Model: M1000
FCC ID: PKRISGM1000

39GHz, Band n260- Power Density Report

April 15, 2019

Revision 2.2

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1 General

1.1 Scope

This report is intended to support FCC compliance for the M1000 hotspot using quantity 4 Qualcomm QTM052-8 antenna modules for dual-polarization beamforming.

Per the location of the Qualcomm QTM052-8 antenna modules inside the M1000 platform, the distance between the antenna array to the body of an end user, at the closest contact point, will be in the near field.

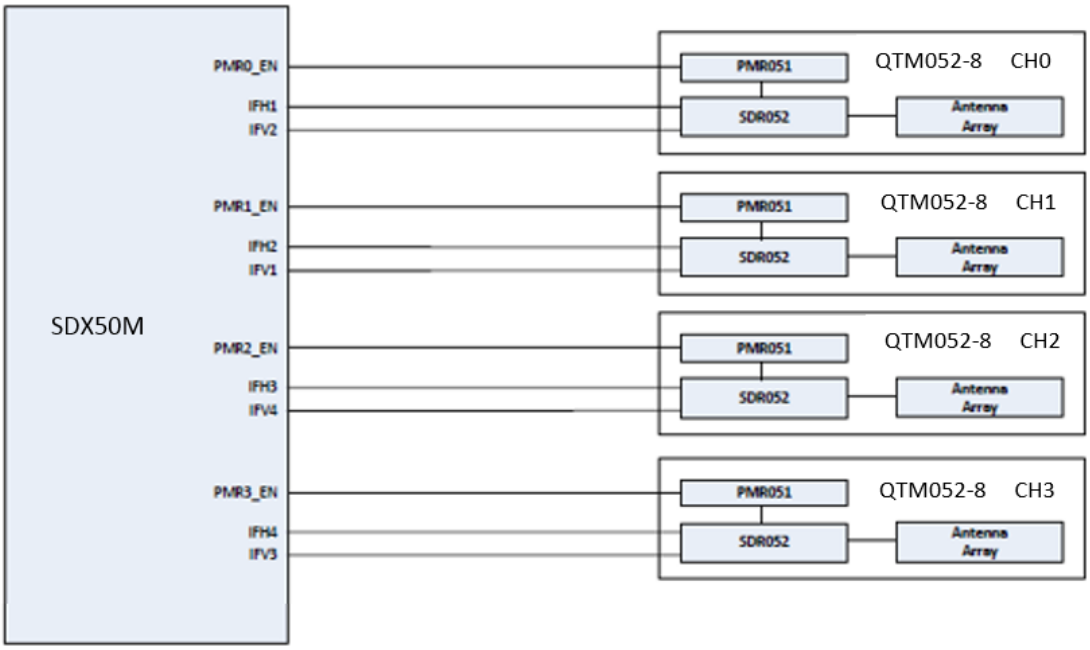
Near field power density calculations were estimated using EM simulation that includes the Qualcomm QTM052-8 antenna module embedded inside the M1000 3D model. These results are documented in the following sections of this report.

To prove the validity of these results, we will show how the results of the simulations are well correlated, to lab measurements of the Qualcomm QTM052-8 antenna module inside the M1000 platform, for transition field to far field distances, where the theoretical far field boundary is calculated for reference. The near field simulation results are also presented in this document.

Chapter 2 provides relevant background on the Qualcomm QTM052-8 antenna module. Chapter 3 describes the simulation methodology to determine RF exposure (power density) levels. Chapter 4 describes simulation setup. Chapter 5 covers validation and correlation between simulation and lab measurements. Chapter 6 shows simulated PD results. Chapter 7 provides a summary of the RF-Exposure analysis.

2 Theory of Operation

2.0 System Block Diagram



2.1 Beam Forming

Due to the high path loss of the mmW signal travelling between the transmitting and receiving points, 5G communication can be achieved by employing antenna arrays with directionally high gain to compensate for the high path loss. Only one QTM052-8 can be functional at any given time.

In the Qualcomm QTM052-8 antenna module, such an electronic steering antenna array with approximately ±45-degree steering angles being used. Beam forming is used to find the right direction for setting both the Rx and Tx beam directions. Many individual beams can be formed from a single module. This is accomplished by changing polarization, phase or combinations thereof.

The number of antenna ports of the QTM052-8 antenna module consists of 16, 8 and 8, respectively. The antenna ports are controlled by SW. The phase, polarization and number of ports used can change. The ports are selected per the Qualcomm created "code book" and is custom for each product. The code book lists the phase, polarization and combinations to be used for beamforming. Example, 8 ports for the 1x4 patch array and 8 ports for the 1x4 dipole array. In the 8 ports available in each patch antenna, 4 ports could be divided into vertical polarization feeding, and 4 ports are divided into horizontal polarization feeding. The dipole array antenna consists of 4 antenna elements and each element uses two ports as a source excitation.

The ideal array structure is constructed to achieve the highest gain when the port combinations of the dipole and or patch array elements are fed in phase to form a forward-looking high gain beam to the antenna origin (Az, El) = (0, 0).

2.2 Tx Duty Cycle

To capture worst-case power density conditions, simulations and measurements were performed assuming a 100% duty cycle. The TX-Duty-Cycle is established based on HW and FW implementation

3.0 Simulation Methodology

3.0 Electromagnetic Simulation

3.1.1 Tool Description

For the EM simulation to calculate power density (PD) for M1000 MIFI with Qualcomm mmWave antenna modules, we use the commercially available ANSYS HFSS 2019 R1. ANSYS HFSS is widely used in industry for simulating 3D full-wave electromagnetic fields for antenna and RF radiation problem of high frequency component. ANSYS HFSS is implemented based on the Finite Element Method (FEM) operates in the frequency domain.

3.1.2 Solver Description

The HFSS tool is employing Finite Element Method in frequency domain to solve the EM fields in 3D space which is based on an accurate direct solver with first or second order basis functions. To start solving the problem, a volume containing the objects will be subdivided into electrically small regions that are call finite elements as the unknown functions. To subdivide system, the adaptive mesh method in HFSS is used. Then, HFSS starts to refine the initial mesh based on the designed wavelength and calculate the error for each iteration process with adaptive mesh refinement. The determination parameter of the number of iterations in HFSS is defined as convergence criteria, delta S, and the iterative adaptive mesh process repeats until the delta S is met. The accuracy of converged results depends on the delta S. The default setting in the HFSS for delta S is 2%. Fig. 1 is an example of finial adaptive mesh of the antenna modules used in the simulation.

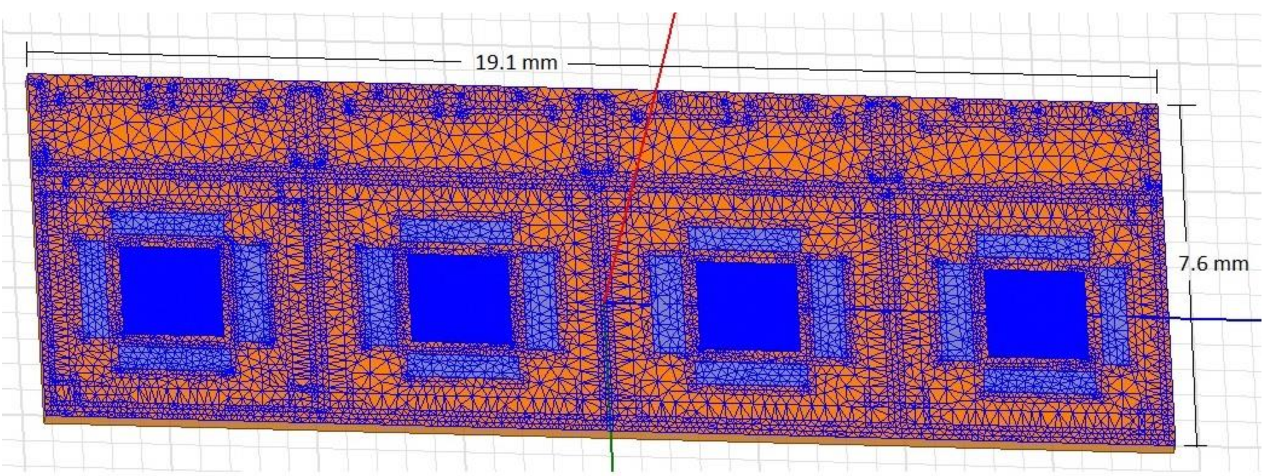


Fig. 1 Example of the adaptive mesh used in HFSS

3.1.3 Power Density Calculation

After simulation, HFSS can generate the electric and magnetic fields in a given surface. For power density calculation, the electric field ($\vec{E}$) and magnetic field ($\vec{H}$) are needed. The actual consumption power can be expressed as the real part of the Poynting vector ($\vec{P}$) from the cross product of $\vec{E}$ and the complex conjugation of $\vec{H}$ as shown below:

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

$\vec{P}$ can be expressed as the localized power density based on a peak value of each spatial point on mesh grids and obtained directly from ANSYS HFSS simulation results. From the localized power density, the average power density can be evaluated over a 4 cm^2 square on any surfaces.
The power density is calculated in the relevant plan (10 mm away from the M1000 plastic housing) over a surface of 4 cm^2 square.

3.1.4 Power Averaging

After the simulation is completed the E and H fields, and power density can be calculated for the predefined surfaces. The figure shown below is an example of the power density for the Qualcomm QTM052-8 antenna module at a predefined surface.

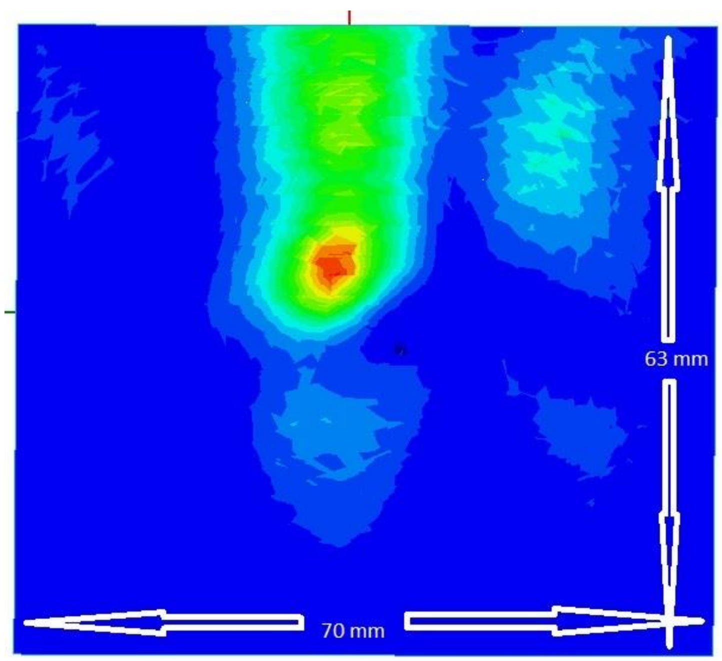


Fig. 2 – Example of calculated power density from HFSS

3.1.5 3D Modeling

Figure 3 shows the 3D simulation model which uses qty. 4, QTM052-8 antenna modules. The simulation modeling includes all the major components of the M1000 hotspot. These include items such as the Housing, PCB, metal antenna holder, display, touch panel, battery, legacy antennas and the QTM052-8 antenna modules Ant-0, Ant-1, Ant-2, Ant-3.

