

SAMSUNG

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Part 0 Power Density Report

Power Density Characterization

Revision A

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SAMSUNG ELECTRONICS

Power Density Characterization

1. Exposure Scenarios

At frequencies > 6 GHz, the total peak spatial averaged power density (psPD) is required to be assessed for all antenna configurations (beams) from all mmW antenna module installed inside the device. This device has a patch antenna arrays (Ant L Patch).

As shown in Figure1, the surfaces near-by each mmW antenna module for PD characterization are identified and listed in Table 1.

Table 1. Evaluation Surfaces for PD Characterization

Band/Mode	Antenna Module	Back	Front	Top	Bottom	Right	Left
NR n258	L	Yes	No	No	No	No	No
NR n261	L	Yes	No	No	No	No	Yes
NR n260	L	Yes	No	No	No	No	Yes

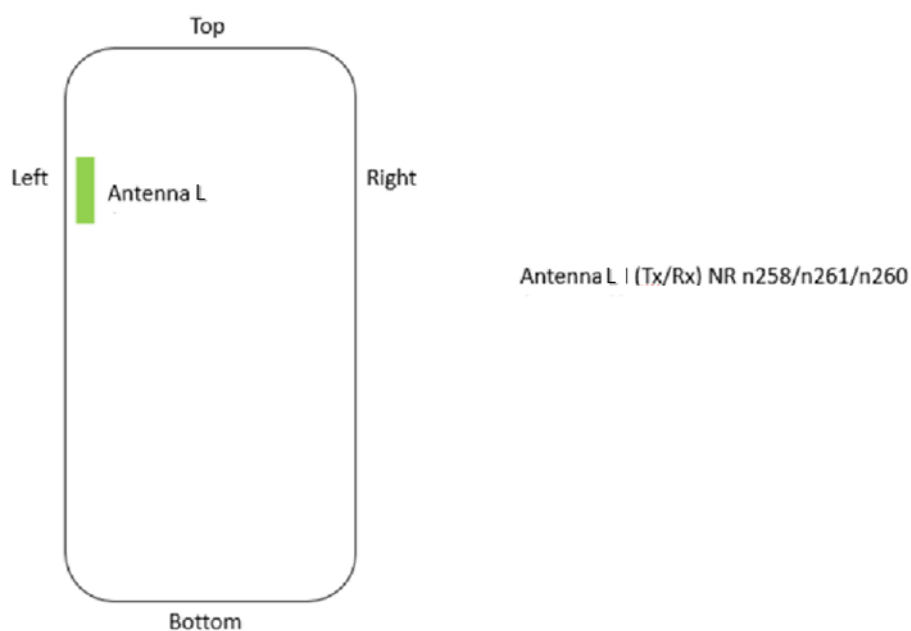
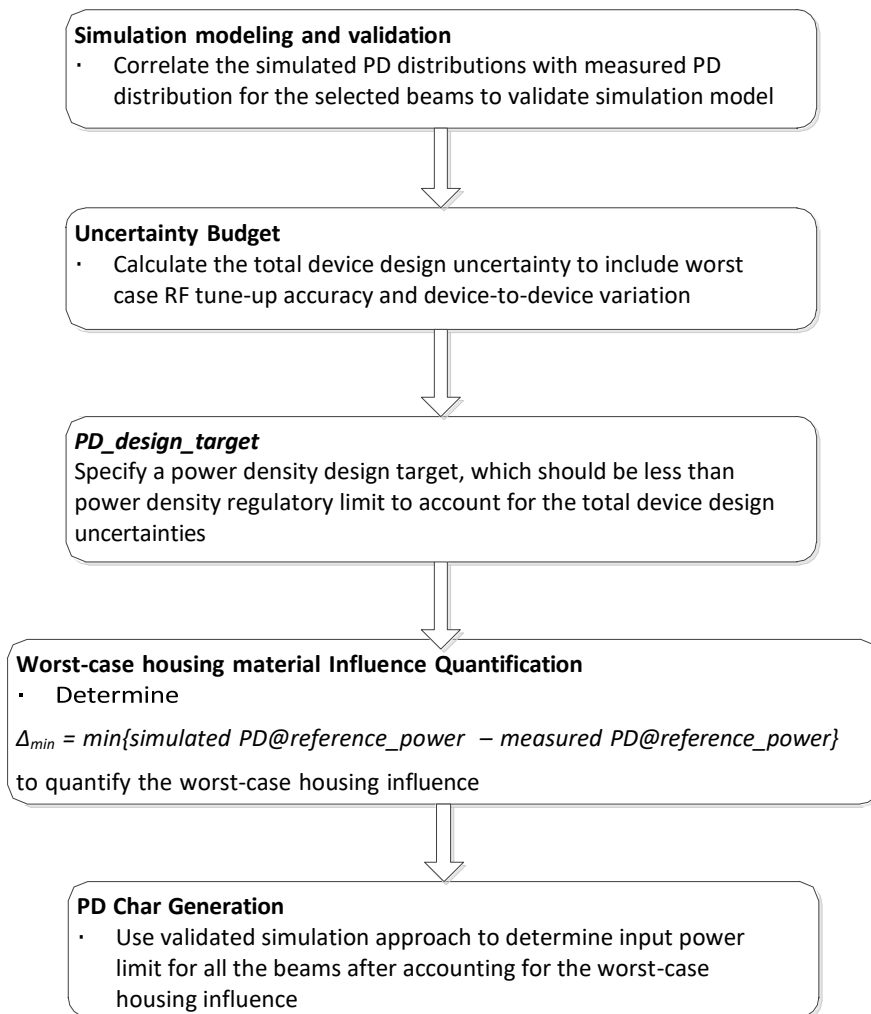


