LG Electronics Model : LM-V450VM

Power Density Simulation and Measurement Report

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1. Purpose

This document provides an overview of the methodology used by LGE and its test partner to characterize MPE compliance of the 5G mm-Wave mobile device model LM-V450VM. At a high level, the discussion is grouped into the following topics:

- Brief review of the device configuration and operation, as the pertain to MPE characterization

- Explanation of the approach to demonstrate MPE compliance in a mobile device, using simulation and measurement

- Detailed description of the simulation methodology and results, as applicable to the MPE measurement

2. Brief Description of the Device

2.1 DUT Description

LM-V450VM contains 4G and 5G radio transceivers, capable of functioning in EN-DC mode. It also have WiFi/BT transceiver function. Transmissions are coordinated both 4G and 5G transmitting simultaneously, and/or WiFi/BT are transmitting simultaneously with cellular radios.

The Array Modules labeled Left, Right are the two 5G mm-Wave antenna array modules on the device. For the LTE antennas, the abbreviations in the figures correspond to the bands as follows:

Low Band : B13, B5

Mid Band : B2, B4, B66

High Band : B48

Each of the two 5G mm-wave array modules are an identical part containing a 1x4 element array of dual-polarization patch antennas. Only one antenna array module is in use by the modem at any one time, i.e. the modem selects one array module at any one time for both transmission and reception operation. Within an array each of the two linear polarizations of the patch antennas is excited by one of the MIMO paths of the modem. Hence during MIMO operation, two independently controlled beams are formed and pointed by the modem, one in each polarization, one in each polarization. Generally, a module can form beams that illuminate a partial hemisphere oriented in the broadside direction orthogonal to the face of the module. Two mm-wave array

module are arranged at Left and right and are located top of mid along the two edge of the device. They are illustrated more clearly in a perspective view in Figure 2.1 in the appendix A in Main Operational description.

* Figure 2.1: Two mm-wave array module location on the device

3. Background

This section discusses device operation as it relates to MPE compliance measurement and simulation

3.1. Summary of FDTD or other numerical modeling algorithm implementation and validation

3.2. Addressing absorbing boundary conditions, source excitation methods, certain standard algorithms for handling thin metallic wires, sheets or dielectric materials, etc...

3.3. Description of the procedures used to validate the basic computing algorithms described and analysis of the computing accuracy based on these algorithms for the particular evaluation

The solver is based on the frequency-domain Finite Element Method (FEM). Unstructured tetrahedral mesh is used for 3D CAD model discretization. Simulation is performed at certain frequencies or in a frequency range with the Fast Frequency Sweep algorithm for asymptotical evaluation of broadband quantities (Scattering parameters, Far-Field & Near-Field values). Dielectric objects are defined through 3D shape, relative permittivity, relative permeability, loss tangent and bulk conductivity. Metals are defined through 3D shape (including solid objects and zero-thickness sheets/coatings) and conductivity which is taken into account in simulation by calculating surface impedance (to introduce additional losses on copper and other metal parts). Sources are defined though Lumped Ports with user-defined impedance. Simulation model is enclosed by an Air Box with Absorbing Boundary Conditions on all boundaries of the box.

4. Operation

4.1. Block diagram

Regarding Figure 4.1, please refer to Appendix A in the Main Operational description.

* Figure 4.1 RF/IF Block diagram of the device

This figure 4.1 shows the RF/IF block diagram of the device. The 4G modem and transceiver connect directly to the 4G antennas at their respective RF frequencies. The 5G modem is connected to each of the two mm-wave antenna array modules via two IF lines, one for each of the two MIMO layers of operation. mm-wave antenna array module contains IF RFIC. So each antenna array module contains up/down conversion and signal-conditioning circuitry to convert the IF signal to/from the RF(mm-wave) signal transmitted/received by the antenna array, as well as the phase-shifting means whereby the complex weights assigned by the modem to form a desired beam are applied to the ports of each element of the array. Further detail of the mm-wave antenna array modules are given in the accompanying long-term-confidential document " QTM052 5G/NR FR2 MILLIMETER WAVE ANTENNA ARRAY REGULATORY INFORMATION – APPLICATION NOTE." Each IF line (MIMO layer_ is associated with one polarization of a 1x4 array of patch antennas in the module. The modem selects one of the two mm-wave antenna array modules for operation at any point in time. In other words, only one module is active for transmit and receive at any point in time. Since 5G mm-wave is a TDD system, the T/R switching means for each module is also included within the module, and under control of the modem.

4.2. 5G NSA EN-DC Operation

The LM-V450VM supports 5G NSA EN-DC operation under the 3GPP standard. This means that the device contains LTE and 5G mm-wave transceivers. The transceivers necessarily operate simultaneously, according to the standard, whenever 5G mm-wave is active. Hence sub-6 GHz SAR exposure and mm-wave power density exposure must be considered together when assessing aggregate MPE compliance. WiFi/BT is also consider as exposure because they are supported with 5G NSA EN-DC operation. To the extent possible with the respective measurement systems, mm-wave power density is measured on the same exposure planes as are used for SAR, as appropriate to a mobile device, to enable this aggregate assessment. This document focuses on the mm-wave portion of the assessment only, while the sub-6 GHz and aggregate exposure are treated in a separate document.

4.3. TX Duty Cycle in TDD System

5G in the mm-wave bands supported by this device is a Time-Division-Duplex system. Under the standard, there is no fixed limitation on uplink/downlink ratio for this system. Although it is understood that initial network deployments may limit the uplink/downlink ratio to some value, it

cannot be guaranteed, under the standard which this device must support, for all future network deployments in the lifetime of the device. For this reason in order to capture worst-case power density conditions, an uplink duty cycle of 100% is assumed for all simulations and measurements.

4.4. Beamforming

The 5G mm-wave system employs electronic beamforming in the user equipment. Each mm-wave antenna array module contains a 1x4 array of dual-polarizations of the array. For each polarization (MIMO layer), the modem directs the antenna module to apply a specific set of complex weight to the signal copies applied to each of the four antenna element input ports, in order to form the desired antenna beam.

Although a large number of independent phase profiles, and hence antenna beams, is hypothetically possible in each polarization of each module, in practice in this device the modem limits the number of independently selectable beams to a small number. Within a module, each polarization supports only 15 distinct beams from which the modem can select; furthermore, beams are paired between polarizations, i.e., beams cannot be selected independently between polarizations. These beams and beam-pairs are defined at design-time for the device. The net result is that each module only supports 15 predefined beam-pairs, from which the modem selects one beam-pair for operation at any instant in time. Additionally, the modem can only select one of the device's two modules for use at any instant in time. Hence, considering 2 modules with 15 beam pairs defined for each, 30 beam pairs form the basis. Although two modules support only 30 paired beams, 60 single beams was considered as simulation and measurement for searching the worst case. Because single beams sum of 2 polarizations are confirmed as the worst case than paired beams. This is because the angles of the two polarizations in paired beam are not well coincided, and the sum of the worst single beams was worse than paired beams considering as highest PD. The tilt angle between the two polarizations of the twin beam will be improved and the twin beam will also be considered the worst case.

Each polarization of the array, i.e. each MIMO layer, is also referred to as an "antenna group." An antenna group is comprised of one feed on each of the four patch antennas, all four of which excite the same polarization of radiation. Hence, the antenna group AG0 is formed of the four excitations (feeds), one on each patch element, that excite the linear polarization parallel to the long axis of the antenna module (when observed in the broadside direction); these are the four antenna feed ports labeled as "H1, H2, H3, and H4" in the Operational Description. Similarly, the

antenna group AG1 is formed of the four excitations (feeds), one on each patch element, that excite the linear polarization orthogonal to the long axis of the antenna module (when observed in the broadside direction); these are the four antenna feed ports labeled as "V1, V2, V3, and V4" in the Operational Description. A beam pair consists of one beam formed in the AG0 antenna group and one beam formed in the AG1 antenna group.

A module is capable of steering beams (or beam pairs) in the hemisphere that is in the broadside direction to that module. (The broadside direction is the direction orthogonal to the front surface of the module and pointing away.) Very roughly, the portion of space that can be illuminated by a module consists of a cone centered on the module's broadside direction, with a total angular spread of about 90 degrees, (that is, +/-45 degrees from the boresight direction) in the plane parallel to the module's short axis. Hence, each module can illuminate a portion of the spherical space around the device.

The codebook defined at design time contains a code-word for each beam in the defined set of beam pairs, which is the list of magnitude and phase weights applied to each antenna group's four feeds to cause the desired beam to be formed. The normalized amplitude weights (normalized to the maximum per-port maximum power for the modulation/transmission mode in operation) can range from 0 to 1, while the phase weights can range from 0 to 360 degrees (i.e., any phase value as needed).