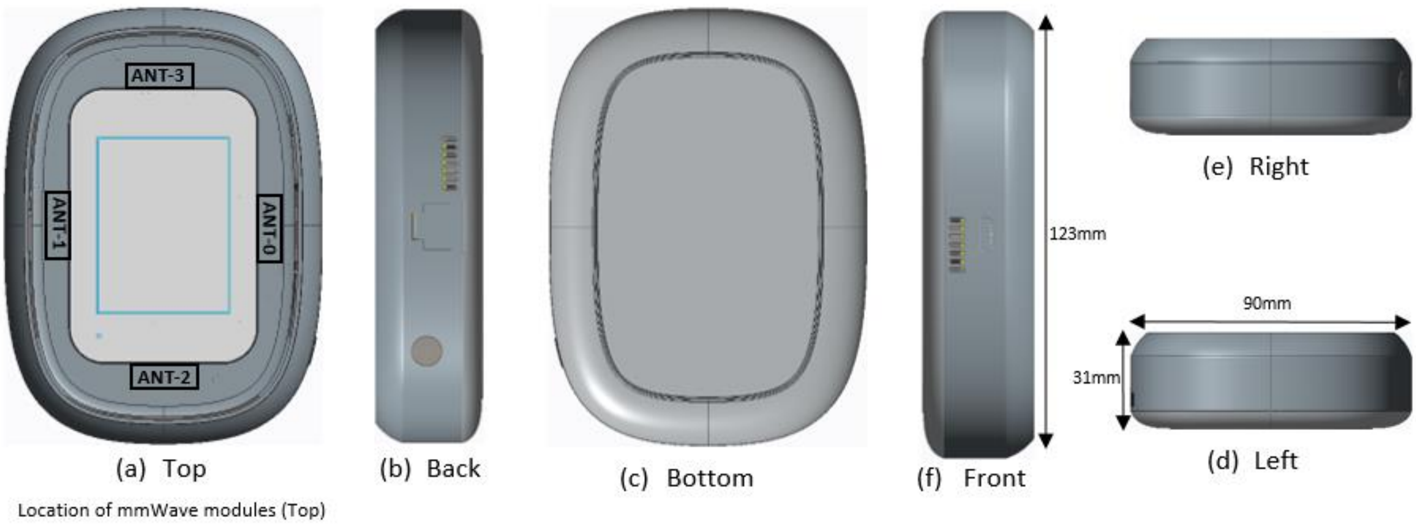


Fig. 3 – 3D model details

All four QTM052-8 antenna modules are mounted above the PCB top layer and legacy antennas That wrap the perimeter of the housing ID. Per figure 3, the QTM052-8 modules are positioned in the following way, Ant-0 faces the back side, Ant-1 faces the front side, Ant-2 faces the left side and Ant-3 faces the right side.

The QTM052-8 antenna modules are mounted to a metal holder which also acts to dissipate heat during normal operation. All four QTM052-8 antenna modules are mounted at a 50-degree angle to the PCB as shown in figure 4. This arrangement of the QTM052-8 antenna modules is believed to provide the best radiating coverage for a hotspot by directing power upward and away from the bottom surface. Simulation results show minimal power radiating from the bottom of the M1000 when compared to the top and side surfaces.

3.1.6 Antenna source excitation

The number of antenna ports of the QTM052-8 antenna modules Ant-0, Ant-1, Ant-2, Ant-3 consists of 16, 8 and 8, respectively. The antenna ports of the QTM052-8 antenna module is divided into 8 ports for the 1x4 patch array and 8 ports for the 1x4 dipoles array. In the 8 ports included in each patch antenna, 4 ports are divided into vertical polarization feeding, and 4 ports are divided into horizontal polarization feeding. The dipole array antenna consists of 4 antenna elements and each element uses two ports as a source excitation.

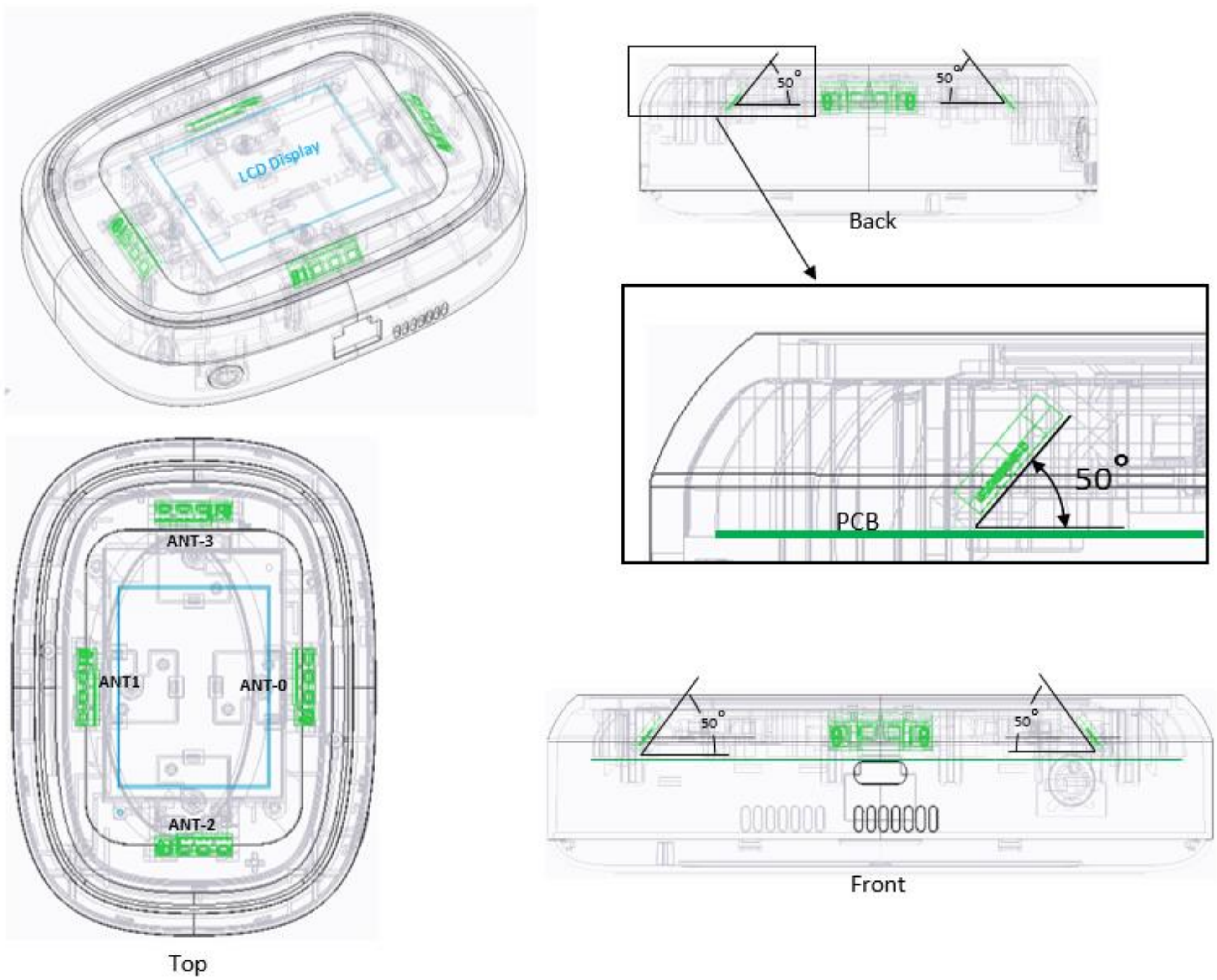


Figure 4 – Simulation model showing the mounted locations of all four QTM052-8 antenna modules

3.1.7 Power Density evaluation planes

Table 1 shows the PD evaluation planes for each QTM052-8 antenna module and Figure 5 illustrates the PD evaluation planes and truncation areas of the simulation model which are used to find the worst-case beamforming cases. Each QTM052-8 antenna module is individually evaluated for worse case PD using three evaluation planes. These planes, S1 through S12, are positioned 10mm away from the M1000 surface. All the material properties used in the simulation model are chosen to be as close to the real device.

Table 1 - PD Simulation evaluation planes

QTM052-8 Ant Module #	TOP	BOTTOM	BACK	FRONT	RIGHT	LEFT
ANT 0	S2	S10	S6	X	X	X
ANT 1	S4	S12	X	S8	X	X
ANT 2	S1	S9	X	X	S5	X
ANT 3	S3	S11	X	X	X	S7