Figure 1: Location of mmW antenna modules looking from Front of the DUT

2. Power Density Characterization Method



3. Codebook for all supported beams

Table 2. 5G mmW NR Band n258 Antenna L Codebook

Band	Antenna Module	Antenna Type	Beam ID	Feed No.	Paired With
n258	L	Patch	0	1	256
n258	L	Patch	1	1	257
n258	L	Patch	2	1	258
n258	L	Patch	3	1	259
n258	L	Patch	4	1	260
n258	L	Patch	5	2	261
n258	L	Patch	6	2	262
n258	L	Patch	7	2	263
n258	L	Patch	8	2	264
n258	L	Patch	9	2	265
n258	L	Patch	10	2	266
n258	L	Patch	11	2	267
n258	L	Patch	12	5	268
n258	L	Patch	13	5	269
n258	L	Patch	14	5	270
n258	L	Patch	15	5	271
n258	L	Patch	16	5	272
n258	L	Patch	17	5	273
n258	L	Patch	18	5	274
n258	L	Patch	19	5	275
n258	L	Patch	20	5	276
n258	L	Patch	256	1	0
n258	L	Patch	257	1	1
n258	L	Patch	258	1	2
n258	L	Patch	259	1	3
n258	L	Patch	260	1	4
n258	L	Patch	261	2	5
n258	L	Patch	262	2	6
n258	L	Patch	263	2	7
n258	L	Patch	264	2	8
n258	L	Patch	265	2	9
n258	L	Patch	266	2	10
n258	L	Patch	267	2	11
n258	L	Patch	268	5	12
n258	L	Patch	269	5	13
n258	L	Patch	270	5	14
n258	L	Patch	271	5	15
n258	L	Patch	272	5	16
n258	L	Patch	273	5	17
n258	L	Patch	274	5	18
n258	L	Patch	275	5	19
n258	L	Patch	276	5	20

Table 3. 5G mmW NR Band n261 Antenna L Codebook

Band	Antenna Module	Antenna Type	Beam ID	Feed No.	Paired With
n261	L	Patch	0	1	256
n261	L	Patch	1	1	257
n261	L	Patch	2	1	258
n261	L	Patch	3	1	259
n261	L	Patch	4	1	260
n261	L	Patch	5	2	261
n261	L	Patch	6	2	262
n261	L	Patch	7	2	263
n261	L	Patch	8	2	264
n261	L	Patch	9	2	265
n261	L	Patch	10	2	266
n261	L	Patch	11	2	267
n261	L	Patch	12	5	268
n261	L	Patch	13	5	269
n261	L	Patch	14	5	270
n261	L	Patch	15	5	271
n261	L	Patch	16	5	272
n261	L	Patch	17	5	273
n261	L	Patch	18	5	274
n261	L	Patch	19	5	275
n261	L	Patch	20	5	276
n261	L	Patch	256	1	0
n261	L	Patch	257	1	1
n261	L	Patch	258	1	2
n261	L	Patch	259	1	3
n261	L	Patch	260	1	4
n261	L	Patch	261	2	5
n261	L	Patch	262	2	6
n261	L	Patch	263	2	7
n261	L	Patch	264	2	8
n261	L	Patch	265	2	9
n261	L	Patch	266	2	10
n261	L	Patch	267	2	11
n261	L	Patch	268	5	12
n261	L	Patch	269	5	13
n261	L	Patch	270	5	14
n261	L	Patch	271	5	15
n261	L	Patch	272	5	16
n261	L	Patch	273	5	17
n261	L	Patch	274	5	18
n261	L	Patch	275	5	19
n261	L	Patch	276	5	20

