

FCC ID: A3LSMF971U

Power Density Simulation Report

Revision A

June 15, 2026

SAMSUNG ELECTRONICS

1. Simulation methodology for Power Density (PD)

1.1 Simulation tool

1.1.1 Tool description

For the simulation approach to calculating power density (PD) evaluation for mobile phone with mmWave antenna modules, ANSYS Electromagnetics suite version 2025.R1 (HFSS) is used. ANSYS HFSS is one of several commercial tools for 3D full-wave electromagnetic simulation used for antenna and RF structure design of high frequency component. ANSYS Electromagnetics suite version 2025.R1 (HFSS) is implemented based on Finite Element Method (FEM), which operates in the frequency domain.

1.1.2 Mesh and Convergence criteria

To solve the PD analysis using FEM, volume area containing simulated objects should be subdivided into electrically small parts that are called finite elements as the unknown functions. To subdivide system, the adaptive mesh technique in ANSYS Electromagnetics suite version 2025.R1 (HFSS) is used. ANSYS Electromagnetics suite version 2025.R1 (HFSS) starts to refine the initial mesh based on wavelength and calculate the error to iterative process for adaptive mesh refinement. The determination parameter of the number of iteration in ANSYS Electromagnetics suite version 2025.R1 (HFSS) is defined as convergence criteria, delta S, and the iterative adaptive mesh process repeats until the delta S is met. In ANSYS Electromagnetics suite version 2025.R1 (HFSS), the accuracy of converged results depends on the delta S. Figure 1 is an example of final adaptive mesh of the device (cross-section of top view).

See set-up photo

Figure 1 Example of the adaptive mesh technique (Top view)

1.1.3 Power density calculation

After solving 3D full-wave electromagnetic simulation, various kinds of physical quantities can be obtained. 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:

$$\langle \vec{S} \rangle = \text{Re} \left(\frac{1}{2} \vec{E} \times \vec{H}^* \right)$$

$\langle \vec{S} \rangle$ can be expressed as point power density based on a peak value of each spatial point on mesh grids, and obtained directly from ANSYS Electromagnetics suite version 2020.R1 (HFSS).

From the point power density $\langle \vec{S} \rangle$, the spatial-averaged power density (PD_{av}) on an evaluated area (A) can be derived as shown below:

$$PD_{av} = \frac{1}{A} \int_A \langle \vec{S} \rangle \cdot d\vec{s} = \frac{1}{2A_{av}} \iint_{A_{av}} \| \text{Re}\{E \times H^*\} \| dA$$

, where the spatial-averaged power density (PD_{av}) is total power density value considering on x, y and z components of point power density $\langle \vec{S} \rangle$ and the evaluated area (A) is 4cm^2 .

1.2 Simulation setup

1.2.1 3D modeling

Figure 2 shows the simulation model which is mounted a mmWave antenna modules. 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 a mmWave antenna module called as Ant H. For a folder open status (Fig. 2-1), Ant H is placed on the back side and antennas are facing the back side of the device. For a folder close status (Fig. 2-2), Ant H is placed same of the folder open status.

See set-up photo

Figure 2-1. Simulation model which is mounted a mmWave antenna module (Folder Open Status)

See set-up photo

Figure 2-2. Simulation model which is mounted a mmWave antenna module (Folder Closed Status)

1.2.2 PD evaluation planes

Table 1 shows the PD evaluation planes for each mmWave antenna module and Figure 3 shows the PD evaluation planes and whole area of the simulation model to find worst case of beamforming cases.

Please note that the “right” and “left” edge of mentioned in this report are defined from the perspective of looking at the device from the front side.

Table 1. PD evaluation planes

Module	Front	Back	Left From Front View	Right From Front View	Top	Bottom
	S1	S2	S3	S4	S5	S6
Ant H	O	O	O	O	O	O