For purposes of assessing worst-case power density, total 60 single beams of two modules were evaluated via simulation tool. The EIRP and peak phase for 60 single beams were measured before simulation and the results were used in the simulation to reflect the actual characteristics of the single beams into the simulation. This is a way to reduce delta between PD simulation and measurement. However, exposure by un-allowed power density should be considered to avoid in any case. Qualcomm smart transmit, which is the transmission control mechanism, the power density can be reduced to meet the compliance assessment.

4.5. Qualcomm Smart Transmit Algorithm

FCC power density limit is defined based on time average RF exposure. Qualcomm Smart Transmit algorithm developed by Qualcomm, when running in a wireless device, will ensure the wireless device is in compliance with FCC limit of power density averaged over a defined time window, at all times. For a given wireless device, power density is proportional to the transmitting power, in other words, once the power density of the wireless device is characterized at a transmit power

level via power density measurement, power density at a different power level for the characterized configuration(s) can be scaled by the change in the corresponding power level. Therefore, for a characterized device, power density compliance can be achieved through transmit power control and management.

5. Simulation and Measurement Approach for MPE

5.1. General Approach

The concept of beamforming adds an additional dimension to the test matrix, effectively increasing the number of the exposure test cases to be checked, by a factor equal to the number of beams that the device can form. This makes it impractical to measure every beam in every measurement plane. Because the mm-wave power density measurement is time-consuming per beam and measurement plane, it is necessary to identify a-priori the worst-case beams for each measurement condition (plane) via simulation, so that these beams can then be measured to characterize the worst-case power density of the device.

5.2. Finding Worst-case Near-Field Results

The simulation results are considered across both domain of beam configuration and physical location. At each x-y-z location on each of reduced measurement planes, the simulated PD for each full-power beam from each of the four modules is assessed. As described previously, this means that the worst beam from each module is found in the measurement planes around the device, for every S1/S2/S3/S4/S5 position in figure 5.2. The worst case of all of these PD results in a measurement plane is then identified, and that module and beam configuration is selected for the measurement of PD on the measurement plane in question. This process thus constitutes an exhaustive direct search across both location and beam configuration domains.

<Figure 5.2 Device surface definition: reference QMC doc.(SAR Char and PD Char Generation) >
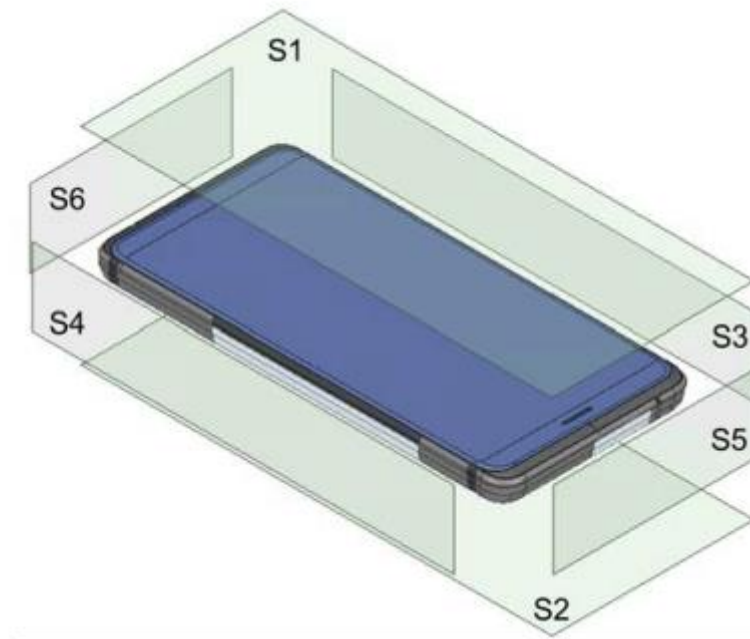
5.3. Simulation Tool

5.3.1. Tool Description

For the mm-wave power density simulations, LG used the tool is developed only for internal use to be optimized for LG development system. The principle of the tool is totally same with any commercial EM simulation tool based on Finite Element Method (FEM), which operate in the frequency domain.

Antenna array simulation method: each port of the array is switched on one by one during the simulation process, while all other ports act as 50 Ohm loads. This allows calculation of any near- or far- field quantity from the array as a superposition of fields calculated from all ports independently with respect to each port's power and phase offset.   To ensure high simulation accuracy, Finite Element mesh is refined near the antenna and feeding elements.   After the simulation is finished, any Near Field (E-field, Power) or Far Field (Radiation Pattern) can be calculated from the given magnitudes and phases on ports (2 ports per each antenna element in an array to analyze V and H polarization).

5.3.2. Solver Description

The Solver employs the Finite Element Method, which operates in the frequency domain.

5.3.3. Convergence criteria and power density calculations

The Tool uses a volume air box containing the simulated area to calculate the EM fields. The box is truncated by an Absorbing Boundary Condition.   Generally, important area such as antenna itself does mesh very finely.   An example of a fully refined mesh through one cross-section of the device is shown in the Figure 5.1 in the Appendix in the Main Operational description.

* Figure 5.1 Tool Mesh in a model of the device

5.4. Description of 3D models used

The simulation modeling includes most of the entire structure of device itself such as PCB, metal frame, battery, cables, and legacy antennas as well as mmWave antenna modules.

For product External design, please refer to the Figure 5.3 in the Appendix in Main Operational description.

* Figure 5.3 External design of the device

5.5 Transmitter model implementation and verification

5.5.1 Description of the essential features that must be modeled correctly for the particular test device model to be valid

Most of the entire structure of device itself such as PCB, metal frame, battery, cables, and legacy antennas as well as mmWave antenna modules.

For product Internal design, please refer to the Figure 5.4 in the Appendix in Main Operational description.

* Figure 5.4 Internal design of the device

5.5.2 Descriptions and illustrations showing the correspondence between the modeled test device and the actual device, with respect to shape, size, dimensions and near-field radiating characteristics

For product External design and antenna information, please refer to the Figure 5.5 in the Appendix in Main Operational description.

* Figure 5.5 External design and Antenna information

5.5.3 Verify that the test device model is equivalent to the actual device for predicting the power density distributions

Please refer to 6. Comparison of simulated and measurement results

5.5.4 Verify the power density distribution for high, middle and low channels

Please refer to the 6. Comparison of simulated and measurement results

5.6 Test device positioning

5.6.1 a description of the device test positions used

5.6.2 Illustrations showing the separation distances between the test device and measurement system
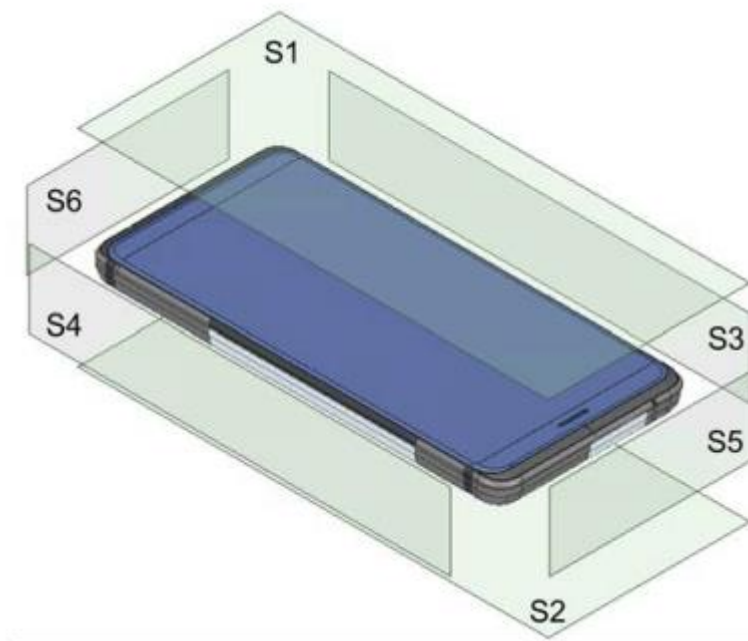
There are 6 surfaces for PD simulation and will be positioned based on distance in setting parameters. After measuring the PD in each PD surfaces, then integrate with 4 cm^2.

5.7 Steady state termination procedures

5.7.1. Description of the criteria and procedures used to determine sinusoidal or equivalent steady state conditions have been reached throughout the computational domain for terminating the computations

Tool doesn't provide this criteria. Instead, tool gives a high density of mesh for module.

To ensure high simulation accuracy, Finite Element mesh is refined near the antenna and feeding elements.

5.7.2. Reporting the number of time steps or sinusoidal cycles executed to reach steady state

Tool doesn't provide this criteria. Instead, tool gives a high density of mesh for module.

To ensure high simulation accuracy, Finite Element mesh is refined near the antenna and feeding elements.

5.7.3. Description of the expected error margin provided by the termination procedures

Tool doesn't provide this criteria. Instead, tool gives a high density of mesh for module.

To ensure high simulation accuracy, Finite Element mesh is refined near the antenna and feeding

elements.