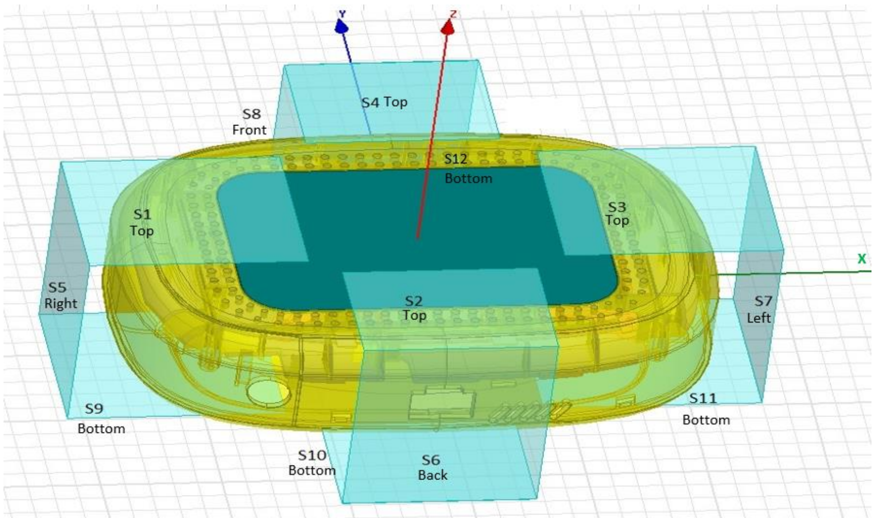


Fig. 5 – power density evaluation planes and truncation areas

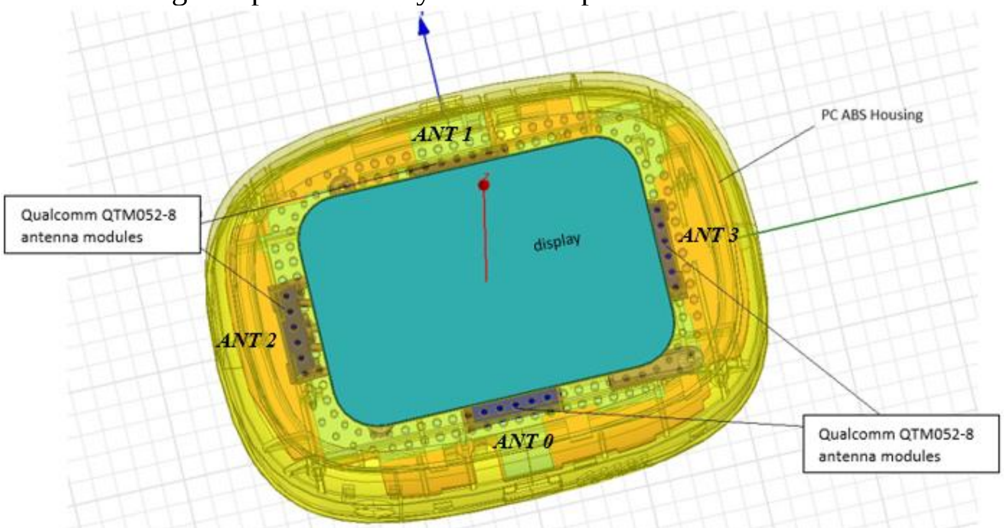


Fig. 5b – QTM052-8 antenna modules shown in simulation mode

3.1.8 Simulation to Find worst case value

To find the maximum power density value, firstly, power density is calculated and displayed on all evaluation surfaces. The power concentration areas for each evaluation surface are then identified. Second, a 2 cm x 2 cm square plane is moved in both X and Y directions across the entire surface and power density is calculated for each location. Third, the resulted maximum power density is divided by the area of the plane to get the average maximum power density over the 2 cm x 2 cm square area.

Fig. 6 shows three 2 cm x 2 cm squares, square 1, 2 and 3, positioned over the highest power density areas. These areas are obtained from the simulation results. This illustrates the process of locating the area having the highest average power density.

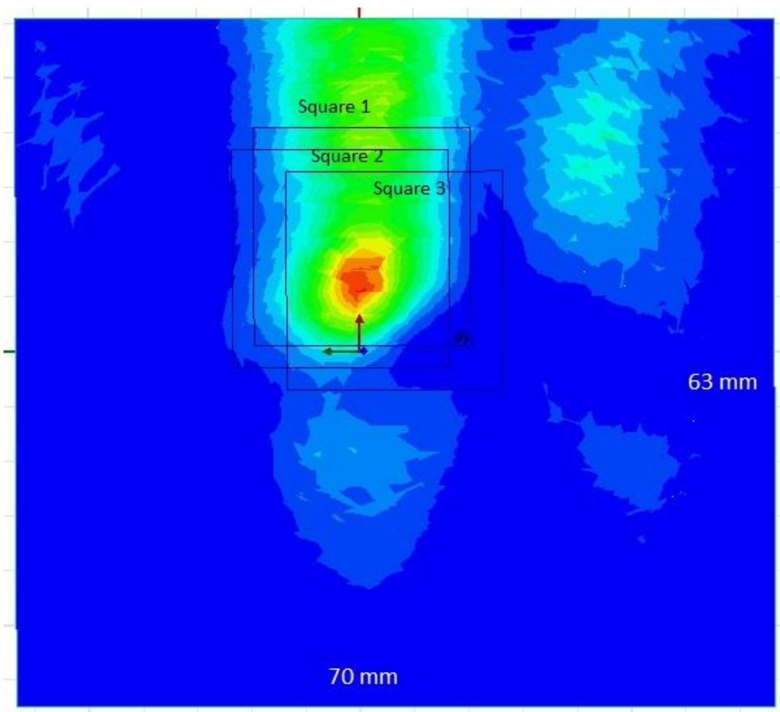


Fig. 6 – maximum value of average power density

4.0 Simulation Setup

4.1 Simulated Setup over the Pre-defined Plane

From the E-Field and H-Field generated by simulations, we can calculate the local power density by employing Poynting theorem. Figure 7 shows the local power density of the computed complex E-field and H-field at 38.5 GHz for the worst case in the pre-defined plane S2 top surface. The excited power for the QTM052-8 antenna module is set to 8dBm input power for each active port. A 4cm^2 square can then be placed around the high intensity zones to find the worst case of average power density as shown in Figure 6.

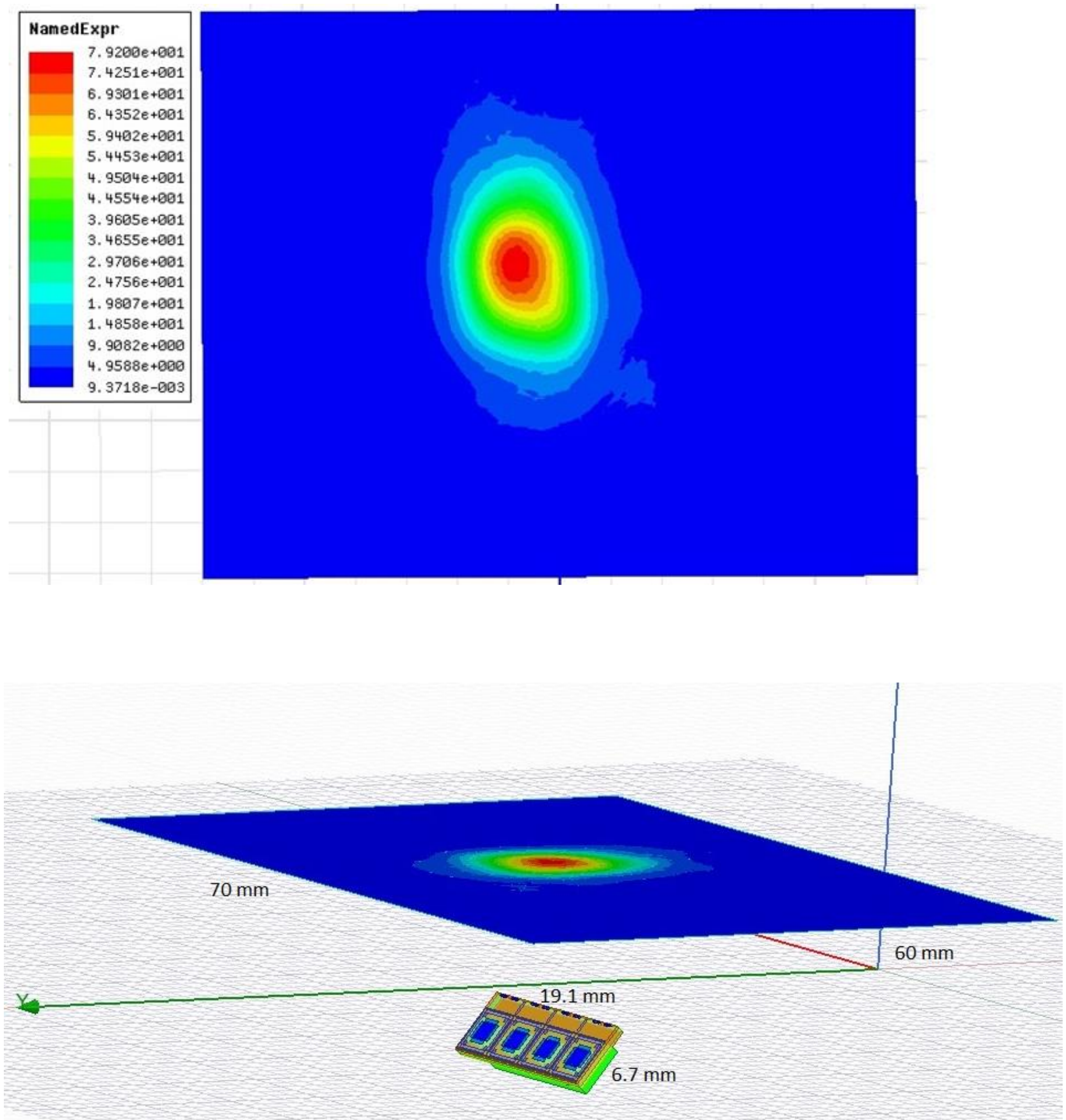


Fig. 7 - Local power density at pre-defined plane (S2 top surface) at 38.5 GHz

Figure 7 shows the simulated power density results at a 10 mm distance from the top side S2 surface of the M1000 correlates well with the actual measured results. Due to the time-consuming method used in measuring near field power density in the mmWave band, the most practical method is to use simulation results to find the antenna beam and surface with worst-case power density. Once the surface and beam are located, the power density measurements are performed on the worst-case power density surface or surfaces.

4.2 Reduced Power Density

The average power density on the M1000 bottom surfaces, S9 thru S12, are much lower than any power concentrations found across the top and side surfaces and intentionally designed to optimize the hotspot performance. The simulations show the bottom surface to have minimal radiated power when compared to the top and side surfaces. Therefore, no further simulations or measurements were performed the bottom surface. Results shown in Figures 8 & 9 below.

The highest-power density points located at the top surface are emitted from the QTM052-8 antenna modules dipole array as simulated on Ant-0 module. These results have a one order magnitude difference for beam 15 on mid channel, band n260 using 8dBm input power for each active port for simulations. The power density at the top surface S2 is 15.01dBm greater than the bottom surface S10. This is due to the PCB ground plane and angled position of the QTM052-8 module which reflects the fields toward the top and side surfaces. These results are typical for the remaining QTM052-8 modules Ant-1, Ant-2 and Ant-3.