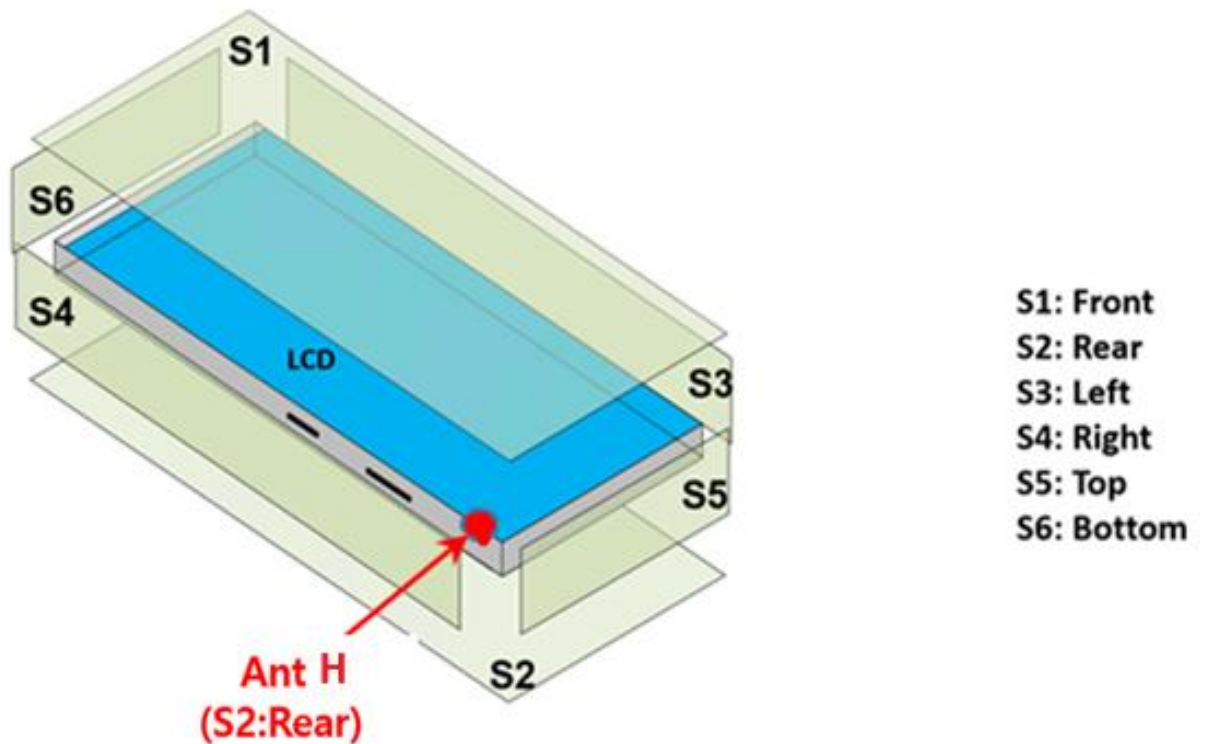


Figure 4. PD evaluation planes

1.2.3 Boundary condition

To simulate electromagnetic tool based on FEM, the boundary condition allows electromagnetic waves to be electrically open at the boundary and radiated far away without reflection. ANSYS Electromagnetics suite version 2025.R1 (HFSS) can support the absorbing boundary condition (ABC) for radiation boundary and make normally a quarter wave length from the radiating structure. In this report, to cover all beamforming cases of mmWave antenna module, 40 mm spacing from each surfaces of the device were adopted. This distance is sufficiently large enough for “Qualcomm IPLG Script” to extract valid E-fields and H-fields from all adjacent exposure surfaces of the EUT.

1.2.4 Source excitation condition

The number of antenna ports of ANT H for source excitation are the same. The antenna port of ANT H is divided into 10 ports for n261 1 x 5 patch array antennas, 10 ports for n260 1 x 5 patch array antennas. In the 10 ports included in each patch antenna, 5 ports are divided into vertical polarization feeding, and the other 5 ports are divided into horizontal polarization feeding.

After finishing 3D full wave electromagnetic simulation of modeling structure, the magnitude and phase information can be loaded for each port by using “Edit Sources” function in ANSYS Electromagnetics suite (HFSS). Figure 5 shows an example of antenna port excitations.