5.8 Computing average power density

5.8.1 Description of the procedures used to compute power density

 Simulate EM, then do post processing (extract of Vector data (E / H field), PD calculation)

 Please refer to 5.9 power density in 4 cm^2 averaging area

5.8.2 Description of the expected error margin provided by algorithms used

  Please refer to 5.9 power density in 4 cm^2 averaging areas

5.9 Power density in 4 cm^2 averaging area

5.9.1. Description of the procedures used to search for the highest power density in **4 cm^2** averaging area among all evaluation planes and amongst all transmitter configurations

5.9.2. Description of the expected error margin provided by algorithms used

- PD calculation algorithm (for 5.9.1 / 5.9.2)
    a. PD post-processing sensors are defined as rectangular planes located at a User-defined distance from the DUT (mobile phone).
    b. For each PD sensor, User defines PD calculation resolution (it was discovered, that resolution of 1mm gives good PD calculation accuracy (further step decreasing does not change the result).
    c. For a given port data set {amplitude, phase} that correspond to a selected beam, PD is calculated as Pointing vector density at the PD sensor plane.
    d. After calculating PD at each point of the sensor plane an additional "peak averaged value" searching algorithm is applied:
    i. User defines the averaging square size (ex., 4 cm^2).
    ii. At each point PD is averaged over the given square area, the averaging square center is located in the point under consideration.
    iii. Peak averaged PD is chosen as a resulting PD value.

iv. If the target averaging square cannot be created around some point (ex., in the corner of the PD sensor plane), the averaging area is transformed into a square (or rectangle if one of the PD sensor dimensions is not enough) by shifting the averaging figure. The area of the transformed averaging figure is equal to the target averaging square (see Fig 1. below).
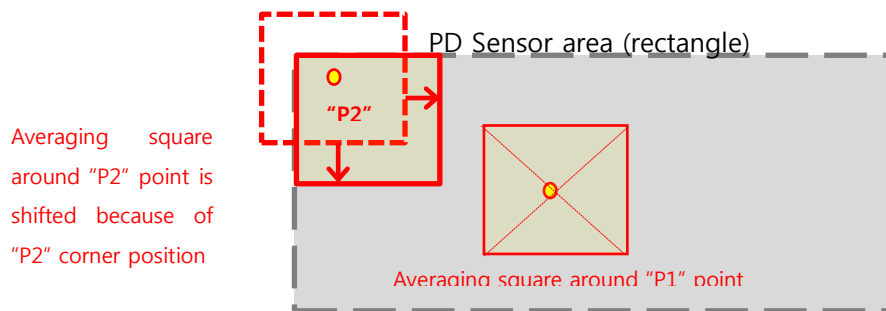

Fig 1. PD averaging algorithm

5.10 Test results for determining worst case or justification for reduced measurement configurations

5.10.1 Illustrations showing the power density distribution of dominant peak locations produced by the test transmitter, with respect to test device

Please refer to the Section 6.

5.10.2 a description of how the maximum device output rating is determined and used

Please refer to the Section 6.

5.10.3 Validation of the transmitter model through relative agreement of simulated results and Measurement in equivalent configurations

Please refer to the Section 6.

6. Comparison of simulated and measurement results

6.1. Simulated PD and EIRP with Target input power

- Target input Power n261 QTM0 8dBm, QTM1 8dBm, n260 QTM0 6.5dBm QTM1 6.5dBm
- The powers per each active port are below for simulation to find worst beam ID for all
  Beam IDs.
- Then the Beam IDs are used to find actual input power to meet PD design target 5W/m2 and
  1<TER during Part1 testing.

QTM		BAND	AG	BEAM ID	Power Density (W/m²) / 0mm				
					Target power[dBm]	Mid			
						Side	Front	Back	Top
QTM0	LEFT	n261 (28GHz)	AG0 (H)	1	8	5.9	2.1	2.4	0.5
QTM0	LEFT	n261 (28GHz)	AG0 (H)	5	8	7.2	2.6	2.7	0.6
QTM0	LEFT	n261 (28GHz)	AG0 (H)	6	8	11.9	5.6	4.8	0.1
QTM0	LEFT	n261 (28GHz)	AG0 (H)	7	8	13.6	4.4	4.9	2.1
QTM0	LEFT	n261 (28GHz)	AG0 (H)	10	8	12.7	5.8	5.3	0.3
QTM0	LEFT	n261 (28GHz)	AG0 (H)	11	8	10.9	4.6	4.0	0.6
QTM0	LEFT	n261 (28GHz)	AG0 (H)	17	8	21.1	7.9	8.4	2.9
QTM0	LEFT	n261 (28GHz)	AG0 (H)	18	8	33.7	15.3	13.0	1.4
QTM0	LEFT	n261 (28GHz)	AG0 (H)	19	8	34.6	16.0	14.1	0.3
QTM0	LEFT	n261 (28GHz)	AG0 (H)	20	8	27.9	9.8	10.8	1.6
QTM0	LEFT	n261 (28GHz)	AG0 (H)	21	8	23.8	7.4	8.3	5.4
QTM0	LEFT	n261 (28GHz)	AG0 (H)	26	8	26.3	12.5	10.3	1.0
QTM0	LEFT	n261 (28GHz)	AG0 (H)	27	8	27.5	12.0	11.4	0.7
QTM0	LEFT	n261 (28GHz)	AG0 (H)	28	8	29.2	12.3	11.3	1.1
QTM0	LEFT	n261 (28GHz)	AG0 (H)	29	8	25.6	7.9	9.2	5.0
QTM0	LEFT	n261 (28GHz)	AG1 (V)	129	8	12.4	4.5	3.7	0.6
QTM0	LEFT	n261 (28GHz)	AG1 (V)	133	8	13.7	5.5	5.0	0.9
QTM0	LEFT	n261 (28GHz)	AG1 (V)	134	8	24.2	10.5	7.8	0.8
QTM0	LEFT	n261 (28GHz)	AG1 (V)	135	8s	16.9	7.5	5.3	0.2
QTM0	LEFT	n261 (28GHz)	AG1 (V)	138	8	25.1	10.8	8.2	1.0
QTM0	LEFT	n261 (28GHz)	AG1 (V)	139	8	17.9	7.9	5.6	0.3
QTM0	LEFT	n261 (28GHz)	AG1 (V)	145	8	27.9	11.7	9.4	2.6
QTM0	LEFT	n261 (28GHz)	AG1 (V)	146	8	42.4	18.7	14.5	0.5
QTM0	LEFT	n261 (28GHz)	AG1 (V)	147	8	46.8	20.3	15.3	1.1

QTM0	LEFT	n261 (28GHz)	AG1 (V)	148	8	40.0	18.3	12.4	0.8
QTM0	LEFT	n261 (28GHz)	AG1 (V)	149	8	30.0	11.9	10.1	0.0
QTM0	LEFT	n261 (28GHz)	AG1 (V)	154	8	40.5	17.4	12.9	1.5
QTM0	LEFT	n261 (28GHz)	AG1 (V)	155	8	51.6	22.7	17.8	0.5
QTM0	LEFT	n261 (28GHz)	AG1 (V)	156	8	40.5	18.2	12.9	0.9
QTM0	LEFT	n261 (28GHz)	AG1 (V)	157	8	33.6	13.4	14.9	1.3
QTM1	RIGHT	n261 (28GHz)	AG0 (H)	0	8	10.8	4.8	4.1	0.5
QTM1	RIGHT	n261 (28GHz)	AG0 (H)	2	8	18.9	7.9	7.3	2.5
QTM1	RIGHT	n261 (28GHz)	AG0 (H)	3	8	19.5	9.1	8.3	1.0
QTM1	RIGHT	n261 (28GHz)	AG0 (H)	4	8	18.4	7.3	5.6	4.4
QTM1	RIGHT	n261 (28GHz)	AG0 (H)	8	8	22.3	10.0	8.7	1.5
QTM1	RIGHT	n261 (28GHz)	AG0 (H)	9	8	21.0	9.1	8.1	1.5
QTM1	RIGHT	n261 (28GHz)	AG0 (H)	12	8	26.3	11.1	11.2	0.8
QTM1	RIGHT	n261 (28GHz)	AG0 (H)	13	8	42.7	19.1	16.8	0.8
QTM1	RIGHT	n261 (28GHz)	AG0 (H)	14	8	43.2	20.3	17.6	0.3
QTM1	RIGHT	n261 (28GHz)	AG0 (H)	15	8	31.2	14.3	12.2	3.4
QTM1	RIGHT	n261 (28GHz)	AG0 (H)	16	8	25.9	9.1	8.8	5.5
QTM1	RIGHT	n261 (28GHz)	AG0 (H)	22	8	35.3	16.2	14.4	0.3
QTM1	RIGHT	n261 (28GHz)	AG0 (H)	23	8	45.4	19.4	17.8	0.7
QTM1	RIGHT	n261 (28GHz)	AG0 (H)	24	8	31.0	14.7	11.9	2.4
QTM1	RIGHT	n261 (28GHz)	AG0 (H)	25	8	26.6	11.7	10.4	3.2
QTM1	RIGHT	n261 (28GHz)	AG1 (V)	128	8	8.5	4.2	2.8	0.3
QTM1	RIGHT	n261 (28GHz)	AG1 (V)	130	8	16.4	7.4	4.9	0.6
QTM1	RIGHT	n261 (28GHz)	AG1 (V)	131	8	25.3	11.6	8.0	0.3
QTM1	RIGHT	n261 (28GHz)	AG1 (V)	132	8	17.6	8.4	5.9	0.4
QTM1	RIGHT	n261 (28GHz)	AG1 (V)	136	8	25.3	11.6	7.7	0.4
QTM1	RIGHT	n261 (28GHz)	AG1 (V)	137	8	16.2	7.6	5.4	0.3
QTM1	RIGHT	n261 (28GHz)	AG1 (V)	140	8	43.8	18.5	13.2	0.6
QTM1	RIGHT	n261 (28GHz)	AG1 (V)	141	8	49.9	22.9	15.3	0.4
QTM1	RIGHT	n261 (28GHz)	AG1 (V)	142	8	47.2	19.4	14.1	0.4
QTM1	RIGHT	n261 (28GHz)	AG1 (V)	143	8	45.8	19.8	13.4	0.6
QTM1	RIGHT	n261 (28GHz)	AG1 (V)	144	8	37.9	15.2	12.2	0.8
QTM1	RIGHT	n261 (28GHz)	AG1 (V)	150	8	46.3	21.1	15.0	1.2
QTM1	RIGHT	n261 (28GHz)	AG1 (V)	151	8	52.9	23.9	16.0	0.3
QTM1	RIGHT	n261 (28GHz)	AG1 (V)	152	8	45.8	19.2	14.1	0.4
QTM1	RIGHT	n261 (28GHz)	AG1 (V)	153	8	43.8	18.5	13.2	0.6
QTM0	LEFT	n260 (39GHz)	AG0 (H)	1	6.5	5.9	2.2	1.7	0.3