Table 4. 5G mmW NR Band n260 Antenna L Codebook

Band	Antenna Module	Antenna Type	Beam ID	Feed no.	Paired With
n260	L	Patch	0	1	256
n260	L	Patch	1	1	257
n260	L	Patch	2	1	258
n260	L	Patch	3	1	259
n260	L	Patch	4	1	260
n260	L	Patch	5	2	261
n260	L	Patch	6	2	262
n260	L	Patch	7	2	263
n260	L	Patch	8	2	264
n260	L	Patch	9	2	265
n260	L	Patch	10	2	266
n260	L	Patch	11	2	267
n260	L	Patch	12	5	268
n260	L	Patch	13	5	269
n260	L	Patch	14	5	270
n260	L	Patch	15	5	271
n260	L	Patch	16	5	272
n260	L	Patch	17	5	273
n260	L	Patch	18	5	274
n260	L	Patch	19	5	275
n260	L	Patch	20	5	276
n260	L	Patch	256	1	0
n260	L	Patch	257	1	1
n260	L	Patch	258	1	2
n260	L	Patch	259	1	3
n260	L	Patch	260	1	4
n260	L	Patch	261	2	5
n260	L	Patch	262	2	6
n260	L	Patch	263	2	7
n260	L	Patch	264	2	8
n260	L	Patch	265	2	9
n260	L	Patch	266	2	10
n260	L	Patch	267	2	11
n260	L	Patch	268	5	12
n260	L	Patch	269	5	13
n260	L	Patch	270	5	14
n260	L	Patch	271	5	15
n260	L	Patch	272	5	16
n260	L	Patch	273	5	17
n260	L	Patch	274	5	18
n260	L	Patch	275	5	19
n260	L	Patch	276	5	20

4. Simulation and Modeling Validation

Power density simulations of all beams and surfaces were performed. Details of these simulations and modeling validation can be found in the Power Density Simulation Report. Table below includes a summary of the validation results to support worst-case housing influence quantification in power density characterization for this model.

With an input power of 6 dBm for n258 band, 6 dBm for n261 band, and 6 dBm for n260 band, PD measurements are conducted for at least one single beam per antenna module on worst-surface(s). PD measurements are performed at mid channel of each mmW band and with CW modulation. All measured PD values are listed in table below along with corresponding simulated PD values for the same configuration.

PD value will be used to determine worst-case housing influence for conservative assessment.

Table 5.

Band	Antenna	Surface	Beam ID	4 cm ² psPD (mW/cm ²)		Delta = Simulated - Measured (dB)
				Simulated	Measured	
n261	L	Rear	19	1.447	0.944	1.85
		Left		0.85	0.615	1.41
		Rear	276	2.297	1.67	1.38
		Left	268	1.163	0.865	1.29
n260	L	Rear	16	1.47	1.08	1.35
		Left		0.911	0.515	2.48
		Rear	275	1.134	1.09	0.17
		Left		0.696	0.304	3.6
n258	L	Rear	20	1.101	0.72	1.84
		Rear	276	1.942	1.77	0.4

5. PD_design_target

Table 4.

PD_design_target	
$PD_design_target < PD_regulatory_limit \times 10^{\frac{-Total\ Uncertainty}{10}}$	
psPD over 4cm ² Averaging Area (mW/cm ²)	
Total Uncertainty	1.4dB
PD_regulatory_limit	1.0 mW/cm ²
PD_design_target	0.724 mW/cm ²

6. Δ_{min}

For non-metal material, the material property cannot be accurately characterized at mmW frequencies to date. The estimated material property for the device housing is used in the simulation model, which could influence the accuracy in simulation for PD amplitude quantification. Since the housing influence on PD could vary from surface to surface where the EM field propagates through, the most underestimated surface is used to quantify the worst-case housing influence for conservative assessment.

Since the mmW antenna modules are placed at different locations, only surrounding material/housing has impact on EM field propagation, and in turn power density. Furthermore, depending on the type of antenna array, i.e., dipole antenna array or patch antenna array, the nature of EM field propagation in the near field is different. Therefore, the worst-case housing influence is determined per antenna module and per antenna type.

For this DUT, the below procedure was used to determine worst-case housing influence,

Δ_{min} :

1. Based on PD simulation, for each module and antenna type, determine one or more worst-surface(s) that has highest 4cm^2 PD for all the single beams per antenna module and per antenna type in the mid channel of each band.
2. For identified worst surface(s) per antenna module and per antenna type group,
 - a. First determine Δ_{min} based on identified worst surface(s), and derive input.power.limit
 - b. Then prove all other near-by surface(s), i.e., non-selected surface(s), is not required for housing material loss quantification (in other words, these non-evaluated surfaces have no influence on the determined input.power.limit) by:
 - i. re-scale all simulated 4cm^2 PD values to input.power.limit to identify the worst-PD beam per each non-evaluated surface
 - ii. Measure 4cm^2 PD at input.power.limit on identified worst-PD beam per each non- evaluated surface
 - iii. Demonstrate all measured 4cm^2 PD values are below PD_design_target
3. If any of the above surface(s) in Step(2.b.iii) have measured 4cm^2 PD $\geq$ PD_design_target, then those surfaces must be included in the Δ_{min} determination in Step(2.a), and re- evaluate input.power.limit with these added surfaces.