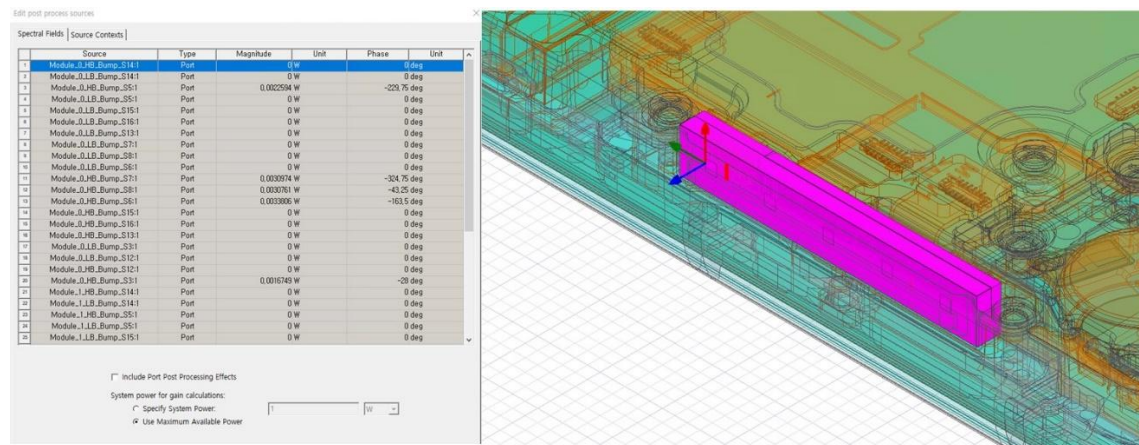


Figure 4. An example of port excitation (ANT H)

Since ANSYS Electromagnetics suite (HFSS) uses FEM solver based on frequency domain analysis method, the input source for the port excitation applies sinusoidal waveform for each frequency.

1.2.5 Condition of simulation completion

The simulation completion condition of ANSYS Electromagnetics suite (HFSS) is defined as delta S. The ANSYS Electromagnetics suite (HFSS) calculates the S-parameter for the mesh conditions of each step and determines whether to proceed with the operation of the next step by comparing the difference between the S-parameters in the previous step. A difference between the previous step and the current step of S-parameter is expressed as delta S, and the delta S generally sets 0.02. The simulation result of this report is the result of setting delta S to 0.02.

2. Simulation verification

2.1 Spatial-averaged power density

As mentioned in the previous chapter, the Poynting vector ($\vec{S}$) can be obtained through cross product of an electric field ($\vec{E}$) and complex conjugate of a magnetic field ($\vec{H}$). The real term of the Poynting vector can be described as the point power density or peak power density. Using the point power density, the spatial-averaged power density can be obtained by the integral of 4 cm^2 at 2.5 mm intervals of the point power density result. Figure 6 shows examples of the distribution plot of point power density and the averaged power density.

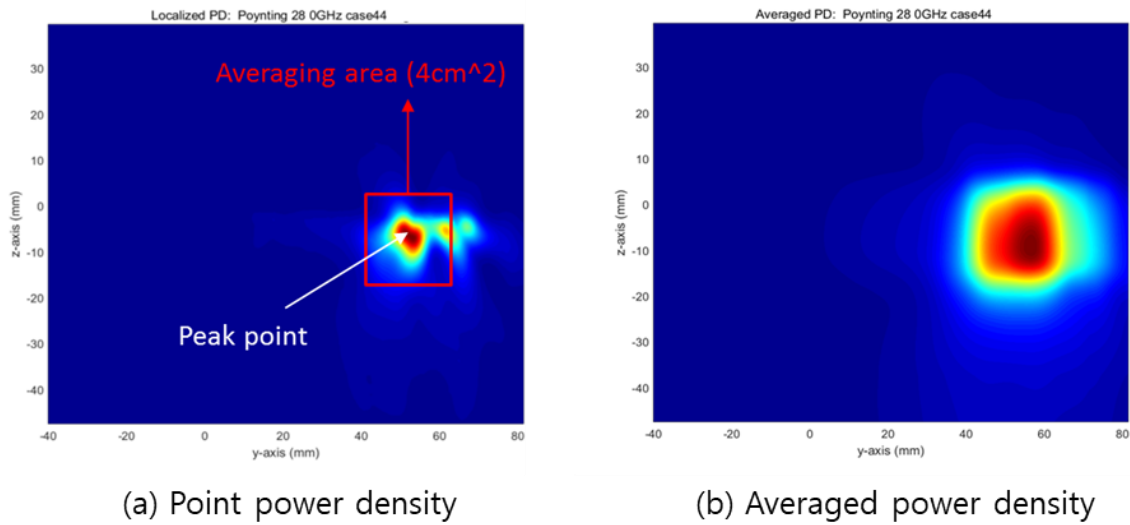


Figure 5. Power density distribution (Example)