QTM0	LEFT	n260 (39GHz)	AG0 (H)	5	6.5	10.0	3.8	3.0	1.1
QTM0	LEFT	n260 (39GHz)	AG0 (H)	6	6.5	17.0	5.9	4.7	1.3
QTM0	LEFT	n260 (39GHz)	AG0 (H)	7	6.5	8.4	3.5	2.8	0.1
QTM0	LEFT	n260 (39GHz)	AG0 (H)	10	6.5	17.0	5.9	4.7	1.3
QTM0	LEFT	n260 (39GHz)	AG0 (H)	11	6.5	7.9	2.5	2.2	0.5
QTM0	LEFT	n260 (39GHz)	AG0 (H)	17	6.5	17.3	5.7	5.2	0.9
QTM0	LEFT	n260 (39GHz)	AG0 (H)	18	6.5	25.6	8.4	6.9	1.0
QTM0	LEFT	n260 (39GHz)	AG0 (H)	19	6.5	15.5	6.1	4.6	0.3
QTM0	LEFT	n260 (39GHz)	AG0 (H)	20	6.5	26.6	8.7	7.0	3.9
QTM0	LEFT	n260 (39GHz)	AG0 (H)	21	6.5	15.4	5.5	4.8	0.6
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QTM0	LEFT	n260 (39GHz)	AG1 (V)	133	6.5	10.6	3.1	2.8	1.1
QTM0	LEFT	n260 (39GHz)	AG1 (V)	134	6.5	7.9	2.4	2.8	0.2
QTM0	LEFT	n260 (39GHz)	AG1 (V)	135	6.5	8.7	2.6	2.5	0.6
QTM0	LEFT	n260 (39GHz)	AG1 (V)	138	6.5	9.0	3.0	3.0	0.6
QTM0	LEFT	n260 (39GHz)	AG1 (V)	139	6.5	10.7	2.9	3.2	0.7
QTM0	LEFT	n260 (39GHz)	AG1 (V)	145	6.5	24.0	5.6	5.6	3.6
QTM0	LEFT	n260 (39GHz)	AG1 (V)	146	6.5	15.7	5.7	4.9	0.4
QTM0	LEFT	n260 (39GHz)	AG1 (V)	147	6.5	14.5	5.1	4.5	0.4
QTM0	LEFT	n260 (39GHz)	AG1 (V)	148	6.5	22.0	6.6	5.8	2.4
QTM0	LEFT	n260 (39GHz)	AG1 (V)	149	6.5	18.0	5.8	4.7	1.7
QTM0	LEFT	n260 (39GHz)	AG1 (V)	154	6.5	16.6	5.9	5.2	0.6
QTM0	LEFT	n260 (39GHz)	AG1 (V)	155	6.5	15.8	5.2	5.8	0.4
QTM0	LEFT	n260 (39GHz)	AG1 (V)	156	6.5	19.4	6.4	6.1	0.8
QTM0	LEFT	n260 (39GHz)	AG1 (V)	157	6.5	24.0	5.7	5.6	3.6
QTM1	RIGHT	n260 (39GHz)	AG0 (H)	0	6.5	5.4	1.9	1.5	0.2
QTM1	RIGHT	n260 (39GHz)	AG0 (H)	2	6.5	10.7	3.8	2.9	0.5
QTM1	RIGHT	n260 (39GHz)	AG0 (H)	3	6.5	10.0	3.8	3.2	0.2
QTM1	RIGHT	n260 (39GHz)	AG0 (H)	4	6.5	14.1	4.2	3.4	0.8
QTM1	RIGHT	n260 (39GHz)	AG0 (H)	8	6.5	11.5	4.1	3.3	0.3
QTM1	RIGHT	n260 (39GHz)	AG0 (H)	9	6.5	10.9	3.2	2.6	0.4
QTM1	RIGHT	n260 (39GHz)	AG0 (H)	12	6.5	29.6	9.7	8.4	1.9
QTM1	RIGHT	n260 (39GHz)	AG0 (H)	13	6.5	17.4	6.4	5.0	0.7

QTM1	RIGHT	n260 (39GHz)	AG0 (H)	14	6.5	18.7	7.1	6.2	0.3
QTM1	RIGHT	n260 (39GHz)	AG0 (H)	15	6.5	21.8	7.2	6.1	1.3
QTM1	RIGHT	n260 (39GHz)	AG0 (H)	16	6.5	29.5	9.2	8.0	1.6
QTM1	RIGHT	n260 (39GHz)	AG0 (H)	22	6.5	24.2	8.3	6.9	1.3
QTM1	RIGHT	n260 (39GHz)	AG0 (H)	23	6.5	17.6	7.1	5.9	0.3
QTM1	RIGHT	n260 (39GHz)	AG0 (H)	24	6.5	18.3	6.5	6.2	0.3
QTM1	RIGHT	n260 (39GHz)	AG0 (H)	25	6.5	27.3	8.8	7.4	1.4
QTM1	RIGHT	n260 (39GHz)	AG1 (V)	128	6.5	5.7	1.8	1.5	0.2
QTM1	RIGHT	n260 (39GHz)	AG1 (V)	130	6.5	8.7	2.3	2.4	0.5
QTM1	RIGHT	n260 (39GHz)	AG1 (V)	131	6.5	8.3	2.7	2.5	0.2
QTM1	RIGHT	n260 (39GHz)	AG1 (V)	132	6.5	9.8	2.5	3.0	0.6
QTM1	RIGHT	n260 (39GHz)	AG1 (V)	136	6.5	10.1	3.3	3.1	0.2
QTM1	RIGHT	n260 (39GHz)	AG1 (V)	137	6.5	9.7	2.6	3.0	0.5
QTM1	RIGHT	n260 (39GHz)	AG1 (V)	140	6.5	22.8	5.1	5.3	1.8
QTM1	RIGHT	n260 (39GHz)	AG1 (V)	141	6.5	18.0	6.6	5.8	0.2
QTM1	RIGHT	n260 (39GHz)	AG1 (V)	142	6.5	14.3	5.0	4.6	0.3
QTM1	RIGHT	n260 (39GHz)	AG1 (V)	143	6.5	23.6	6.6	5.8	1.8
QTM1	RIGHT	n260 (39GHz)	AG1 (V)	144	6.5	19.8	4.6	4.7	1.4
QTM1	RIGHT	n260 (39GHz)	AG1 (V)	150	6.5	15.2	4.9	5.0	0.2
QTM1	RIGHT	n260 (39GHz)	AG1 (V)	151	6.5	18.2	6.2	6.0	0.3
QTM1	RIGHT	n260 (39GHz)	AG1 (V)	152	6.5	19.1	6.7	5.9	0.4
QTM1	RIGHT	n260 (39GHz)	AG1 (V)	153	6.5	21.5	4.9	5.0	1.7

6.2. Comparison table of test configurations, simulated results, measurement results and % difference

- In this section, the simulated power density distributions and measured power density distributions are compared based on worst beam Id and the power to meet TER.