Following above procedure, based on Samsung PD simulation report, the worst- surface(s) having highest

4 cm² PD for all the single beams per each antenna type and each antenna module group in the mid channel of n258, n261, and n260 bands are identified in the following table :

Table 7 . Worst-surface(s)

Band/Mode	Antenna Module	Back	Front	Top	Bottom	Right	Left
NR n258	L	Yes	No	No	No	No	No
NR n261	L	Yes	No	No	No	No	Yes
NR n260	L	Yes	No	No	No	No	Yes

Thus, when comparing a simulated 4cm²-averaged PD and measured 4cm²-averaged PD for the identified worst surface(s), the worst error introduced for each antenna type and each antenna module group when using the estimated material property in the simulation is highlighted in bold numbers in the table below.

Thus, the worst-case housing influence, denoted as $\Delta_{\min} = \text{Sim. PD} - \text{Meas. PD}$, is determined as

Table 8 . $\Delta_{\min}$

Band	Antenna	$\Delta_{\min}$ (dB)
n261	L	1.29
n260	L	0.17
n258	L	0.4

$\Delta_{\min}$ represents the worst case where RF exposure is underestimated the most in simulation when using the estimated material property of the housing. For conservative assessment, the $\Delta_{\min}$ is used as the worst-case factor and applied to all the beams in the corresponding antenna type and antenna module group to determine input power limits in PD char for compliance.

The detail input.power.limit derivation is described in Section 7.

Simulated 4cm² PD values in the Power Density Simulation Report are scaled to input.power.limit and are listed in the tables below for all single beams for all identified surfaces, when assuming the simulation is performed with correct housing influence.

Determine the *worst beam* for each of non-selected surface(s), identified in the table below:

Table 9 . Non-Selected Surface(s)

Band/Mode	Antenna Module	Back	Front	Top	Bottom	Right	Left
NR n258	L	No	Yes	Yes	Yes	Yes	Yes
NR n261	L	No	Yes	Yes	Yes	Yes	No
NR n260	L	No	Yes	Yes	Yes	Yes	No

Then perform PD measurement for all determined worst-case beams, highlighted in orange in the tables below, on the corresponding surface. Measurement is performed in the mid channel of each band with CW modulation. The evaluation distance is at 2mm.

Table 10 .
n258/mid channel, Antenna L Patch simulated 4cm² PD at PD_Design_Target
(if simulation performed with correct housing material properties) (Δmin)

Antenna	Beam ID_1	Simulated 4cm ² PD(mW/cm ²) Corresponding to PD_design_target if the simulation was performed with correct No. Module Type hosing material properties					
		S4(Right)	S3(Left)	S5(Top)	S6(Bottom)	S1(Front)	S2(Rear)
L	0	0.053	0.262	0.057	0.004	0.053	0.636
L	1	0.048	0.182	0.095	0.009	0.026	0.707
L	2	0.043	0.149	0.094	0.012	0.039	0.697
L	3	0.049	0.394	0.165	0.013	0.049	0.684
L	4	0.059	0.253	0.108	0.011	0.041	0.609
L	5	0.047	0.331	0.153	0.010	0.039	0.648
L	6	0.060	0.245	0.075	0.005	0.033	0.680
L	7	0.077	0.213	0.087	0.004	0.043	0.724
L	8	0.040	0.244	0.053	0.007	0.040	0.635
L	9	0.039	0.163	0.106	0.007	0.041	0.724
L	10	0.077	0.213	0.087	0.004	0.043	0.724
L	11	0.063	0.236	0.055	0.005	0.041	0.670
L	12	0.025	0.314	0.120	0.005	0.065	0.724
L	13	0.062	0.197	0.088	0.006	0.033	0.702
L	14	0.105	0.279	0.057	0.008	0.036	0.690
L	15	0.080	0.353	0.132	0.004	0.053	0.675
L	16	0.058	0.130	0.034	0.008	0.030	0.657
L	17	0.046	0.213	0.101	0.005	0.053	0.724
L	18	0.113	0.256	0.105	0.005	0.027	0.686
L	19	0.098	0.198	0.048	0.005	0.031	0.672
L	20	0.088	0.152	0.048	0.003	0.027	0.708
L	256	0.008	0.287	0.033	0.008	0.018	0.724
L	257	0.004	0.232	0.036	0.004	0.009	0.652
L	258	0.007	0.265	0.060	0.005	0.010	0.644
L	259	0.014	0.133	0.085	0.005	0.009	0.674
L	260	0.011	0.137	0.063	0.008	0.008	0.724
L	261	0.009	0.271	0.092	0.005	0.012	0.632
L	262	0.008	0.270	0.058	0.001	0.015	0.653
L	263	0.006	0.261	0.011	0.003	0.010	0.690
L	264	0.006	0.283	0.004	0.007	0.015	0.679
L	265	0.007	0.266	0.049	0.001	0.014	0.660
L	266	0.006	0.258	0.019	0.002	0.008	0.687
L	267	0.007	0.272	0.007	0.006	0.012	0.682
L	268	0.014	0.249	0.167	0.002	0.021	0.673
L	269	0.018	0.246	0.086	0.002	0.007	0.663
L	270	0.018	0.228	0.011	0.001	0.007	0.685
L	271	0.015	0.270	0.009	0.001	0.013	0.690
L	272	0.011	0.287	0.009	0.006	0.018	0.681
L	273	0.015	0.247	0.129	0.002	0.014	0.677
L	274	0.019	0.242	0.050	0.002	0.006	0.668
L	275	0.018	0.254	0.010	0.001	0.011	0.696
L	276	0.013	0.284	0.012	0.001	0.015	0.681