For the Smart transmit GEN1, the “Qualcomm IPLG script” were used to extract E-fields and H-fields from the validated simulation and to assess the mutual coupling between all the mmWave antenna modules and all the beams in the codebook to determine the backoff value for each mmWave module. Note the assessment and backoff value derivation are automated with “Qualcomm IPLG 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 `PD_design_target`. This mode take the minimum `sim.power.limit` out of all three channels (low, mid and high) of each band and use the resulted `sim.power.limit..`

2.2 Comparison between simulation and measurement

In this section, the simulated-power density distributions and measured-power density distributions are compared to each mmWave antenna. Furthermore, to verify the Smart transmit GEN1, the PD distributions printing out from the “Qualcomm IPLG script” are added.

Based on comparison of power density distributions, simulated power density and measured power density have a good correlation. The discrepancy in amplitude between simulated 4cm² averaged power density and measured 4cm² averaged power density is considered as housing influence and used in determining input power limit for each beam for RF exposure compliance.

The input powers per each active port are listed below for both Simulation and Measurement validation and power density characterization. For Simulation, these values were entered directly into HFSS model. For measurement, FTM S/W was used to input these values for each active port also.

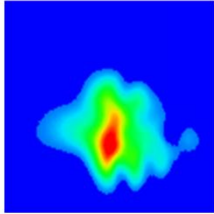
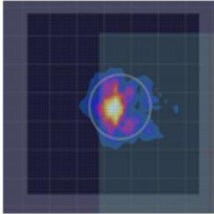
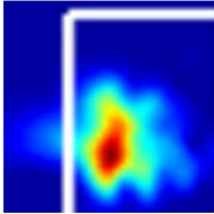
Mode/Band	Antenna	Input Power (dBm) SISO	Input Power (dBm) MIMO
5G NR n261	H Patch	6.0	6.0
5G NR n260	H Patch	6.0	6.0
5G NR n258	H Patch	6.0	6.0

* The below simulation and measurement result were performed at 2mm evaluation distance and 28GHz / 38.5GHz. The *input.power.limit* was determined based on below results in RF Exposure Part 0 Report.

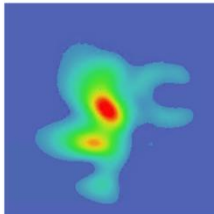
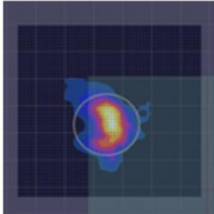
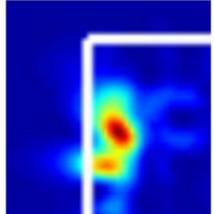
conditon	Band	Channel	Module	Type(P or D)	Side	Beam ID	PLS (10 dBm)	Sim. PD (mW/cm2)	Meas. PD (mW/cm2) * Circle Avg
Folder Closed	n261	Mid Ch. 2077915 (27924.96 MHz)	H	Patch	Rear	14	60	1.54	1.04
						276		1.43	1.38
	n260	Mid Ch. 2254165 (38499.96 MHz)	H	Patch	Right	15	60	0.75	0.539
						275		0.68	0.226
					Rear	18		1.23	0.908
						274		1.15	0.886
	n258	Mid Ch. 2025833 (24800.04 MHz)	H	Patch	Right	13	60	0.69	0.462
					Rear	18		1.19	0.688
						271		1.84	1.47
conditon	Band	Channel	Module	Type(P or D)	Side	Beam ID	PLS (10 dBm)	Sim. PD (mW/cm2)	Meas. PD (mW/cm2) * Circle Avg
Folder Open	n261	Mid Ch. 2077915 (27924.96 MHz)	H	Patch	Rear	14	60	1.63	1.06
						276		1.54	1.39
	n260	Mid Ch. 2254165 (38499.96 MHz)	H	Patch	Right	17	60	0.85	0.360
						272		0.72	0.212
					Rear	18		1.69	0.882
						269		1.35	0.711
	n258	Mid Ch. 2025833 (24800.04 MHz)	H	Patch	Right	13	60	0.69	0.479
					Rear	12		1.26	0.516
						276		1.84	1.12

[Folder Closed Status]