- +0.2dBm for n261 and -0.2dBm for n260, which are used to implement PD target 5W/m^2 and 1<TER, were validated by both PD simulation and PD measurement which are based on the input power.

- Measurement uncertainty in mmWave frequency in measurement side and in accuracy of material properties in mmWave frequency in the simulation side are considered as error factors

Band	Antenna	Beam	Test Position	Beam ID	Target AGC	Measured PD (W/m² over 4 cm²) 2mm distance	Simulated PD (W/m² over 4 cm²) 0mm distance	Difference (%)
n261 (28GHz)	QTM0	H	Left	19	2	2.740	2.869	4.49%
				18	2	2.920	3.094	5.62%
			Front	19	2	1.190	1.293	7.95%
			Back	19	2	1.320	1.120	-17.84%
		V	Left	155	2	3.660	4.656	21.39%
				147	2	3.770	4.304	12.41%
			Front	155	2	1.680	2.100	20.02%
			Back	155	2	1.160	1.609	27.90%
	QTM1	H	Right	23	2	2.420	2.137	-13.22%
				14	2	2.330	2.828	17.61%
			Front	23	2	1.190	1.294	8.05%
			Back	23	2	1.070	0.887	-20.61%
		V	Right	151	2	3.810	3.134	-21.56%
				141	2	3.930	3.108	-26.46%
			Front	151	2	1.700	1.405	-20.98%
			Back	151	2	1.490	0.887	-67.96%
n260 (39GHz)	QTM0	H	Left	20	-2	2.070	1.998	-3.61%
				18	-2	2.070	1.484	-39.48%
			Front	20	-2	0.707	0.628	-12.53%
			Back	20	-2	0.570	0.551	-3.43%
		V	Left	145	-2	2.260	2.929	22.83%
				157	-2	2.350	1.868	-25.81%
			Front	148	-2	0.588	0.453	-29.73%
			Back	156	-2	0.295	0.722	59.14%
	QTM1	H	Right	12	-2	2.630	1.028	-155.93%
				16	-2	2.520	1.058	-138.08%
			Front	12	-2	1.010	0.382	-164.55%
			Back	12	-2	0.731	0.367	-99.23%
		V	Right	143	-2	2.270	1.273	-78.26%
				140	-2	2.350	1.428	-64.61%
			Front	152	-2	0.640	0.631	-1.42%
			Back	151	-2	0.525	0.539	2.61%

• n261 QTM#0: Horizontal, Beam ID: 19, Left	
(a) Measurement(2mm)	(b) Simulation(0mm)
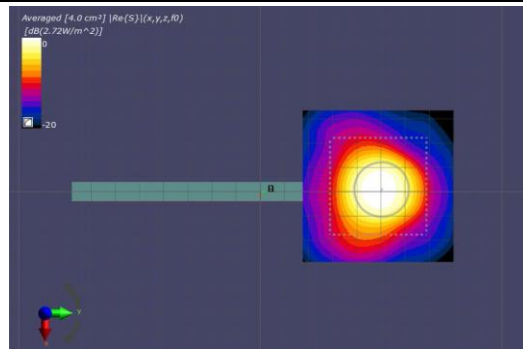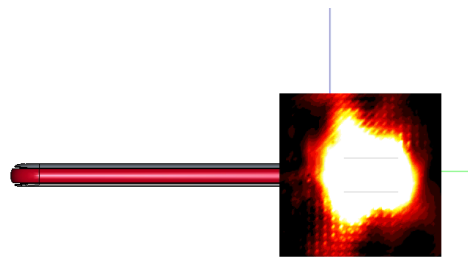
• n261 QTM#0: Horizontal, Beam ID: 18, Left	
(a) Measurement(2mm)	(b) Simulation(0mm)
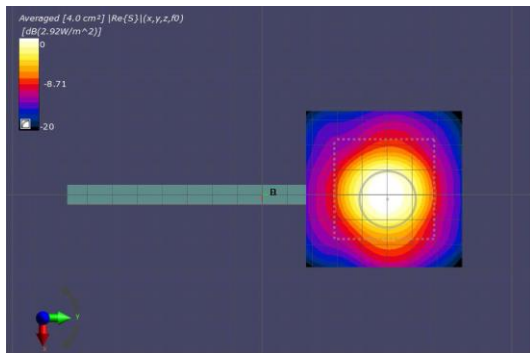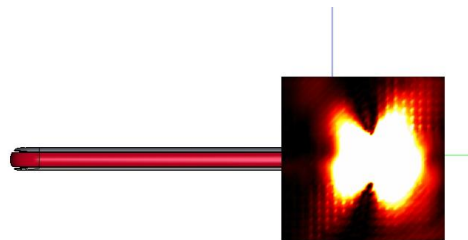
• n261 QTM#0: Horizontal, Beam ID: 19, Front	
(a) Measurement(2mm)	(b) Simulation(0mm)
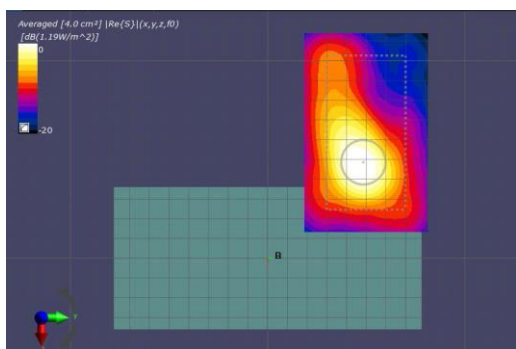
• n261 QTM#0: Horizontal, Beam ID: 19, Back	
(a) Measurement(2mm)	(b) Simulation(0mm)
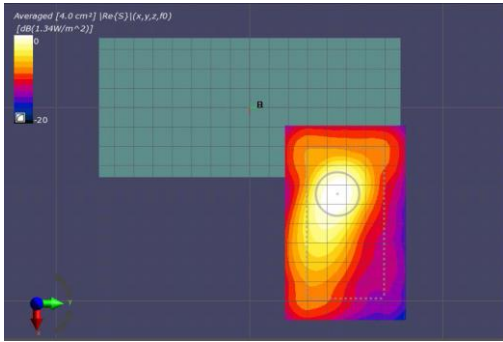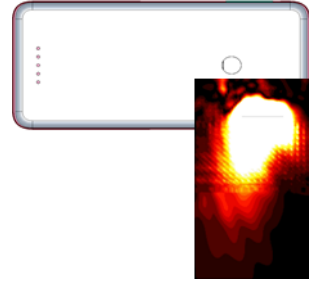
• n261 QTM#0: Vertical, Beam ID: 155, Left	
(a) Measurement(2mm)	(b) Simulation(0mm)
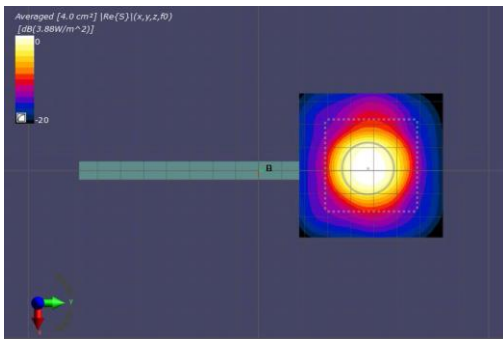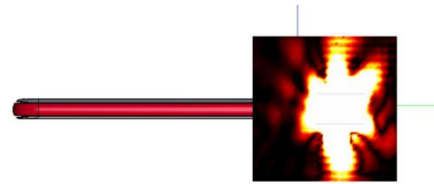
• n261 QTM#0: Vertical, Beam ID: 147, Left	
(a) Measurement(2mm)	(b) Simulation(0mm)

• n261 QTM#0: Vertical, Beam ID: 155, Front	
(a) Measurement(2mm)	(b) Simulation(0mm)

• n261 QTM#0: Vertical, Beam ID: 155, Back	
(a) Measurement(2mm)	(b) Simulation(0mm)

