FCC 47 CFR § 2.1093
IEC TR 63170-2018

POWER DENSITY EVALUATION REPORT

(Part 0 : POWER DENSITY CHARACTERIZATION)

FOR

WCDMA/LTE/5G NR Laptop + BT/BLE, DTS/UNII a/b/g/n/ac/ax

MODEL NUMBER: NP545XLA, NP545XLA-KA1TT, NP545XLA-KA1VZ

FCC ID: A3LNP545XLA

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Prepared for

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TL-637

Revision History

Rev.	Date	Revisions	Revised By
V1	6/15/2021	Initial Issue	--

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1. Attestation of Power Density Characterization

Applicant Name	SAMSUNG ELECTRONICS CO.,LTD.
FCC ID	A3LNP545XLA
Model Number	NP545XLAB, NP545XLA-KA1TT, NP545XLA-KA1VZ
Applicable Standards	FCC 47 CFR § 2.1093 IEC TR 63170-2018
Report type	Part.0 : Power Density Characterization
Date Tested	5/10/2021 to 6/2/2021
Part 0 requirement	This report is the procedures for determining input.power.limit for 5G mmW NR to satisfy PD_design_target in order to FCC limit's requirement.

UL Korea, Ltd. tested the above equipment in accordance with the requirements set forth in the above standards. All indications of Pass/Fail in this report are opinions expressed by UL Korea, Ltd. based on interpretations and/or observations of test results. Measurement Uncertainties were not taken into account and are published for informational purposes only. The test results show that the equipment tested is capable of demonstrating compliance with the requirements as documented in this report.

Note: The results documented in this report apply only to the tested sample, under the conditions and modes of operation as described herein. This document may not be altered or revised in any way unless done so by UL Korea, Ltd. and all revisions are duly noted in the revisions section. Any alteration of this document not carried out by UL Korea, Ltd. will constitute fraud and shall nullify the document. This report must not be used by the client to claim product certification, approval, or endorsement by IAS, any agency of the Federal Government, or any agency of any government. This report is written to support regulatory compliance of the applicable standards stated above.

Approved & Released By:	Prepared By:
	
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2. Exposure Scenarios

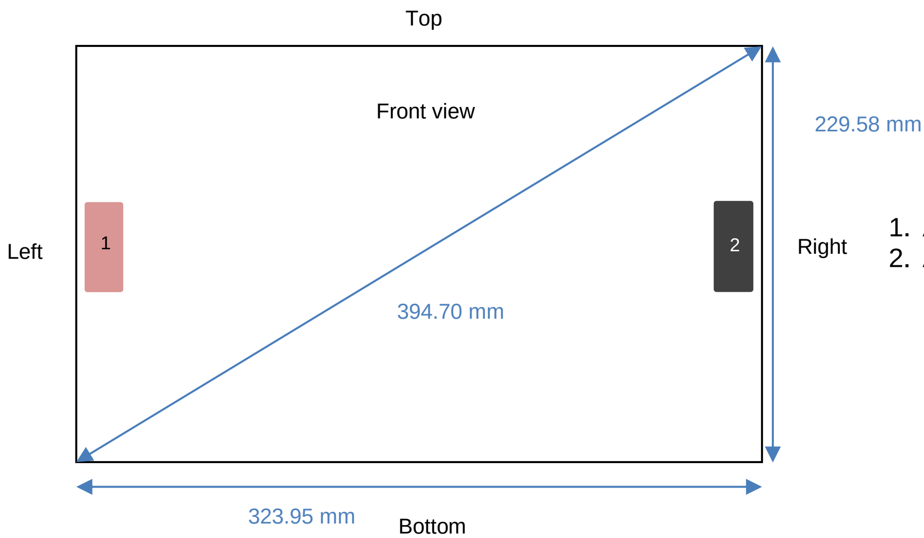
At frequencies > 6 GHz, the total peak spatial averaged power density (psPD) is required to be assessed for all antenna configurations (beams) from all mmW antenna modules installed inside the device. This device has 2 patch antenna arrays (K Patch, L Patch).