Table 11 .
n261/mid channel, Antenna L Patch simulated 4cm2 PD at PD_Design_Target
(if simulation performed with correct housing material properties) (Δmin)

Antenna	Beam ID_1	Simulated 4cm ² PD(mW/cm ²) Corresponding to PD_design_target if the simulation was performed with correct No. Module Type housing material properties					
		S4(Right)	S3(Left)	S5(Top)	S6(Bottom)	S1(Front)	S2(Rear)
L	0	0.026	0.261	0.018	0.008	0.020	0.724
L	1	0.037	0.351	0.075	0.009	0.037	0.724
L	2	0.019	0.336	0.060	0.003	0.019	0.724
L	3	0.035	0.345	0.051	0.003	0.038	0.680
L	4	0.035	0.372	0.067	0.003	0.032	0.693
L	5	0.035	0.178	0.115	0.007	0.030	0.618
L	6	0.028	0.266	0.061	0.003	0.025	0.688
L	7	0.022	0.348	0.039	0.003	0.017	0.697
L	8	0.034	0.351	0.049	0.013	0.032	0.724
L	9	0.033	0.277	0.046	0.005	0.014	0.724
L	10	0.037	0.379	0.090	0.019	0.034	0.724
L	11	0.047	0.204	0.122	0.007	0.057	0.660
L	12	0.035	0.260	0.144	0.010	0.068	0.594
L	13	0.026	0.398	0.082	0.002	0.027	0.724
L	14	0.027	0.397	0.027	0.003	0.025	0.714
L	15	0.053	0.331	0.020	0.005	0.021	0.724
L	16	0.039	0.216	0.047	0.009	0.035	0.612
L	17	0.028	0.272	0.097	0.003	0.033	0.650
L	18	0.031	0.408	0.041	0.004	0.028	0.724
L	19	0.031	0.426	0.018	0.003	0.025	0.724
L	20	0.048	0.259	0.033	0.005	0.024	0.681
L	256	0.010	0.228	0.036	0.007	0.012	0.665
L	257	0.007	0.223	0.023	0.003	0.005	0.714
L	258	0.005	0.259	0.050	0.004	0.007	0.707
L	259	0.009	0.303	0.089	0.004	0.009	0.715
L	260	0.009	0.322	0.108	0.004	0.009	0.724
L	261	0.009	0.257	0.047	0.003	0.012	0.691
L	262	0.007	0.276	0.046	0.002	0.008	0.715
L	263	0.007	0.278	0.007	0.003	0.007	0.720
L	264	0.011	0.254	0.007	0.008	0.012	0.694
L	265	0.012	0.338	0.155	0.002	0.012	0.724
L	266	0.006	0.291	0.059	0.003	0.011	0.713
L	267	0.010	0.307	0.020	0.005	0.011	0.708
L	268	0.007	0.393	0.185	0.001	0.025	0.705
L	269	0.015	0.329	0.105	0.001	0.007	0.713
L	270	0.019	0.332	0.026	0.001	0.005	0.721
L	271	0.021	0.290	0.007	0.002	0.012	0.718
L	272	0.011	0.319	0.007	0.008	0.019	0.713
L	273	0.013	0.355	0.150	0.001	0.017	0.715
L	274	0.016	0.325	0.050	0.002	0.004	0.720
L	275	0.018	0.335	0.015	0.001	0.010	0.721
L	276	0.015	0.281	0.006	0.002	0.015	0.711

Table 12 .
n260/mid channel, Antenna L Patch simulated 4cm² PD at PD_Design_Target
(if simulation performed with correct housing material properties) (Δmin)