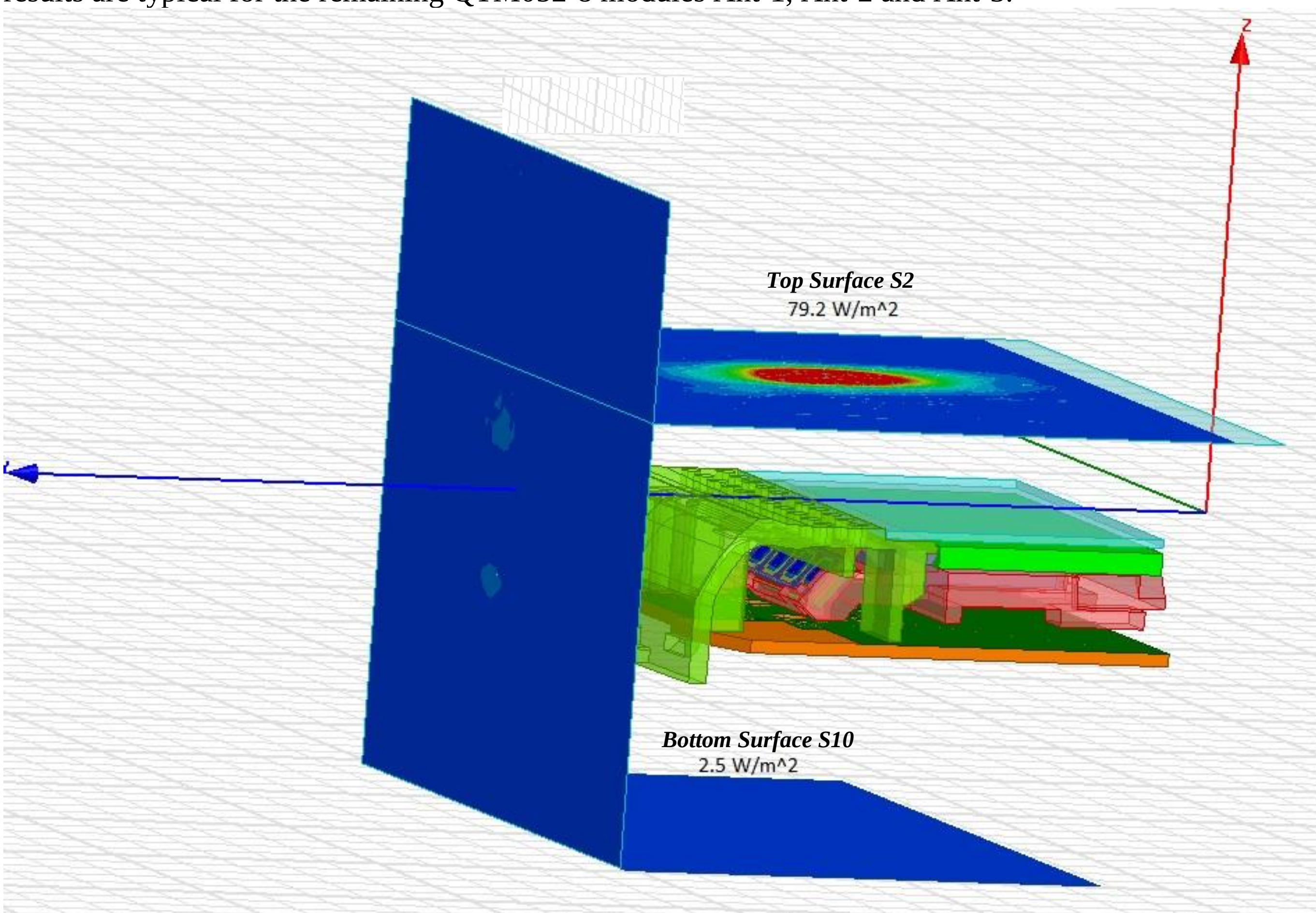


Fig. 8 - Simulated worse case power density top/bottom comparisons dipole antenna array

The highest-power density points located at the front surface are emitted from the QTM052-8 antenna module patch array as shown below on Ant-1. These results have a one order magnitude difference for beam 177 on Mid channel, band n260 using 8dBm input power for each active port for simulations. The power density at the front side surface S8 is 14.83dBm greater than the bottom surface S12. This is due to the PCB ground plane and angled position of the QTM052-8 module which reflects the fields toward the top and side surfaces. These results are typical for the remaining QTM052-8 modules Ant-0, Ant-2 and Ant-3.

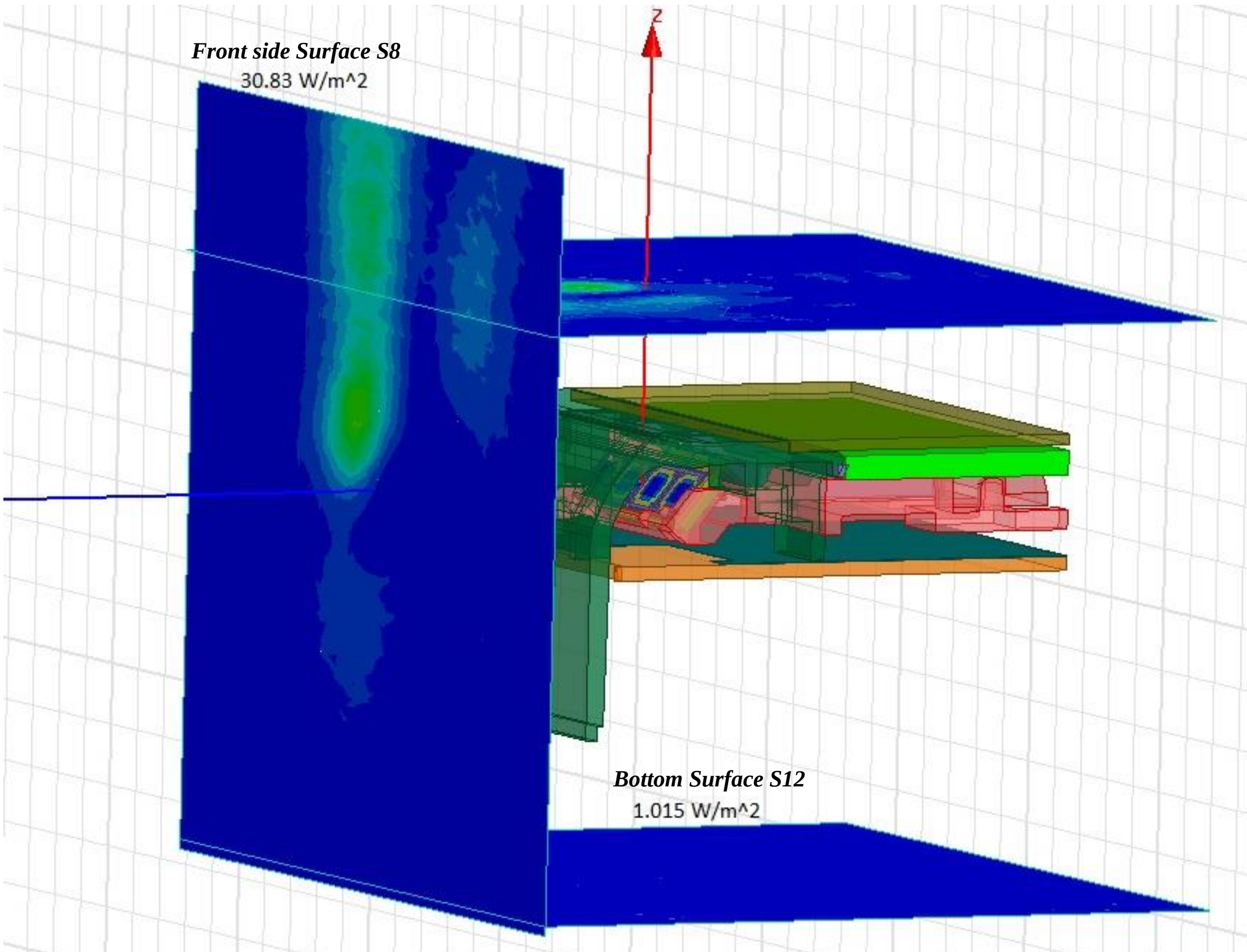


Fig. 9 - Simulated worse case power density front/bottom comparisons patch antenna array

4.3 Input Power

Table 3 shows the input powers used for each active port for both Simulation and Measurement. For measurements, Qualcomm factory Test Mode SW was used to input these values for each active port. For simulations, these values were entered directly into the HFSS parameters used in the simulation model.

Table 3 – Measured and Simulated input powers used for each active port

Mode/Band	Antenna Element Type	Input Power (dBm) SISO	Input Power (dBm) MIMO
5G NR n260	ANT-0 Dipole	8	5
	ANT-0 Patch	8	5
	ANT-1 Dipole	8	5
	ANT-1 Patch	8	5
	ANT-2 Dipole	8	5
	ANT-2 Patch	8	5
	ANT-3 Dipole	8	5
	ANT-3 Patch	8	5

5 Validation of Simulation Model

5.1 Comparison between Simulated and Measured

The beam characterization code book provided by Qualcomm provides the relative phase between each input port of the antenna array and therefore defines all beams formed in real-world operation. Simulated and measured power density distributions for the antenna modules are shown in the below data. Based on these comparisons, the simulated and measured power densities have good correlation. Measurement uncertainty in mmWave frequency simulation has measurement inaccuracy for material properties and are considered as error factors. Validation of simulations were performed in CW mode.

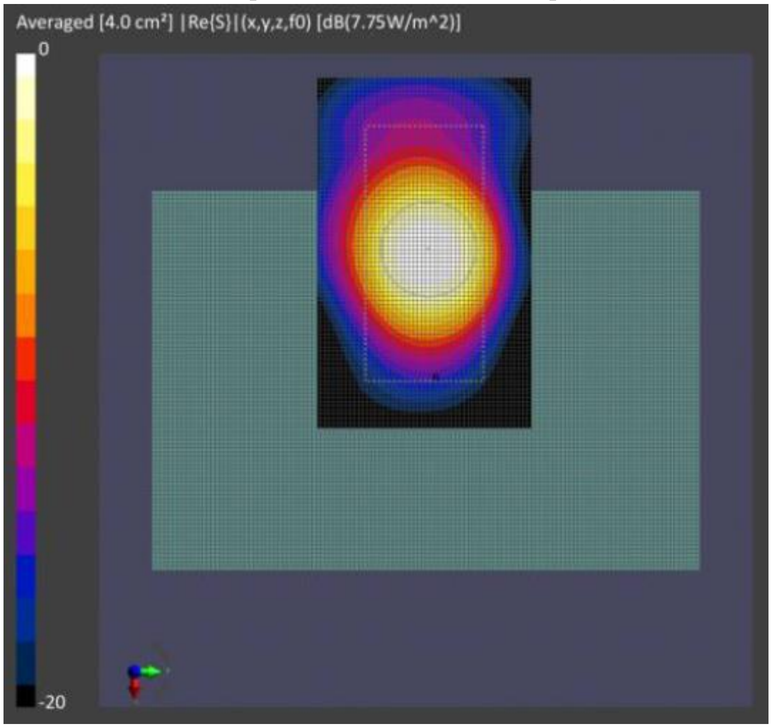
5.1.1 Correlation Of Measurements And Simulation