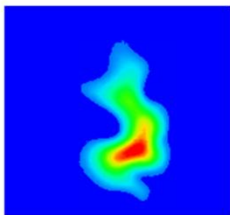
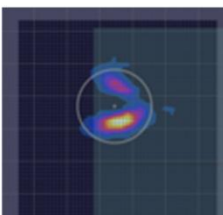
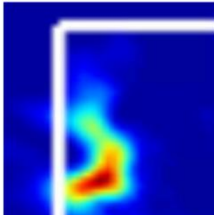
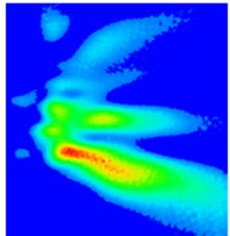
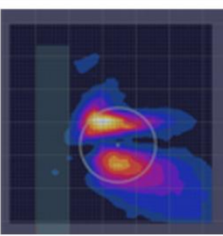
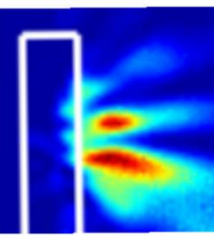
- Table 2-1, n261 ANT H-Patch

Beam ID	Surface	View	Simulated PD	Measured PD	Print out from Qualcomm IPLG Script
14	S2 (Rear)	See set-up photo			

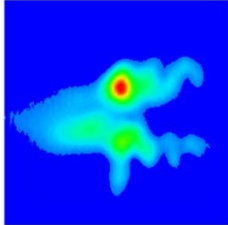
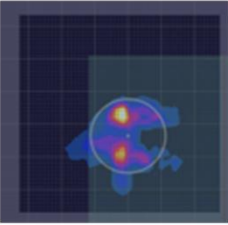
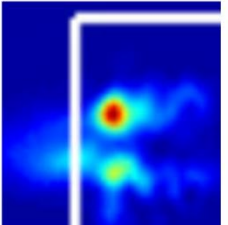
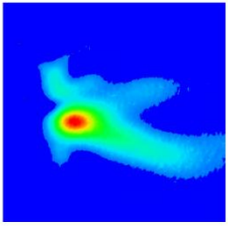
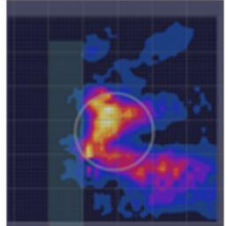
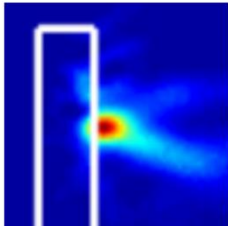
- Table 2-2, n261 ANT H-Patch

Beam ID	Surface	View	Simulated PD	Measured PD	Print out from Qualcomm IPLG Script
276	S2 (Rear)	See set-up photo			

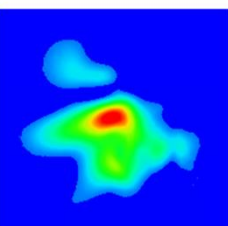
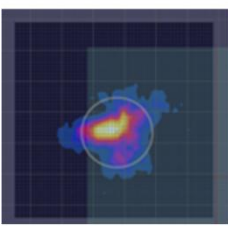
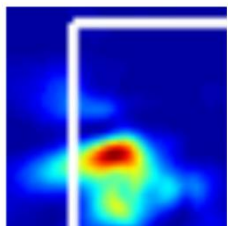
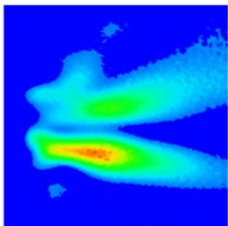
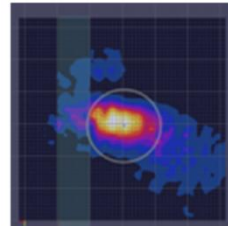
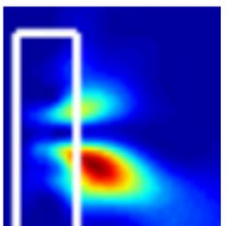
- Table 2-3, n260 ANT H-Patch

Beam ID	Surface	View	Simulated PD	Measured PD	Print out from Qualcomm IPLG Script
18	S2 (Rear)	See set-up photo			
15	S4 (Right)	See set-up photo			

