas.4cm^2 sPD*(11,1)* = 0.0341 x 4.769 + 1.0000 x 5.125 = 5.2876 W/m^2

sPD_design_target + uncertainty at reference power level of 1 dB	$= 5*10^{(+1/10)} = 6.3$ W/m^2
Verify	combined sPD < sPD_design_target + uncertainty at reference power level

Note *c(i,j)* is obtained from Table C.8.