Antenna	Beam ID_1	Simulated 4cm ² PD(mW/cm ²) Corresponding to PD_design_target if the simulation was performed with correct No. Module Type housing material properties					
		S4(Right)	S3(Left)	S5(Top)	S6(Bottom)	S1(Front)	S2(Rear)
L	0	0.013	0.333	0.033	0.003	0.008	0.724
L	1	0.017	0.288	0.046	0.002	0.015	0.705
L	2	0.010	0.309	0.045	0.005	0.015	0.682
L	3	0.024	0.347	0.100	0.003	0.015	0.695
L	4	0.011	0.428	0.144	0.003	0.011	0.724
L	5	0.010	0.297	0.063	0.005	0.023	0.644
L	6	0.020	0.311	0.091	0.004	0.019	0.651
L	7	0.028	0.361	0.012	0.001	0.009	0.724
L	8	0.018	0.333	0.060	0.006	0.012	0.724
L	9	0.010	0.296	0.068	0.004	0.018	0.700
L	10	0.026	0.345	0.022	0.001	0.007	0.701
L	11	0.022	0.330	0.042	0.005	0.007	0.724
L	12	0.012	0.411	0.200	0.006	0.026	0.649
L	13	0.016	0.437	0.116	0.002	0.017	0.724
L	14	0.040	0.392	0.035	0.001	0.008	0.724
L	15	0.034	0.356	0.077	0.002	0.008	0.687
L	16	0.015	0.448	0.170	0.010	0.021	0.724
L	17	0.013	0.417	0.198	0.006	0.027	0.654
L	18	0.017	0.296	0.103	0.003	0.019	0.566
L	19	0.044	0.397	0.045	0.001	0.008	0.723
L	20	0.022	0.417	0.117	0.004	0.011	0.724
L	256	0.027	0.403	0.027	0.005	0.018	0.688
L	257	0.020	0.244	0.043	0.003	0.030	0.628
L	258	0.018	0.383	0.059	0.003	0.021	0.724
L	259	0.012	0.313	0.089	0.003	0.024	0.724
L	260	0.016	0.337	0.078	0.004	0.035	0.724
L	261	0.024	0.244	0.074	0.005	0.030	0.713
L	262	0.022	0.245	0.057	0.004	0.028	0.724
L	263	0.018	0.474	0.036	0.002	0.030	0.666
L	264	0.028	0.244	0.055	0.010	0.024	0.596
L	265	0.012	0.328	0.123	0.003	0.025	0.724
L	266	0.020	0.390	0.042	0.002	0.026	0.678
L	267	0.015	0.325	0.063	0.002	0.018	0.724
L	268	0.025	0.363	0.177	0.014	0.039	0.724
L	269	0.035	0.280	0.057	0.003	0.021	0.724
L	270	0.018	0.406	0.062	0.001	0.036	0.705
L	271	0.013	0.380	0.028	0.001	0.020	0.610
L	272	0.019	0.233	0.182	0.014	0.046	0.724
L	273	0.029	0.289	0.061	0.004	0.026	0.697
L	274	0.037	0.328	0.079	0.002	0.044	0.699
L	275	0.019	0.445	0.027	0.001	0.021	0.724
L	276	0.018	0.343	0.084	0.003	0.021	0.724

The test results in the table below shows that the all measured 4cm² PD values are less than PD_design_target of 0.724 mW/cm², thus, the non-selected surfaces have no influence on the determined Δ_{min} and input.power.limit in Section 7.

Table 13.
4cm² PD of the selected beams measured on the corresponding surfaces that are not selected for Δ_{min} determination

Band	Antenna	Beam ID	Surface	Tested Power Level (dBm)	input.power.limit (dBm)	Meas. 4 cm ² PD (mW/cm ²)
n258	L	12	Front	5.5	5.2	0.143
		268	Top	2.7	2.4	0.168
		18	Right	4.4	4.1	0.067
		3	Bottom	11.9	12.2	0.034
		3	Left	12.5	12.2	0.311
n261	L	12	Front	8.3	8	0.049
		268	Top	2.1	1.8	0.127
		10	Bottom	10.5	10.8	0.009
		15	Right	4.4	4.1	0.011
n260	L	272	Front	5.8	5.5	0.037
		12	Top	3.3	3	0.127
		272	Bottom	5.2	5.5	0.005
		19	Right	4.4	4.1	0.014

7 PD Char

7.1 Single Beams

To determine the input power limit at each antenna port, simulation was performed at low, mid, and high channel for each mmW band supported, with 6 dBm input power per active port for n258 band, 6 dBm input power per active port for n261 band and 6 dBm input power per active port for n260 band:

1. Obtained PD surface value (the worst PD among all identified surfaces of the DUT) at all three channels for all single beams specified in the codebook.

2. Derived a scaling factor at low, mid and high channel, $S(i)_{low_or_mid_or_high}$, by:

$$s(i)_{low_or_mid_or_high} = \frac{PD_design_target}{sim.PD_{surface}(i)}, i \in single\ beams \quad (1)$$

3. Determined the worst-case scaling factor, $S(i)$, among low, mid and high channels:

$$s(i) = \min\{S_{low}(i), S_{mid}(i), S_{high}(i)\}, i \in single\ beams \quad (2)$$

For Smart Transmit Plus, “Qualcomm IPLG” prints the $sim.power_{limit}$ for all three channels, denoted as $sim.power_{limit_L}$, $sim.power_{limit_M}$, and $sim.power_{limit_H}$.