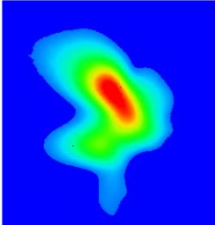
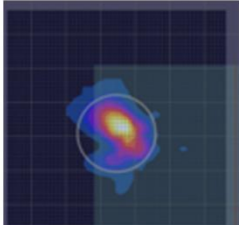
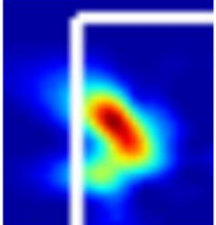
- Table 2-4, n260 ANT H-Patch

Beam ID	Surface	View	Simulated PD	Measured PD	Print out from Qualcomm IPLG Script
274	S2 (Rear)	See set-up photo			
275	S4 (Right)	See set-up photo			

- Table 2-5, n258 ANT H-Patch

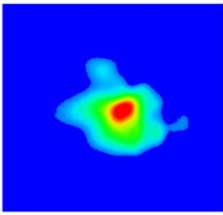
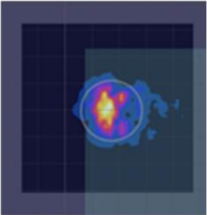
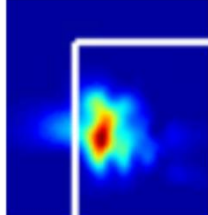
Beam ID	Surface	View	Simulated PD	Measured PD	Print out from Qualcomm IPLG Script
18	S2 (Rear)	See set-up photo			
13	S4 (Right)	See set-up photo			

- Table 2-6, n258 ANT H-Patch

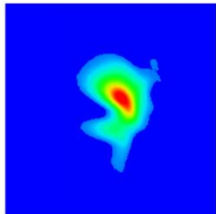
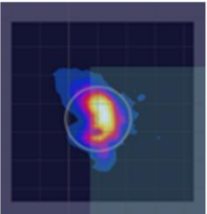
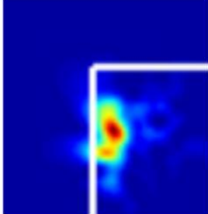
Beam ID	Surface	View	Simulated PD	Measured PD	Print out from Qualcomm IPLG Script
271	S2 (Rear)	See set-up photo			

[Folder Opened Status]

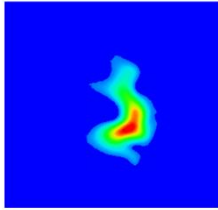
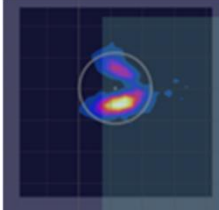
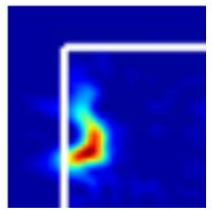
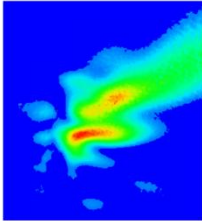
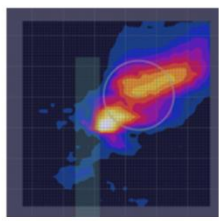
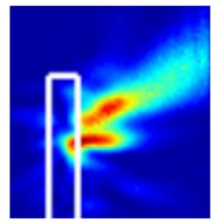
- Table 2-7, n261 ANT H-Patch

Beam ID	Surface	View	Simulated PD	Measured PD	Print out from Qualcomm IPLG Script
14	S2 (Rear)	See set-up photo			

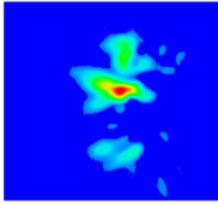
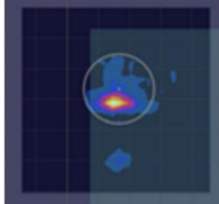
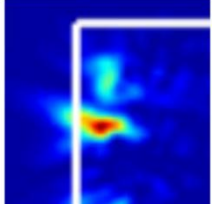
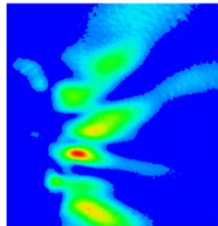
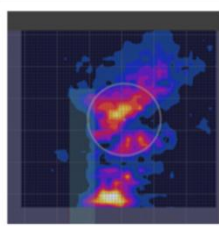
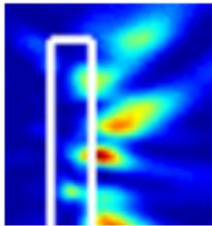
- Table 2-8, n261 ANT H-Patch