• n261 QTM#1: Horizontal, Beam ID: 23, Right	
(a) Measurement(2mm)	(b) Simulation(0mm)
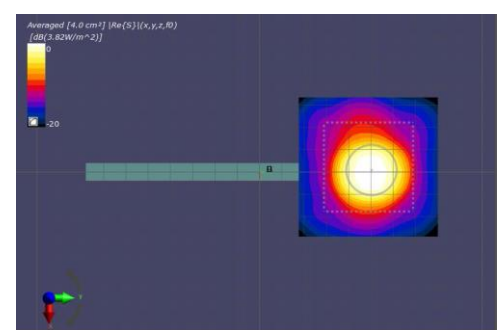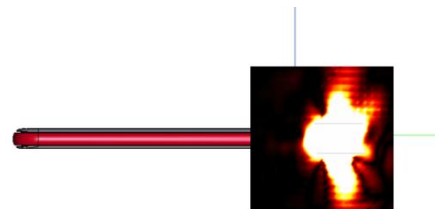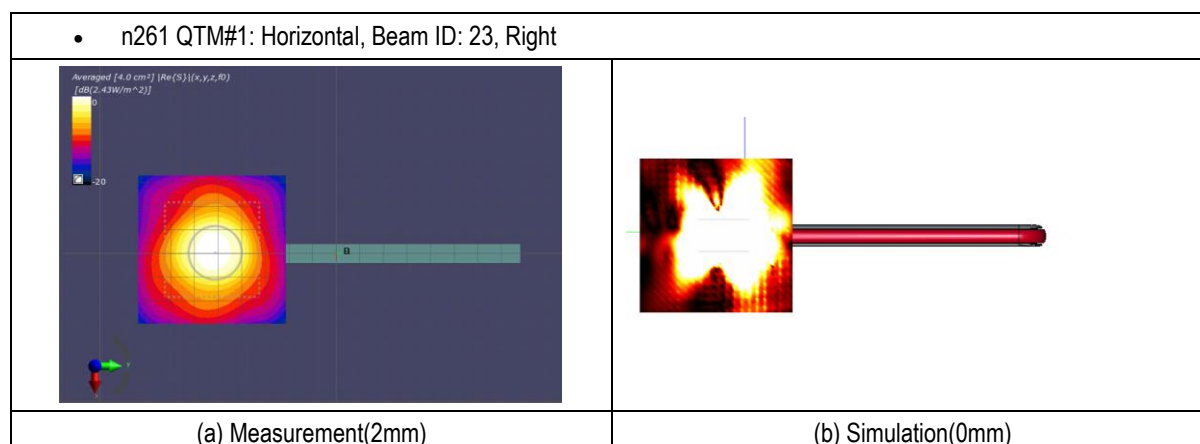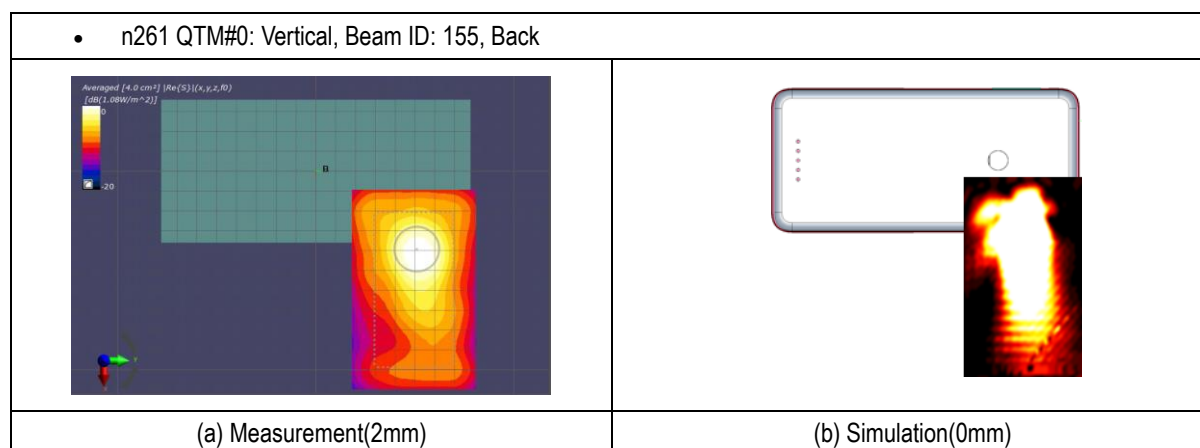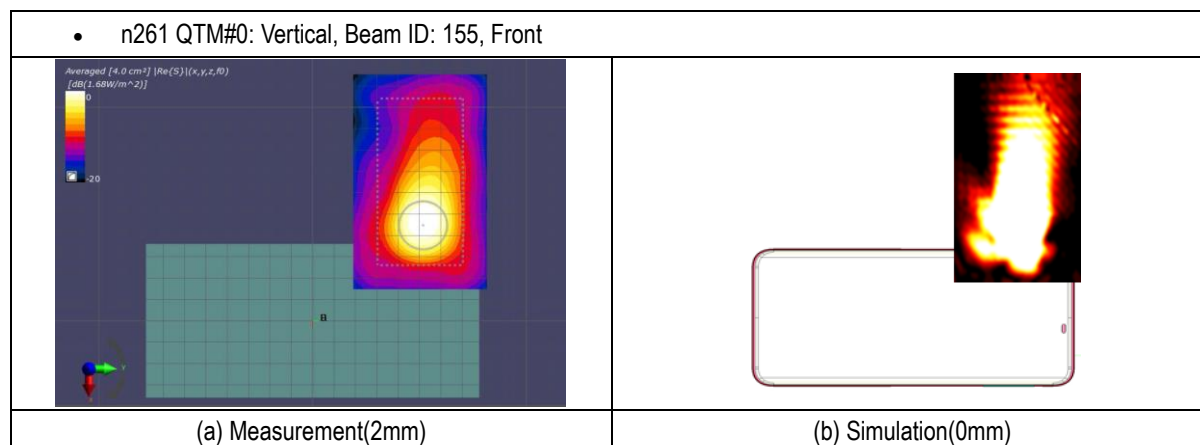
• n261 QTM#1: Horizontal, Beam ID: 14, Right	
(a) Measurement(2mm)	(b) Simulation(0mm)
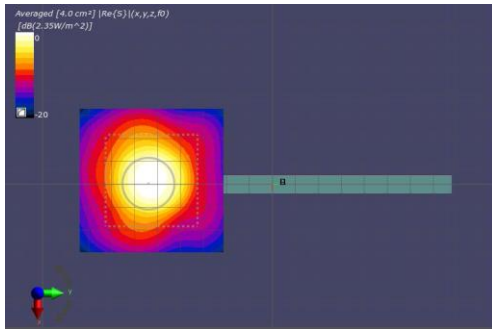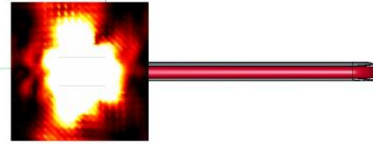
• n261 QTM#1: Horizontal, Beam ID: 23, Front	
(a) Measurement(2mm)	(b) Simulation(0mm)
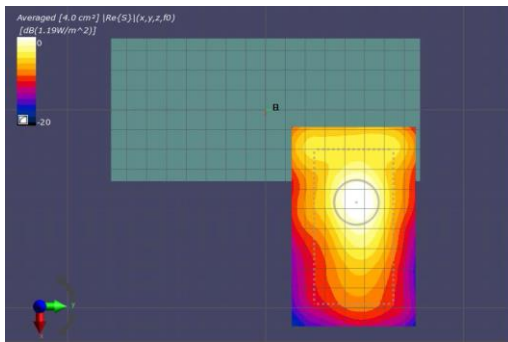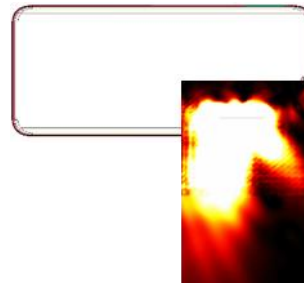
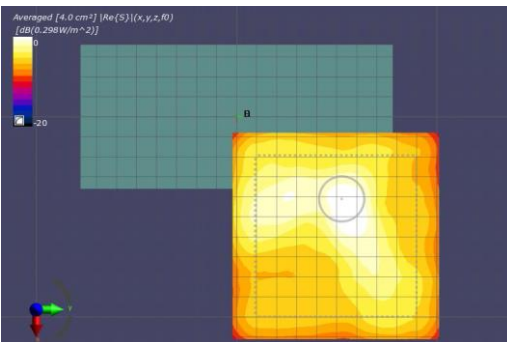| • n261 QTM#1: Horizontal, Beam ID: 23, Back	
(a) Measurement(2mm)	(b) Simulation(0mm)
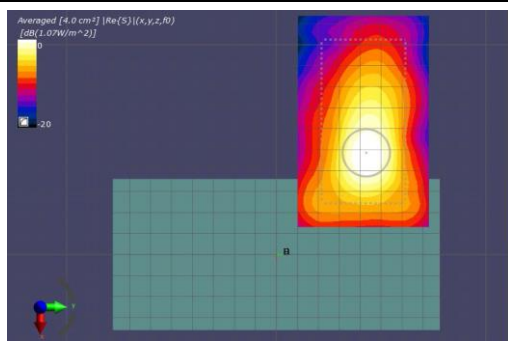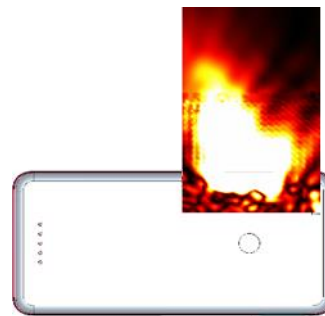
- n261 QTM#1: Vertical, Beam ID: 151, Right
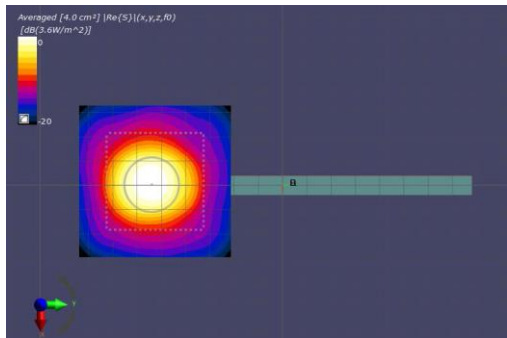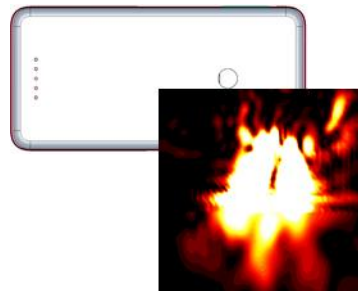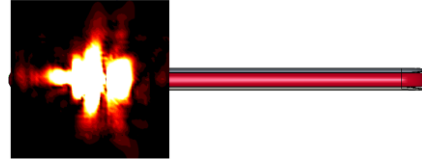