The $sim.power_{limit}$ is determined by:

$$sim.power_{limit} = \min\{sim.power_{limit_L}, sim.power_{limit_M}, sim.power_{limit_H}\}$$

7.2 Beam Pairs

Per the manufacturer, the relative phase between beam pair is not controlled in the chipset design and could vary from run to run. Therefore, for each beam pair, based on the simulation results, the worst-case scaling factor was determined mathematically to ensure the compliance. The worst-case PD for MIMO operations was found by sweeping the relative phase for all possible angles to ensure a conservative assessment.

The power density simulation report contains the worst-case power density for each surface after sweeping through all relative phases between beams.

Once the power density was determined for the worst-case $\emptyset$, the scaling factor was obtained by the below equation for low, mid and high channels:

$$s(i)_{low_or_mid_or_high} = \frac{PD_design_target}{total\ PD(\emptyset(i)_{worstcase})}, i \in beam\ pairs \quad (3)$$

The total PD ($\emptyset_{worstcase}$) varies with channel and beam pair, the lowest scaling factor among all three channels, $s(i)$, is determined for the beam pair i :

$$s(i) = \min\{S_{low}(i), S_{mid}(i), S_{high}(i)\}, i \in single\ beams \quad (4)$$

7.3 Input.Power.Limit Calculations

The PD Char specifies the limit of input power at antenna port that corresponds to PD_design_target for all the beams.

Ideally, if there is no uncertainty associated with hardware design, the input power limit, denoted as $input.power.limit(i)$, for beam i can be obtained after accounting for the housing influence (Δ_{min}) given by:

- For n258, n261, and n261

$$input.power.limit(i) = sim.power_{limit} + 10 * \log(s(i)) + \Delta_{min}, \quad i \in all\ beams \quad (5)$$

where 6 dBm is the input power used in simulation for n258,n261 and n260, respectively; $s(i)$ is the scaling factor obtained from Eq. (2) or Eq. (4) for beam i ; Δ_{min} is the worst-case housing influence factor for beam i .

If simulation overestimates the housing influence, then Δ_{min} (= simulated PD – measured PD) is negative, which means that the measured PD would be higher than the simulated PD. The input power to antenna elements determined via simulation must be decreased for compliance.

Similarly, if simulation underestimates the loss, then Δ_{min} is positive (measured PD would be lower than the simulated value). Input power to antenna elements determined via simulation can be increased and still be PD compliant.

In reality the hardware design has uncertainty which must be properly considered. The device design related uncertainty is embedded in the process of Δ_{min} determination. Since the device uncertainty is already accounted for in PD_design_target, it needs to be removed to avoid double counting this uncertainty.

Thus, Equation 5 is modified to:

if $-TxAGC\ uncertainty < \Delta_{min} < TxAGC\ uncertainty$,

$$input.power.limit(i) = sim.power_{limit}(i), \quad i \in all\ beams, \ n258, n261, and\ n260 \quad (6)$$

else if $\Delta_{min} < -TxAGC\ uncertainty$,

$$input.power.limit(i) = sim.power_{limit}(i) + (\Delta_{min} + TxAGC\ uncertainty), \quad i \in all\ beams, n258, n261, and\ n260 \quad (7)$$

else if $\Delta_{min} > TxAGC\ uncertainty$,

$$input.power.limit(i) = sim.power_{limit}(i) + (\Delta_{min} - TxAGC\ uncertainty), \quad i \in all\ beams, n258, n261, and\ n260 \quad (8)$$

Following above logic, the input.power.limit for this DUT can be calculated using Equations (6), (7), and (8), i.e.,

Table 14. *input.power.limit* Calculation

Band	Antenna	$\Delta_{\min}$ (dB)	TxAGC Uncertainty (dB)	Input.power.limit (dBm)	notes
n261	L	1.29	0.47	$\text{input.power.limit}(i) = \text{sim.power_limit} + 0.82$	Using Eq.8
n260	L	0.17	0.47	$\text{input.power.limit}(i) = \text{sim.power_limit}$	Using Eq.6
n258	L	0.4	0.47	$\text{input.power.limit}(i) = \text{sim.power_limit}$	Using Eq.6

Table 15. *Permanent backoff* applied to calculated *input.power.limit*

Band	Antenna	Backoff (dB)
n258	L	0.3
n261	L	0.3
n260	L	0.3

Note. The above backoff values have been permanently applied to the input.power.limits calculated from the equations above. The final input.power.limits implemented in the EFS are in the tables below.