Beam ID	Surface	View	Simulated PD	Measured PD	Print out from Qualcomm IPLG Script
276	S2 (Rear)	See set-up photo			

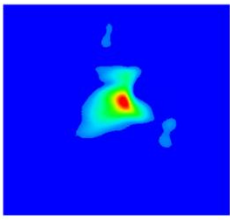
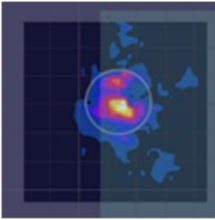
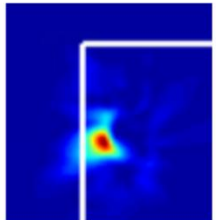
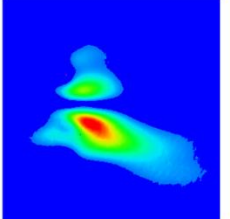
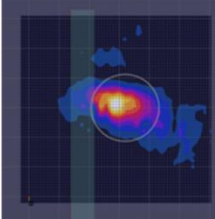
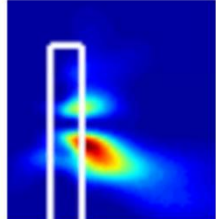
- Table 2-9, n260 ANT H-Patch

Beam ID	Surface	View	Simulated PD	Measured PD	Print out from Qualcomm IPLG Script
18	S2 (Rear)	See set-up photo			
17	S4 (Right)	See set-up photo			

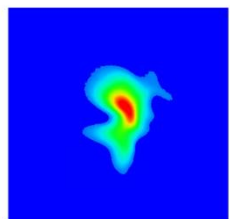
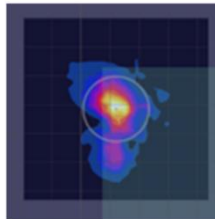
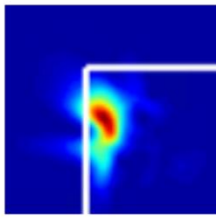
- Table 2-10, n260 ANT H-Patch

Beam ID	Surface	View	Simulated PD	Measured PD	Print out from Qualcomm IPLG Script
269	S2 (Rear)	See set-up photo			
272	S4 (Right)	See set-up photo			

● Table 2-11, n258 ANT H-Patch

Beam ID	Surface	View	Simulated PD	Measured PD	Print out from Qualcomm IPLG Script
12	S2 (Rear)	See set-up photo			
13	S4 (Right)	See set-up photo			

● Table 2-12, n258 ANT H-Patch

Beam ID	Surface	View	Simulated PD	Measured PD	Print out from Qualcomm IPLG Script
276	S2 (Rear)	See set-up photo			

The Smart transmit GEN1 cannot be finalized until the additional verifications are performed and passed. Follow the below steps for verifications in the mid channel:

VERIFICATION 1 : Use “Qualcomm IPLG script” to print the PD plots for all the beams selected and evaluated for model validation.

- Throughout above comparisons (Table 2-1 to 2-12), the model validation including IPLG script were verified.

This model take “GEN2_SUB6” mode, thus, only verification 1 is required.

3 Simulation results

This section shows the PD simulation results of Ant H at 24GHz, 28GHz and 39GHz for each evaluation plane specified in Table 3 at two separation distances of 2mm and 10mm for open condition and for closed conditions. The ratio of PD exposure from front surface to the worst surface at 2mm, and the ratio of PD exposure from 2mm to 10mm (open and closed) evaluation distance for each beam are also reported in this section to support RF exposure

The relative phase between beam pairs is not controlled in the chipset design. Therefore, the relative phase between each beam pair was considered mathematically to identify the worst case conditions. The below MIMO results represent the highest reported MIMO simulation results after sweeping across the relative phase between beams a 5° step interval from 0° to 360° ,

- Table 3-1, PD of Ant H – patch antenna (24GHz – n258)

- Low CH

- Mid CH

[illegible]

- High CH

[Folder Closed Status]

- Low CH

- Mid CH

- High CH

- Mid CH

- High CH

[Folder Closed Status]

- Low CH

- Mid CH

- High CH

[illegible]