(a) Measurement(2mm)	(b) Simulation(0mm)
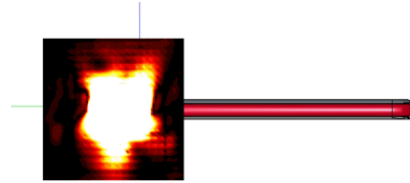
- n261 QTM#1: Vertical, Beam ID: 141, Right
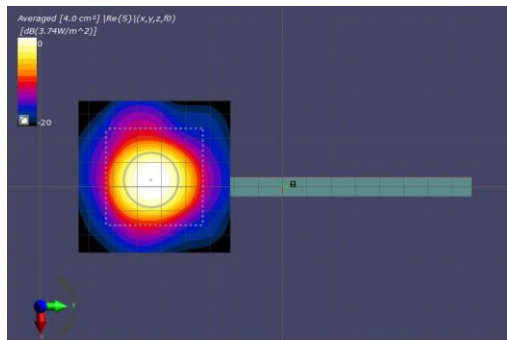
(a) Measurement(2mm)	(b) Simulation(0mm)
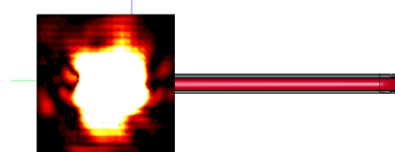
- n261 QTM#1: Vertical, Beam ID: 151, Front
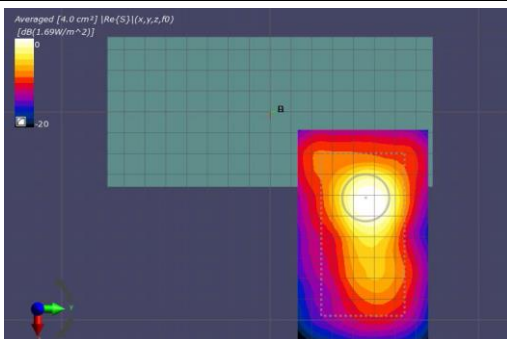
(a) Measurement(2mm)	(b) Simulation(0mm)

- n261 QTM#1: Vertical, Beam ID: 151, Back
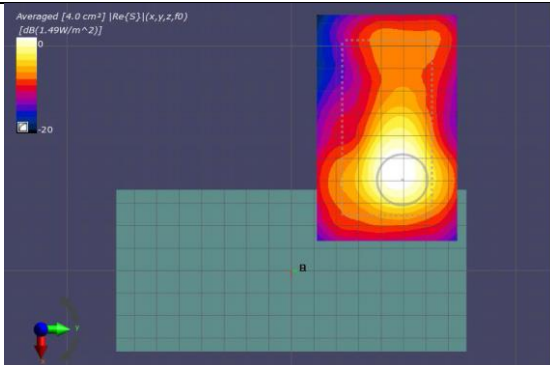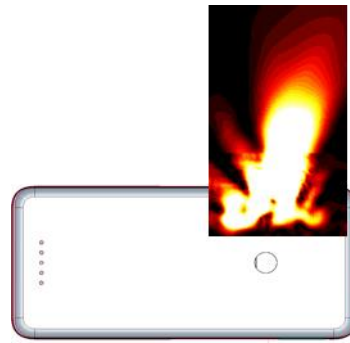
(a) Measurement(2mm)	(b) Simulation(0mm)

- n260 QTM#0: Horizontal, Beam ID: 20, Left
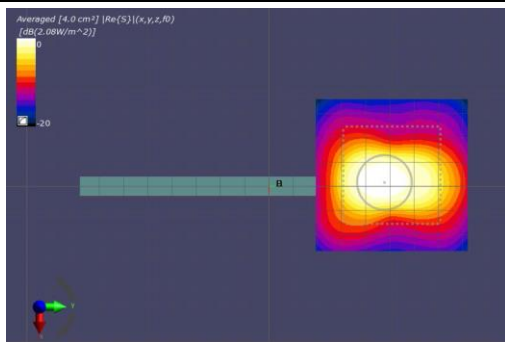
(a) Measurement(2mm)	(b) Simulation(0mm)

- n260 QTM#0: Horizontal, Beam ID: 18, Left
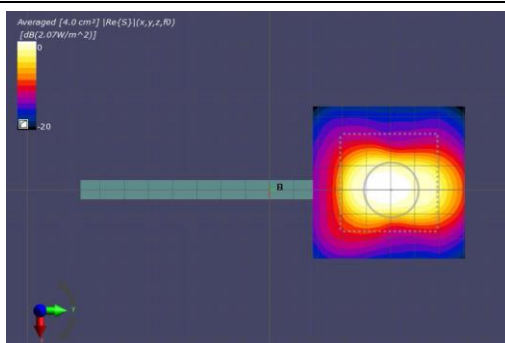
- n260 QTM#0: Horizontal, Beam ID: 20, Front
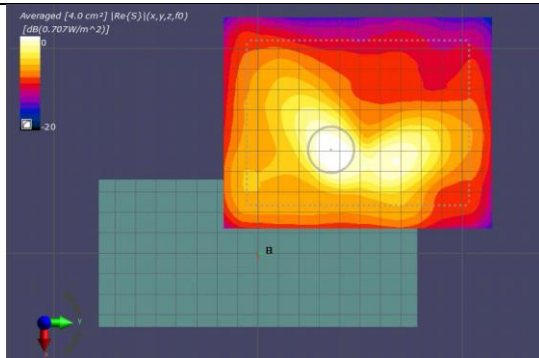
(a) Measurement(2mm)	(b) Simulation(0mm)
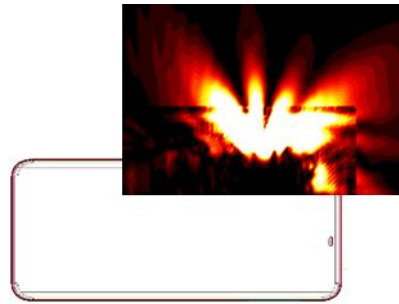
- n260 QTM#0: Horizontal, Beam ID: 20, Back
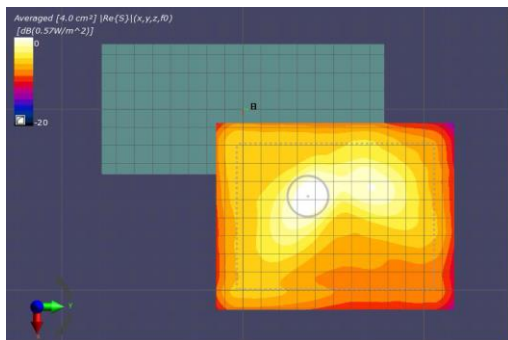
(a) Measurement(2mm)	(b) Simulation(0mm)

- n260 QTM#0: Vertical, Beam ID: 145, Left
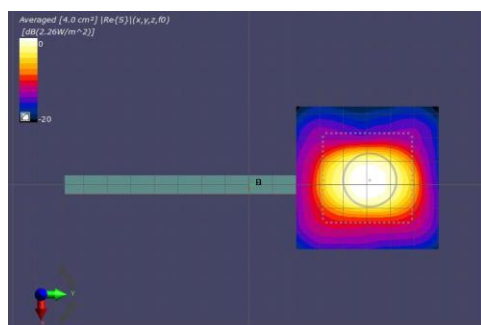
(a) Measurement(2mm)	(b) Simulation(0mm)