*Simulated vs Measured data validation, CW mode

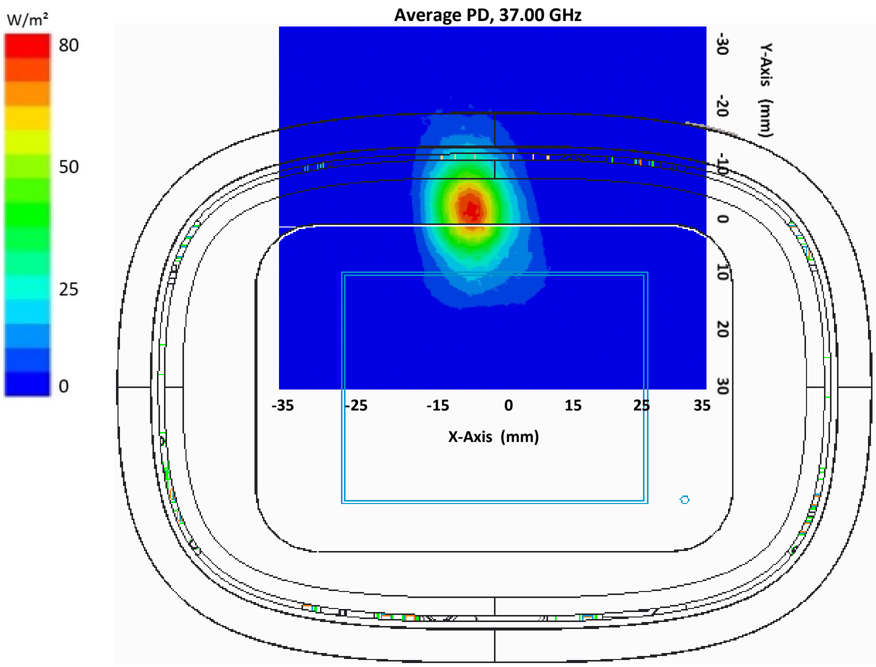
n260 Power Density Results: 4cm², CW										
Channel #	Frequency MHz	QTM Antenna	Paired Beam ID	DUT Surface ID	DUT Position	Probe Position mm	Measured PD (100% DC) mW/cm²	Scaled Measured PD (25% DC) mW/cm²	Simulated PD (100% DC) mW/cm²	Scaled Simulated PD (25% DC) mW/cm²
2229166	37000 (low)	0	15/142	S2	Top	10	0.775	0.193	2.220	0.555
2254166	38500 (mid)	0	15/142	S2	Top	10	1.420	0.355	2.410	0.603
2279165	40000 (high)	0	15/142	S2	Top	10	1.430	0.358	2.340	0.585
2229166	37000 (low)	1	177/49	S8	Front	10	0.471	0.118	0.840	0.210
2279165	38500 (mid)	1	177/49	S8	Front	10	0.502	0.125	1.050	0.263
2279165	40000 (high)	1	177/49	S8	Front	10	0.490	0.123	0.890	0.223

Power Density @ 37.00 GHz

- ANT-0 Dipole: Low Channel, H-pol Beam ID: 15/142, Top (S2)



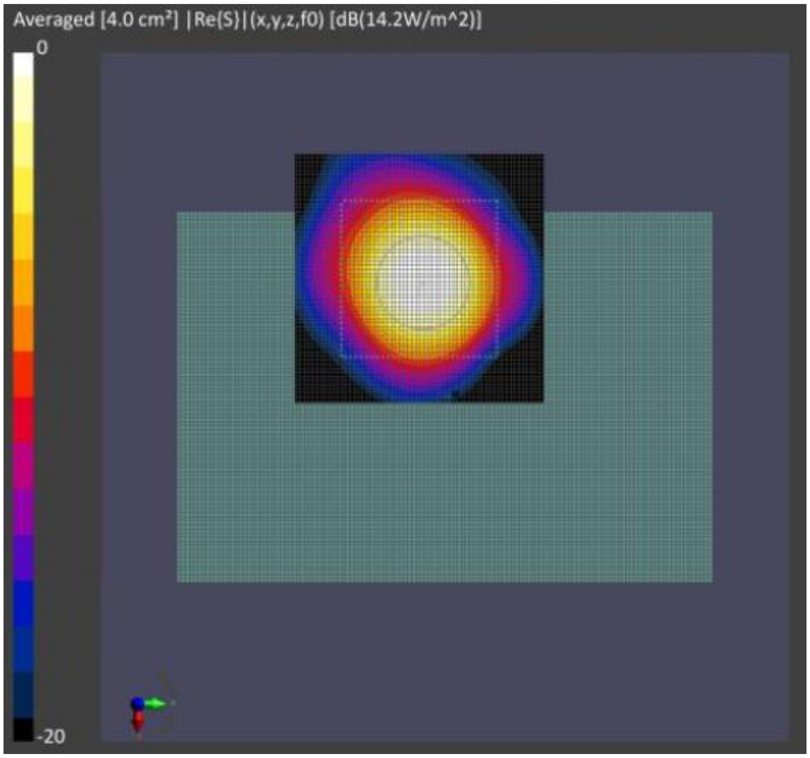
(a) Measured



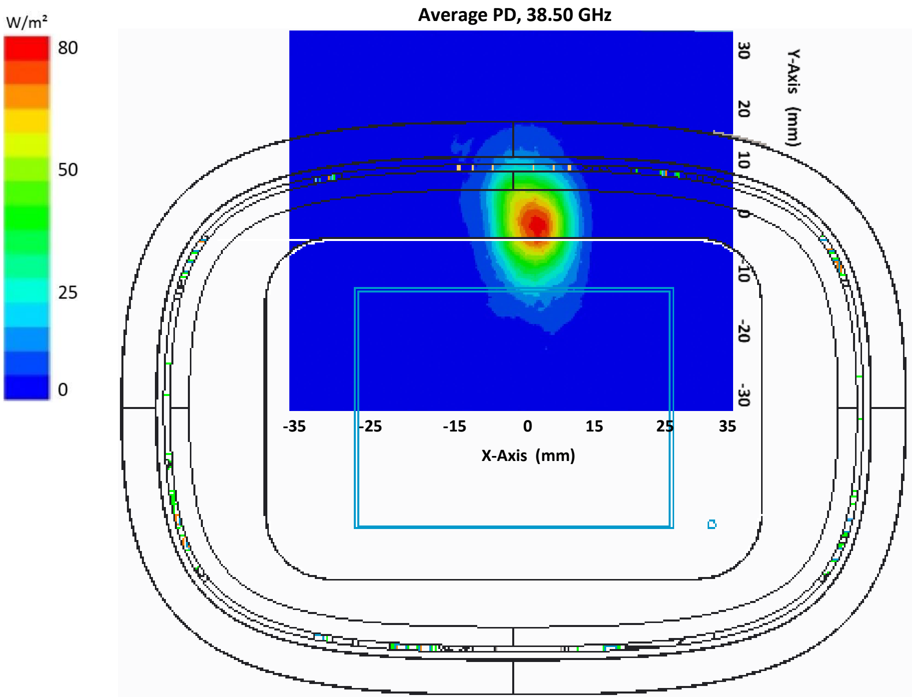
(b) simulated

Power Density @ 38.5 GHz

- ANT-0 Dipole: Mid Channel, H-pol Beam ID: 15/142, Top (S2)



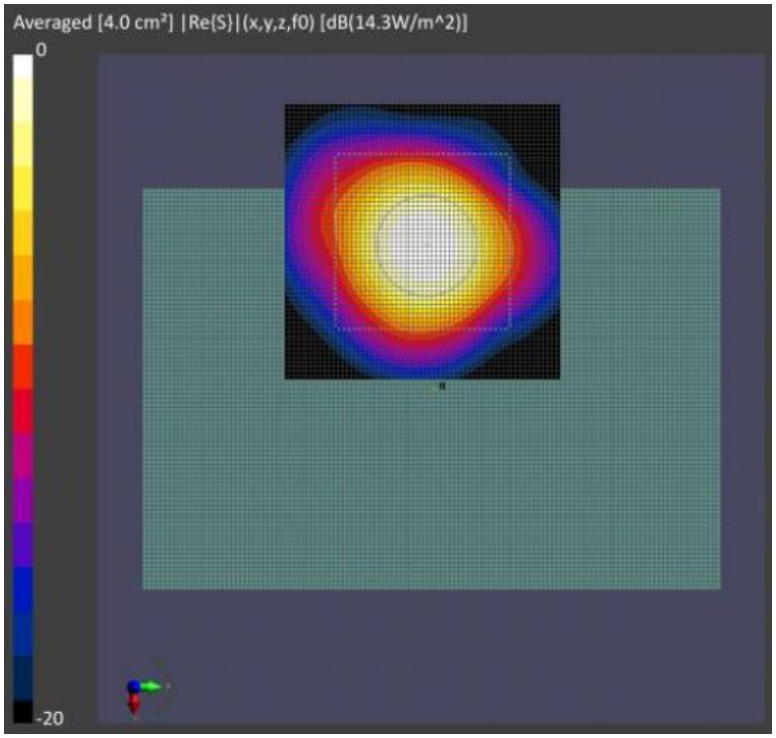
(a) Measured



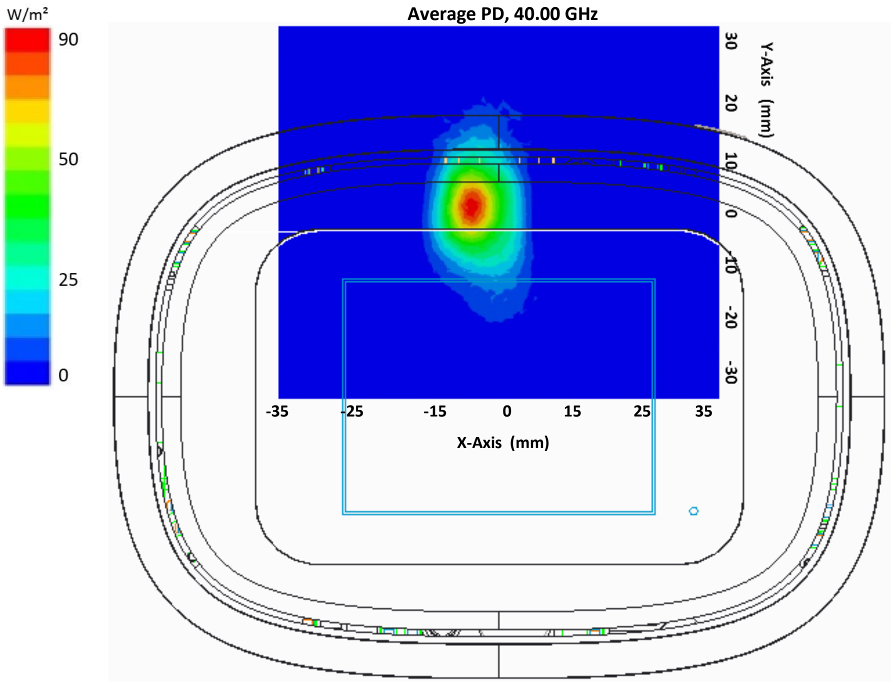
(b) simulated

Power Density @ 40.0 GHz

- ANT-0 Dipole: High Channel, H-pol Beam ID: 15/142, Top (S2)