Table 17. 5G NR FR2 n258 Antenna L Patch *input.power.limit*

Band	Beam ID	Paired With ID	input.power.limit
n258	0		11.2
n258	1		12.1
n258	2		11.7
n258	3		12.2
n258	4		11.4
n258	5		8.7
n258	6		7.9
n258	7		8.6
n258	8		8.3
n258	9		8.2
n258	10		8.6
n258	11		8.2
n258	12		5.2
n258	13		4.3
n258	14		4.6
n258	15		5.4
n258	16		3.8
n258	17		5.3
n258	18		4.1
n258	19		4.0
n258	20		3.8
n258	256		9.8
n258	257		9.3
n258	258		9.7
n258	259		9.3
n258	260		10.0
n258	261		6.9
n258	262		6.4
n258	263		4.8
n258	264		5.1
n258	265		6.0
n258	266		5.0
n258	267		4.9
n258	268		2.4
n258	269		1.6
n258	270		1.5
n258	271		1.3
n258	272		1.4
n258	273		1.9
n258	274		1.2
n258	275		1.5
n258	276		1.2
n258	0	256	7.0
n258	1	257	6.7
n258	2	258	7.1
n258	3	259	7.1
n258	4	260	7.2
n258	5	261	4.5
n258	6	262	4.0
n258	7	263	3.0
n258	8	264	3.1
n258	9	265	3.3
n258	10	266	2.9
n258	11	267	3.2
n258	12	268	-1.0
n258	13	269	-1.0
n258	14	270	-0.9
n258	15	271	-0.4
n258	16	272	-1.2
n258	17	273	-1.0
n258	18	274	-1.0
n258	19	275	-0.8
n258	20	276	-1.1

Table 18. 5G NR FR2 n261 Antenna L Patch *input.power.limit*

Band	Beam ID	Paired With ID	input.power.limit
n261	0		10.6
n261	1		13.3
n261	2		10.9
n261	3		11.6
n261	4		11.6
n261	5		9.9
n261	6		8.4
n261	7		8.9
n261	8		9.3
n261	9		9.0
n261	10		10.8
n261	11		10.5
n261	12		8.0
n261	13		5.0
n261	14		3.8
n261	15		4.1
n261	16		6.0
n261	17		6.3
n261	18		4.2
n261	19		3.6
n261	20		4.8
n261	256		10.3
n261	257		9.0
n261	258		9.0
n261	259		9.3
n261	260		9.9
n261	261		6.2
n261	262		5.6
n261	263		5.3
n261	264		6.1
n261	265		6.0
n261	266		6.0
n261	267		5.6
n261	268		1.8
n261	269		1.5
n261	270		1.9
n261	271		1.7
n261	272		1.4
n261	273		1.7
n261	274		1.9
n261	275		1.9
n261	276		1.5
n261	0	256	7.1
n261	1	257	7.1
n261	2	258	6.8
n261	3	259	7.1
n261	4	260	7.3
n261	5	261	4.8
n261	6	262	3.4
n261	7	263	3.4
n261	8	264	4.0
n261	9	265	5.5
n261	10	266	4.7
n261	11	267	4.2
n261	12	268	-0.1
n261	13	269	-0.5
n261	14	270	-0.5
n261	15	271	-0.7
n261	16	272	-0.7
n261	17	273	-0.1
n261	18	274	-0.5
n261	19	275	-0.8
n261	20	276	-0.8

Table 19. 5G NR FR2 n260 Antenna L Patch *input.power.limit*

Band	Beam ID	Paired With ID	input.power.limit
n260	0		9.7
n260	1		9.6
n260	2		9.7
n260	3		10.4
n260	4		10.3
n260	5		6.3
n260	6		7.1
n260	7		7.0
n260	8		6.5
n260	9		6.8
n260	10		7.4
n260	11		6.6
n260	12		3.0
n260	13		3.1
n260	14		4.2
n260	15		4.2
n260	16		2.7
n260	17		3.0
n260	18		3.8
n260	19		4.1
n260	20		3.5
n260	256		12.3
n260	257		11.0
n260	258		10.4
n260	259		10.4
n260	260		11.7
n260	261		7.7
n260	262		7.4
n260	263		8.2
n260	264		8.7
n260	265		7.4
n260	266		8.8
n260	267		8.0
n260	268		4.8
n260	269		4.5
n260	270		4.4
n260	271		4.7
n260	272		5.5
n260	273		4.2
n260	274		5.0
n260	275		3.8
n260	276		5.3
n260	0	256	7.4
n260	1	257	7.0
n260	2	258	6.6
n260	3	259	7.2
n260	4	260	7.6
n260	5	261	3.3
n260	6	262	3.7
n260	7	263	4.5
n260	8	264	4.1
n260	9	265	4.4
n260	10	266	4.2
n260	11	267	4.1
n260	12	268	0.2
n260	13	269	0.0
n260	14	270	0.9
n260	15	271	0.6
n260	16	272	0.0
n260	17	273	-0.2
n260	18	274	0.3
n260	19	275	0.5
n260	20	276	0.9