• n260 QTM#0: Vertical, Beam ID: 157, Left	
(a) Measurement(2mm)	(b) Simulation(0mm)
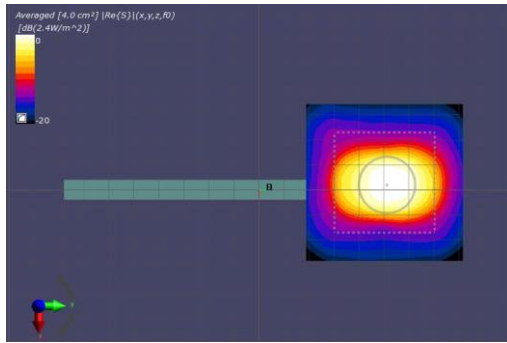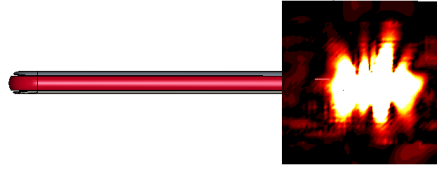
• n260 QTM#0: Vertical, Beam ID: 148, Front	
(a) Measurement(2mm)	(b) Simulation(0mm)
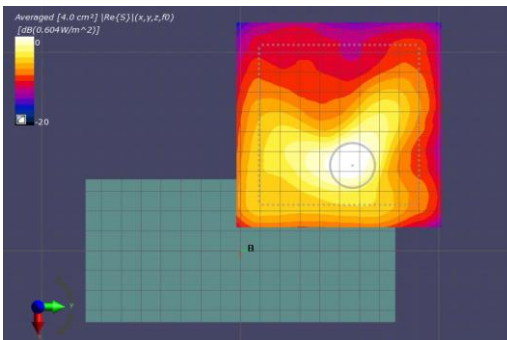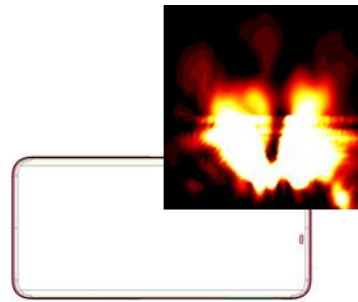
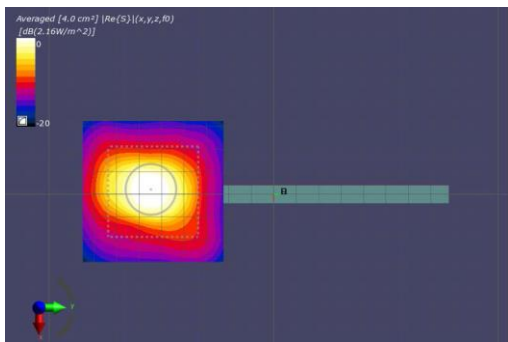| • n260 QTM#0: Vertical, Beam ID: 156, Back	
(a) Measurement(2mm)	(b) Simulation(0mm)

- n260 QTM#1: Horizontal, Beam ID: 12, Right
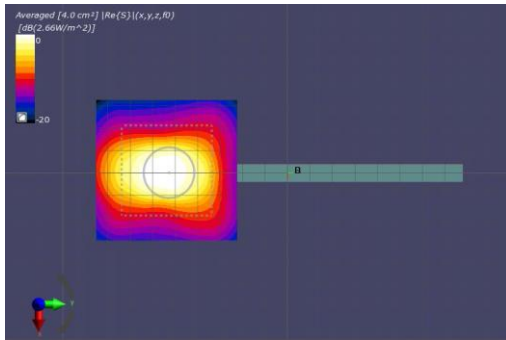
(a) Measurement(2mm)	(b) Simulation(0mm)

- n260 QTM#1: Horizontal, Beam ID: 16, Right
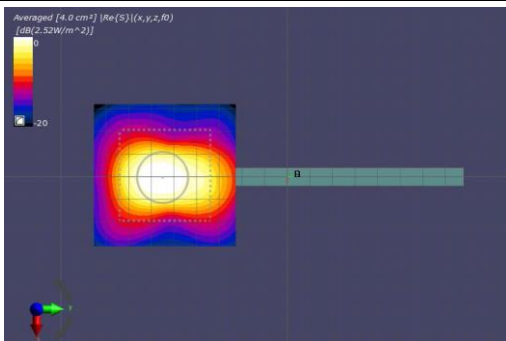
(a) Measurement(2mm)	(b) Simulation(0mm)

- n260 QTM#1: Horizontal, Beam ID: 12, Front
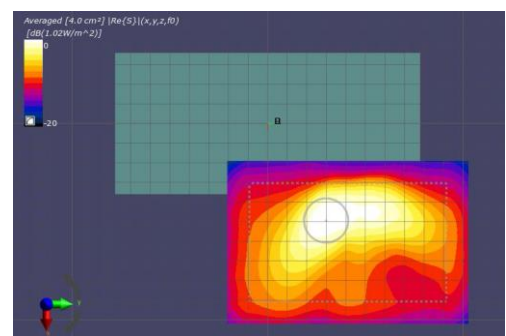
(a) Measurement(2mm)	(b) Simulation(0mm)

• n260 QTM#1: Horizontal, Beam ID: 12, Back	
(a) Measurement(2mm)	(b) Simulation(0mm)
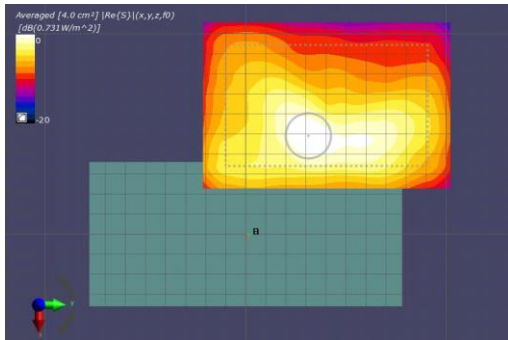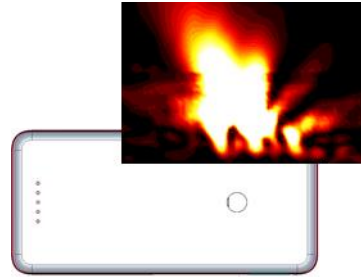
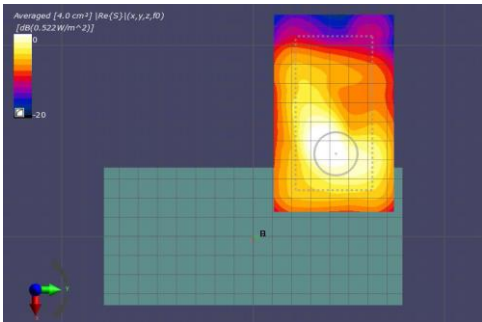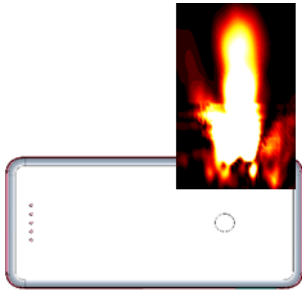| • n260 QTM#1: Vertical, Beam ID: 143, Right	
(a) Measurement(2mm)	(b) Simulation(0mm)
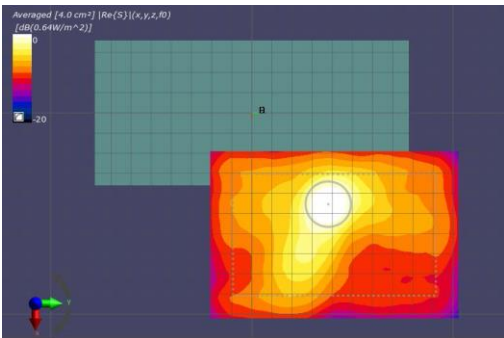
• n260 QTM#1: Vertical, Beam ID: 140, Right	
(a) Measurement(2mm)	(b) Simulation(0mm)
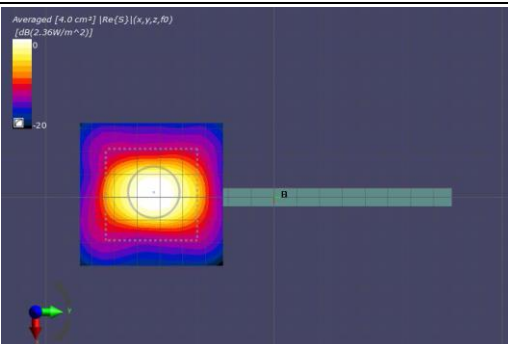
• n260 QTM#1: Vertical, Beam ID: 152, Front	
(a) Measurement(2mm)	(b) Simulation(0mm)

• n260 QTM#1: Vertical, Beam ID: 151, Back	
(a) Measurement(2mm)	(b) Simulation(0mm)

7. Uncertainty

The amplitude level of PD simulation has an error factor due to material property parameter configuration in device at high frequencies. Material property is difficult to model due to complexity of material and operating frequency. Therefore, it is not possible to assign an exact uncertainty for simulation result. However, for this RF exposure evaluation, simulation results were only used to select worst(highest) beam ID measurement. All final power density evaluations were validated with QMC QTM052 uncertainty 2.8dB and uncertainty of simulation 1.1dB approximately.