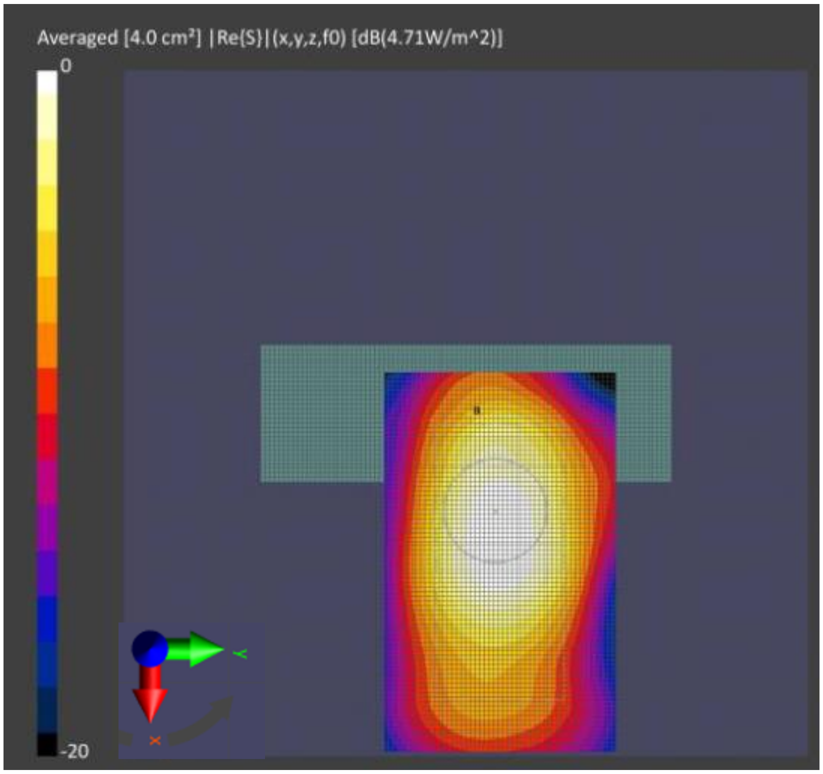
(a) Measured



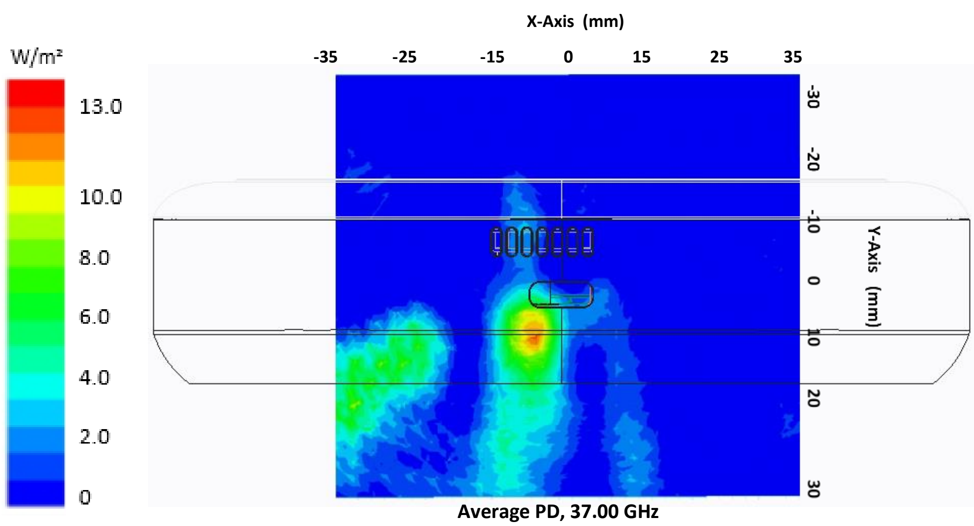
(b) simulated

Power Density @ 37.0 GHz

- ANT-1 Patch: Low Channel, V-pol Beam ID: 177/49, Front (S8)



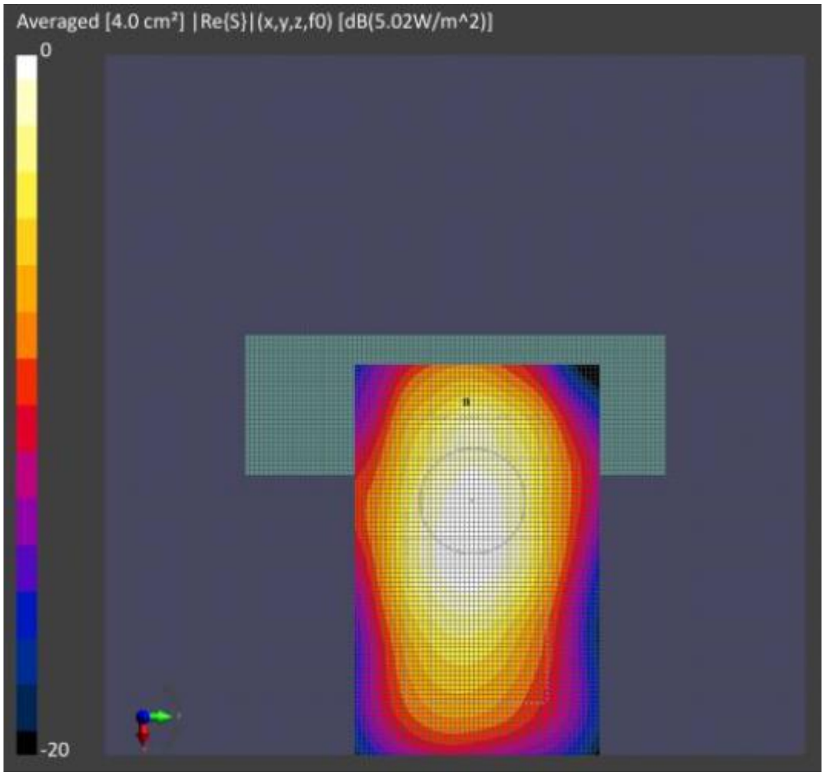
(a) Measured



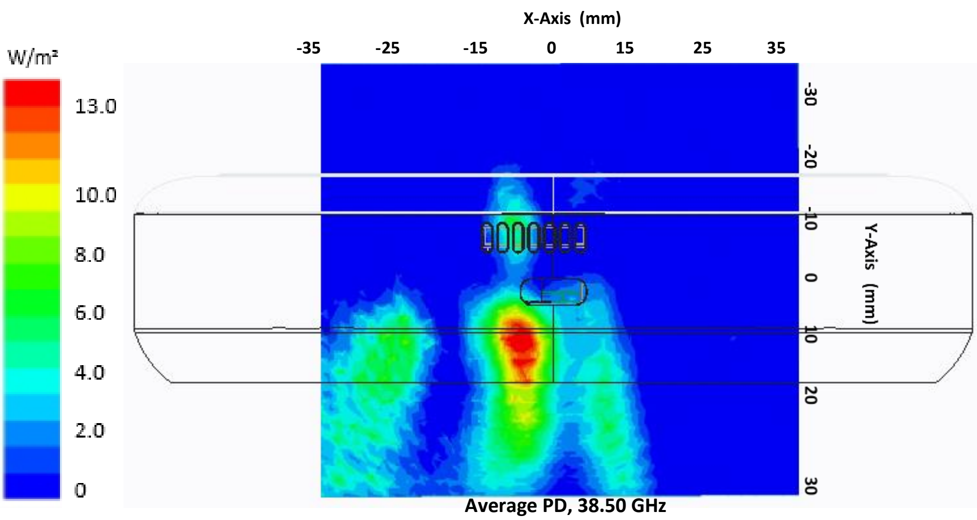
(b) simulated

Power Density @ 38.5 GHz

- ANT-1 Patch: Mid Channel, V-pol Beam ID: 177/49, Front (S8)



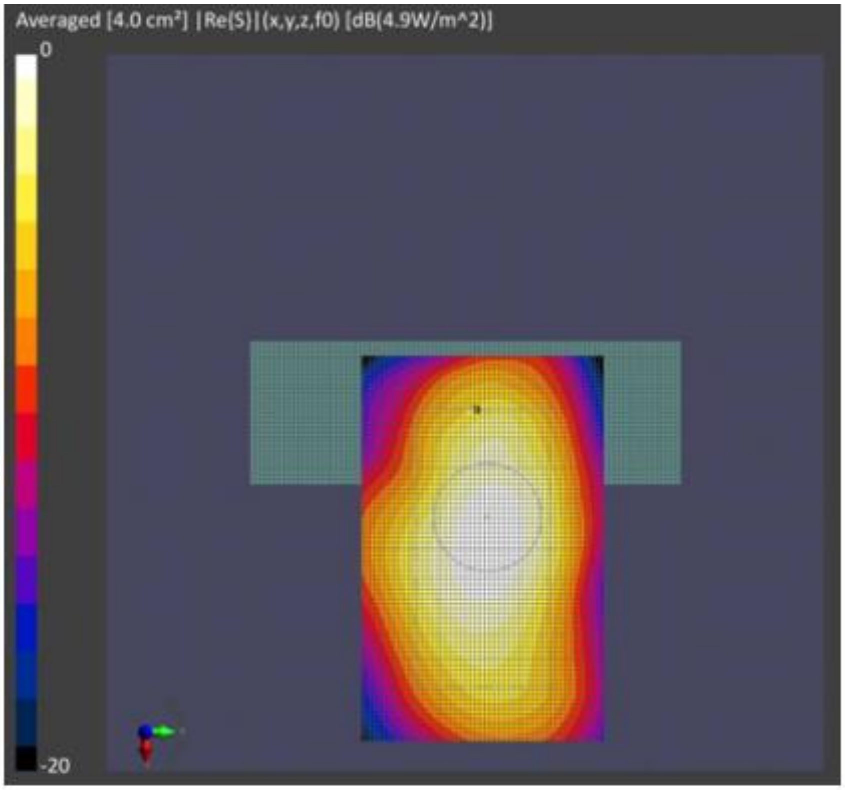
(a) Measured



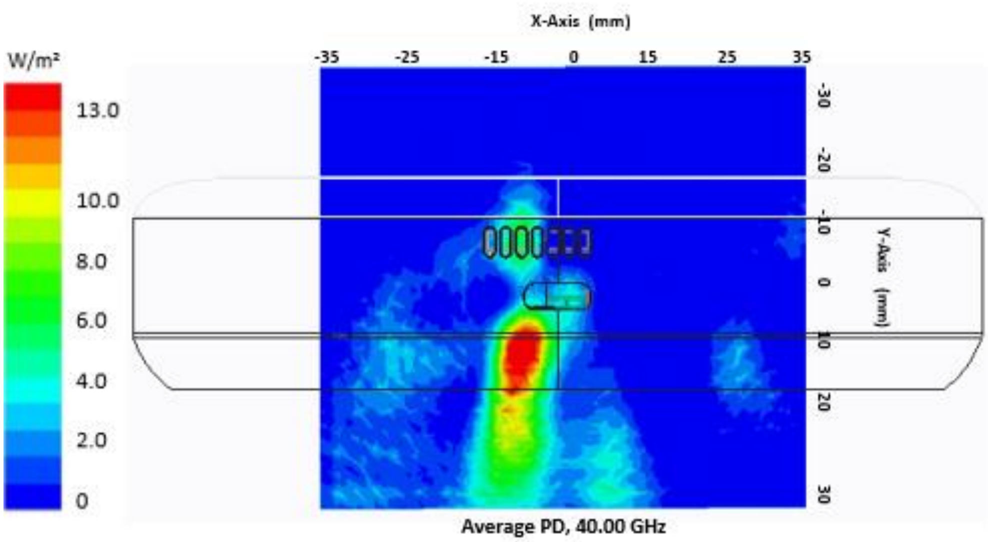
(b) simulated

Power Density @40.0 GHz

- ANT-1 Patch: High Channel, V-pol Beam ID: 177/49, Front (S8)



(a) Measured



(b) simulated

6 Simulation Results

6.1 power density for band n260: Low, Mid, High Channels

Note: Simulations in Tables 4, 5, 6 and 7 were made using only the worst-case power density beams.

6.1.1 Ant-0 – Dipole/Patch Antenna

Table 4 – Simulated Power Density Ant-0 - patch/dipole

PD Simulation (mW/cm²)			@ Operating Target Tx Power			10mm spacing Channel Low	Mid	High	Low	Mid	High
	Patch/Dipole	SISO/MIMO & Polarization	Tx Power (dBm)	Beam ID		(S2) Top Surface			(S6) Back Surface		
Ant-0	Patch	Single Beam H-pol	8		53				0.485	0.394	0.338
			8		54				0.307	0.287	0.221
			8		55				0.358	0.247	0.183
			8		56				0.427	0.354	0.298
			8		**57**				**0.496**	**0.412**	**0.373**
			8		72				0.399	0.326	0.301
			8		73				0.312	0.186	0.147
			8		74				0.411	0.296	0.244
			8		75				0.420	0.362	0.342
		Single Beam V-pol	8		185				0.452	0.526	0.347
			8		184				0.454	0.563	0.404
			8		183				0.660	0.736	0.501
			8		**182**				**0.754**	**0.829**	**0.576**
			8		181				0.541	0.609	0.403
			8		203				0.489	0.547	0.406
			8		202				0.462	0.500	0.344
			8		201				0.700	0.700	0.599
			8		200				0.664	0.806	0.500
		Paired Beam	5	53	184				0.469	0.460	0.343
			5	54	185				0.381	0.425	0.313
			5	55	183				0.509	0.492	0.342
			5	56	181				0.519	0.502	0.371
			5	**57**	**182**				**0.591**	**0.592**	**0.437**
			5	72	201				0.444	0.437	0.354
			5	73	202				0.387	0.343	0.246
			5	74	200				0.556	0.498	0.422
			5	75	203				0.542	0.584	0.421
	Dipole	Single Beam H-pol	8		14	0.721	0.846	0.896			
			8		**15**	**2.315**	**2.474**	**2.389**			
			8		16	2.077	2.183	2.040			
			8		36	1.665	1.967	2.003			
			8		37	2.235	2.446	2.366			
		Single Beam V-pol	8		143	1.483	1.673	1.669			
			8		**142**	**2.187**	**2.525**	**2.403**			
			8		144	0.707	0.921	1.080			
			8		164	0.638	0.706	0.900			
			8		165	1.604	1.916	1.934			
		Paired Beam	5	14	143	1.102	1.260	1.283			
			5	**15**	**142**	**2.251**	**2.500**	**2.396**			
			5	16	144	1.392	1.552	1.560			
			5	36	164	1.152	1.337	1.452			
			5	37	165	1.920	2.181	2.150			

6.1.2 Ant-1 – Dipole/Patch Antenna

Table 5 – Simulated Power Density of Ant-1 - patch/dipole

PD Simulation (mW/cm²)			@ Operating Target Tx Power			10mm spacing Channel					
						Low	Mid	High	Low	Mid	High
	Patch/Dipole	SISO/MIMO & Polarization	Tx Power (dBm)	Beam ID		(S4) Top Surface			(S8) Front Surface		
Ant-1	Patch	Single Beam H-pol	8		48				0.413	0.318	0.326
			8		**49**				**0.689**	**0.620**	**0.602**
			8		50				0.304	0.219	0.231
			8		51				0.650	0.564	0.482
			8		52				0.674	0.598	0.517
			8		68				0.464	0.463	0.448
			8		69				0.377	0.324	0.343
			8		70				0.281	0.186	0.197
			8		71				0.643	0.565	0.477
		Single Beam V-pol	8		176				0.500	0.608	0.434
			8		**177**				**0.800**	**1.069**	**0.898**
			8		178				0.355	0.741	0.597
			8		180				0.633	0.762	0.547
			8		179				0.480	0.541	0.374
			8		196				0.219	0.365	0.293
			8		197				0.486	0.552	0.404
			8		198				0.751	1.013	0.805
			8		199				0.796	1.055	0.773
		Paired Beam	5	48	176				0.457	0.463	0.380
			5	**49**	**177**				**0.720**	**0.810**	**0.625**
			5	50	178				0.330	0.480	0.414
			5	51	180				0.642	0.663	0.515
			5	52	179				0.577	0.570	0.446
			5	68	196				0.342	0.414	0.371
			5	69	197				0.432	0.438	0.374
			5	70	198				0.516	0.600	0.501
			5	71	199				0.607	0.694	0.612
	Dipole	Single Beam H-pol	8		8	0.623	0.769	0.644			
			8		9	1.788	1.111	2.067			
			8		10	1.400	0.956	1.397			
			8		**32**	**1.794**	**1.161**	**2.057**			
			8		33	1.649	0.984	1.760			
		Single Beam V-pol	8		137	1.000	1.097	1.027			
			8		136	0.993	1.166	1.003			
			8		138	0.662	0.807	0.647			
			8		**160**	**1.475**	**1.489**	**1.372**			
			8		161	1.257	1.357	1.202			
		Paired Beam	5	8	137	0.812	0.933	0.836			
			5	9	136	1.391	1.139	1.535			
			5	10	138	1.031	0.882	1.022			
			5	**32**	**160**	**1.635**	**1.325**	**1.715**			
			5	33	161	1.453	1.171	1.481			

6.1.3 Ant-2 – Dipole/Patch Antenna

Table 6 – Simulated Power Density of Ant-2 - patch/dipole

PD Simulation (mW/cm²)			@ Operating Target Tx Power			10mm spacing Channel					
						Low	Mid	High	Low	Mid	High
	Patch/ Dipole	SISO/MIMO & Polarization	Tx Power (dBm)	Beam ID		(S1) Top Surface			(S5) Right Surface		
Ant-2	Patch	Single Beam H-pol	8		63				0.289	0.333	0.279
			8		64				0.302	0.218	0.156
			8		65				0.624	0.565	0.486
			8		66				0.618	0.638	0.592
			8		67				0.349	0.398	0.431
			8		80				0.319	0.309	0.260
			8		81				0.429	0.388	0.323
			8		**82**				**0.665**	**0.628**	**0.559**
			8		83				0.492	0.491	0.512
		Single Beam V-pol	8		191				0.330	0.323	0.307
			8		192				0.386	0.481	0.369
			8		193				0.539	0.593	0.489
			8		194				0.399	0.502	0.423
			8		195				0.290	0.217	0.223
			8		208				0.279	0.314	0.266
			8		209				0.289	0.324	0.329
			8		**210**				**0.682**	**0.769**	**0.589**
			8		211				0.337	0.306	0.303
		Paired Beam	5	63	191				0.310	0.328	0.293
			5	64	192				0.344	0.350	0.263
			5	65	193				0.582	0.579	0.488
			5	66	194				0.509	0.570	0.508
			5	67	195				0.320	0.308	0.327
			5	80	208				0.299	0.312	0.263
			5	81	209				0.359	0.356	0.326
			5	**82**	**210**				**0.674**	**0.699**	**0.574**
			5	83	211				0.415	0.399	0.408
	Dipole	Single Beam H-pol	8		29	1.606	1.858	1.888			
			8		**30**	**2.226**	**2.535**	**2.349**			
			8		31	1.805	1.990	1.768			
			8		46	2.065	2.388	2.303			
			8		47	2.176	2.444	2.224			
		Single Beam V-pol	8		157	1.327	1.586	1.724			
			8		**159**	**1.480**	**1.931**	**2.046**			
			8		158	1.212	1.532	1.614			
			8		175	0.702	0.790	0.838			
			8		174	0.646	0.692	0.686			
		Paired Beam	5	29	157	1.467	1.722	1.806			
			5	**30**	**159**	**1.853**	**2.233**	**2.198**			
			5	31	158	1.509	1.761	1.691			
			5	46	175	1.384	1.589	1.571			
			5	47	174	1.411	1.568	1.455			

6.1.4 Ant-3 – Dipole/Patch Antenna

Table 7 – Simulated Power Density of Ant-3 - patch/dipole

<table>
<tr><td colspan="3" rowspan="3">PD Simulation (mW/cm²)</td><td colspan="3" rowspan="3">@ Operating Target Tx Power</td><td colspan="6">10mm spacing</td></tr>
<tr><td colspan="6">Channel</td></tr>
<tr><td>Low</td><td>Mid</td><td>High</td><td>Low</td><td>Mid</td><td>High</td></tr>
<tr><td rowspan="43">Ant-3</td><td>Patch/ Dipole</td><td>SISO/MIMO & Polarization</td><td>Tx Power (dBm)</td><td colspan="2">Beam ID</td><td colspan="3">(S3) Top Surface</td><td colspan="3">(S7) Front Surface</td></tr>
<tr><td rowspan="27">Patch</td><td rowspan="9">Single Beam H-pol</td><td>8</td><td></td><td>58</td><td></td><td></td><td></td><td>0.670</td><td>0.678</td><td>0.641</td></tr>
<tr><td>8</td><td></td><td>59</td><td></td><td></td><td></td><td>0.414</td><td>0.468</td><td>0.427</td></tr>
<tr><td>8</td><td></td><td>60</td><td></td><td></td><td></td><td>0.372</td><td>0.390</td><td>0.342</td></tr>
<tr><td>8</td><td></td><td>61</td><td></td><td></td><td></td><td>0.810</td><td>0.742</td><td>0.629</td></tr>
<tr><td>8</td><td></td><td>62</td><td></td><td></td><td></td><td>0.468</td><td>0.551</td><td>0.578</td></tr>
<tr><td>8</td><td></td><td>76</td><td></td><td></td><td></td><td>0.518</td><td>0.563</td><td>0.524</td></tr>
<tr><td>8</td><td></td><td>77</td><td></td><td></td><td></td><td>0.424</td><td>0.365</td><td>0.314</td></tr>
<tr><td>8</td><td></td><td>78</td><td></td><td></td><td></td><td>0.754</td><td>0.714</td><td>0.586</td></tr>
<tr><td>8</td><td></td><td>79</td><td></td><td></td><td></td><td>0.617</td><td>0.626</td><td>0.635</td></tr>
<tr><td rowspan="9">Single Beam V-pol</td><td>8</td><td></td><td>188</td><td></td><td></td><td></td><td>1.098</td><td>1.242</td><td>1.000</td></tr>
<tr><td>8</td><td></td><td>186</td><td></td><td></td><td></td><td>0.688</td><td>0.766</td><td>0.658</td></tr>
<tr><td>8</td><td></td><td>187</td><td></td><td></td><td></td><td>0.713</td><td>0.904</td><td>0.701</td></tr>
<tr><td>8</td><td></td><td>189</td><td></td><td></td><td></td><td>0.693</td><td>0.853</td><td>0.717</td></tr>
<tr><td>8</td><td></td><td>190</td><td></td><td></td><td></td><td>0.649</td><td>0.558</td><td>0.451</td></tr>
<tr><td>8</td><td></td><td>205</td><td></td><td></td><td></td><td>0.838</td><td>1.053</td><td>0.814</td></tr>
<tr><td>8</td><td></td><td>204</td><td></td><td></td><td></td><td>0.566</td><td>0.570</td><td>0.497</td></tr>
<tr><td>8</td><td></td><td>206</td><td></td><td></td><td></td><td>0.773</td><td>1.033</td><td>0.805</td></tr>
<tr><td>8</td><td></td><td>207</td><td></td><td></td><td></td><td>0.663</td><td>0.626</td><td>0.539</td></tr>
<tr><td rowspan="9">Paired Beam</td><td>5</td><td>58</td><td>188</td><td></td><td></td><td></td><td>0.884</td><td>0.960</td><td>0.821</td></tr>
<tr><td>5</td><td>59</td><td>186</td><td></td><td></td><td></td><td>0.551</td><td>0.617</td><td>0.543</td></tr>
<tr><td>5</td><td>60</td><td>187</td><td></td><td></td><td></td><td>0.543</td><td>0.647</td><td>0.522</td></tr>
<tr><td>5</td><td>61</td><td>189</td><td></td><td></td><td></td><td>0.752</td><td>0.798</td><td>0.673</td></tr>
<tr><td>5</td><td>62</td><td>190</td><td></td><td></td><td></td><td>0.559</td><td>0.555</td><td>0.515</td></tr>
<tr><td>5</td><td>76</td><td>205</td><td></td><td></td><td></td><td>0.678</td><td>0.808</td><td>0.669</td></tr>
<tr><td>5</td><td>77</td><td>204</td><td></td><td></td><td></td><td>0.495</td><td>0.468</td><td>0.406</td></tr>
<tr><td>5</td><td>78</td><td>206</td><td></td><td></td><td></td><td>0.764</td><td>0.874</td><td>0.696</td></tr>
<tr><td>5</td><td>79</td><td>207</td><td></td><td></td><td></td><td>0.640</td><td>0.626</td><td>0.587</td></tr>
<tr><td rowspan="15">Dipole</td><td rowspan="5">Single Beam H-pol</td><td>8</td><td></td><td>20</td><td>0.764</td><td>0.800</td><td>0.800</td><td></td><td></td><td></td></tr>
<tr><td>8</td><td></td><td>21</td><td>1.476</td><td>1.781</td><td>2.100</td><td></td><td></td><td></td></tr>
<tr><td>8</td><td></td><td>22</td><td>1.306</td><td>1.553</td><td>1.858</td><td></td><td></td><td></td></tr>
<tr><td>8</td><td></td><td>40</td><td>1.290</td><td>1.483</td><td>1.659</td><td></td><td></td><td></td></tr>
<tr><td>8</td><td></td><td>41</td><td>1.476</td><td>1.835</td><td>2.198</td><td></td><td></td><td></td></tr>
<tr><td rowspan="5">Single Beam V-pol</td><td>8</td><td></td><td>149</td><td>1.345</td><td>1.499</td><td>1.587</td><td></td><td></td><td></td></tr>
<tr><td>8</td><td></td><td>150</td><td>1.325</td><td>1.520</td><td>1.529</td><td></td><td></td><td></td></tr>
<tr><td>8</td><td></td><td>148</td><td>1.123</td><td>1.240</td><td>1.229</td><td></td><td></td><td></td></tr>
<tr><td>8</td><td></td><td>168</td><td>0.677</td><td>0.736</td><td>0.658</td><td></td><td></td><td></td></tr>
<tr><td>8</td><td></td><td>169</td><td>1.465</td><td>1.695</td><td>1.771</td><td></td><td></td><td></td></tr>
<tr><td rowspan="5">Paired Beam</td><td>5</td><td>20</td><td>149</td><td>1.055</td><td>1.150</td><td>1.194</td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>21</td><td>150</td><td>1.401</td><td>1.651</td><td>1.815</td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>22</td><td>148</td><td>1.215</td><td>1.397</td><td>1.544</td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>40</td><td>168</td><td>0.984</td><td>1.110</td><td>1.159</td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>41</td><td>169</td><td>1.471</td><td>1.765</td><td>1.985</td><td></td><td></td><td></td></tr>
</table>

6.2 Summarized Simulated vs Measured PD Test Results

Mid channel power density @ 37.5 GHz

Power Density: ANT-0									
Surface Side	Surface ID	Element Type	Channel	Antenna	Beam ID	Measured (100% DC) mW/cm²	Measured (25% DC) mW/cm²	Simulated (100% DC) mW/cm²	Simulated (25% DC) mW/cm²
Top	S2	Dipole	Mid	0	15	0.784	0.196	2.474	0.619
Top	S2	Dipole	Mid	0	142	0.334	0.084	2.525	0.631
Top	S2	Dipole	Mid	0	15/142	**1.020**	**0.255**	2.500	0.625
Bottom	S10	Dipole	Mid	0	15/142	0.003	0.001	N/A	N/A
Front	S4	Dipole	Mid	0	15/142	0.004	0.001	N/A	N/A
Back	S6	Dipole	Mid	0	15/142	0.110	0.028	N/A	N/A
Left	S7	Dipole	Mid	0	15/142	0.015	0.004	N/A	N/A
Right	S5	Dipole	Mid	0	15/142	0.042	0.011	N/A	N/A
Back	S6	Patch	Mid	0	182	0.267	0.067	0.829	0.207

Power Density: ANT-1									
Surface Side	Surface ID	Element Type	Channel	Antenna	Beam ID	Measured (100% DC) mW/cm²	Measured (25% DC) mW/cm²	Simulated (100% DC) mW/cm²	Simulated (25% DC) mW/cm²
Top	S4	Dipole	Mid	1	32	**0.513**	**0.128**	1.161	0.290
Top	S4	Dipole	Mid	1	160	0.117	0.029	1.489	0.372
Top	S4	Dipole	Mid	1	32/160	0.397	0.099	1.325	0.331
Bottom	S12	Dipole	Mid	1	32	0.007	0.002	N/A	N/A
Front	S8	Dipole	Mid	1	32	0.075	0.019	N/A	N/A
Back	S6	Dipole	Mid	1	32	0.030	0.008	N/A	N/A
Left	S7	Dipole	Mid	1	32	0.031	0.008	N/A	N/A
Right	S5	Dipole	Mid	1	32	0.046	0.012	N/A	N/A
Front	S8	Patch	Mid	1	177	0.352	0.088	1.069	0.267

`Power Density: ANT-2									
Surface Side	Surface ID	Element Type	Channel	Antenna	Beam ID	Measured (100% DC) mW/cm²	Measured (25% DC) mW/cm²	Simulated (100% DC) mW/cm²	Simulated (25% DC) mW/cm²
Top	S1	Dipole	Mid	2	30	**0.466**	**0.117**	2.535	0.634
Top	S1	Dipole	Mid	2	159	0.111	0.028	1.931	0.483
Top	S1	Dipole	Mid	2	30/159	0.266	0.067	2.233	0.558
Bottom	S9	Dipole	Mid	2	30	0.006	0.001	N/A	N/A
Front	S8	Dipole	Mid	2	30	0.016	0.004	N/A	N/A
Back	S6	Dipole	Mid	2	30	0.020	0.005	N/A	N/A
Left	S7	Dipole	Mid	2	30	0.022	0.006	N/A	N/A
Right	S5	Dipole	Mid	2	30	0.109	0.027	N/A	N/A
Right	S5	Patch	Mid	2	210	0.294	0.074	0.769	0.192

Power Density: ANT-3									
Surface Side	**Surface ID**	**Element Type**	**Channel**	**Antenna**	**Beam ID**	**Measured (100% DC) mW/cm²**	**Measured (25% DC) mW/cm²**	**Simulated (100% DC) mW/cm²**	**Simulated (25% DC) mW/cm²**
Top	S3	Dipole	Mid	3	41	**0.936**	**0.234**	1.835	0.459
Top	S3	Dipole	Mid	3	169	0.304	0.076	1.695	0.424
Top	S3	Dipole	Mid	3	41/169	0.728	0.182	1.765	0.441
Bottom	S11	Dipole	Mid	3	41	0.007	0.002	N/A	N/A
Front	S8	Dipole	Mid	3	41	0.008	0.002	N/A	N/A
Back	S6	Dipole	Mid	3	41	0.050	0.012	N/A	N/A
Left	S7	Dipole	Mid	3	41	0.113	0.028	N/A	N/A
Right	S5	Dipole	Mid	3	41	0.040	0.010	N/A	N/A
Left	S7	Patch	Mid	3	188	0.415	0.104	1.242	0.311

As described in section 4.2, the power density levels are extremely low and difficult to accurately simulate, therefore bottom simulations were omitted from the table, as noted “N/A”.

Particular DUT edges were not required to be evaluated for Power Density if the edges were greater than 2.5 cm from the transmitting antenna according to FCC KDB Publication 941225 D06v02r01 Section III.

Power Density results were scaled down from the test software duty cycle of 100% to the maximum duty cycle (as attested by the carrier(s)) to demonstrate compliance.

7 Summary

7.1.1 Uncertainty

The amplitude level of power density simulation is biased due to material property parameters and the internal configuration at mmWave frequencies. Therefore, it’s not possible to assign an exact uncertainty for the simulation results. However, for the RF exposure evaluation, simulation results were only used to select the highest worst-case beam ID for measurements. Power density results for measurement and simulation show similar results to justify the selection of the Beam ID used for measurements. All final power density evaluations were performed on a measurement system with uncertainty of approximately 1.5dB.