As showed in Figure 1, 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

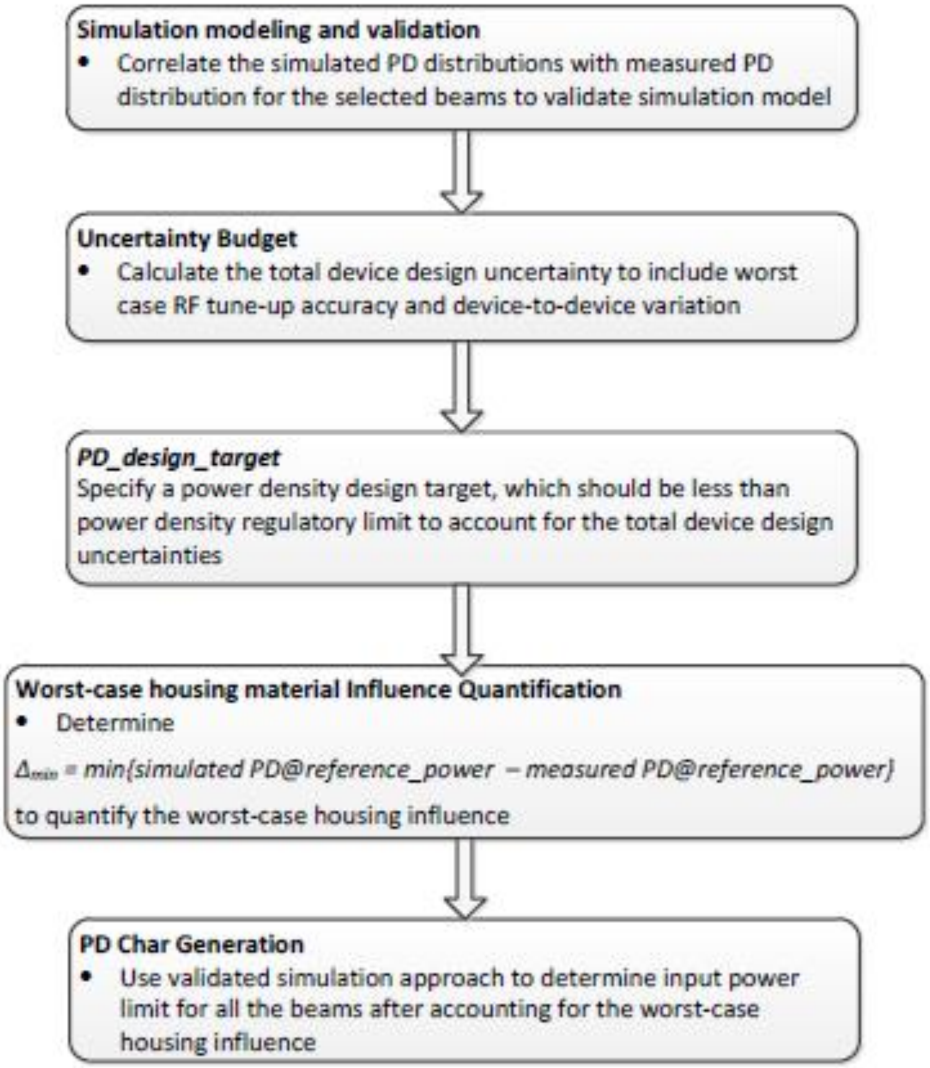
Band & Mode	Antenna	Back (S2)	Front (S1)	Top (S5)	Bottom (S6)	Left (S4)	Right (S3)
5G NR Band n261	K Patch	Yes	Yes				Yes
	L Patch	Yes	Yes			Yes	
5G NR Band n260	K Patch	Yes	Yes				Yes
	L Patch	Yes	Yes			Yes	



1. Antenna L (Tx/Rx) NR n261/n260
2. Antenna K (Tx/Rx) NR n261/n260

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

3. Power Density Characterization Method



4. Test Equipment

The measuring equipment used to perform the tests documented in this report has been calibrated in accordance with the manufacturers' recommendations, and is traceable to recognized national standards.

System Check

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
5G probe	SPEAG	EummWV4	9493	8-18-2021
5G probe	SPEAG	EummWV4	9536	4-24-2022
5G probe	SPEAG	EummWV4	9559	4-1-2022
Data Acquisition Electronics	SPEAG	DAE4	1468	8-25-2021
Data Acquisition Electronics	SPEAG	DAE4	1667	4-8-2022
Data Acquisition Electronics	SPEAG	DAE4	1668	4-8-2022
5G Verification Source (30GHz)	SPEAG	5G verification source_30GHz	1047	1-22-2022
5G Verification Source (30GHz)	SPEAG	5G verification source_30GHz	1082	4-7-2022
Thermometer	Lutron	MHB-382SD	AH.91463	8-11-2021
Thermometer	Lutron	MHB-382SD	AK.12102	4-27-2022

5. Codebook for all supported beams

Table 2

5G NR band n261 Ant L Code book

Band	Module (Ant)	Ant_Type	Beam ID_1	Bema ID_2
n261	L	Patch	1	
			3	
			8	
			9	
			10	
			11	
			15	
			16	
			17	
			23	
			24	
			25	
			26	
			27	
			32	
			33	
			34	
			35	
				129
				131
				136
				137
				138
				139
				143
				144
				145
				151
				152
				153
				154
				155
				160
				161
				162
				163
			1	129
			3	131
			8	136
			9	137
			10	138
			11	139
			15	143
			16	144
			17	145
			23	151
			24	152
			25	153
			26	154
			27	155
			32	160
			33	161
			34	162
			35	163

Table 3

5G NR band n261 Ant K Code book

Band	Module (Ant)	Ant_Type	Beam ID_1	Bema ID_2
n261	K	Patch	0	
			2	
			4	
			5	
			6	
			7	
			12	
			13	
			14	
			18	
			19	
			20	
			21	
			22	
			28	
			29	
			30	
			31	
				128
				130
				132
				133
				134
				135
				140
				141
				142
				146
				147
				148
				149
				150
				156
				157
				158
				159
			0	128
			2	130
			4	132
			5	133
			6	134
			7	135
			12	140
			13	141
			14	142
			18	146
			19	147
			20	148
			21	149
			22	150
			28	156
			29	157
			30	158
			31	159

Table 4

5G NR band n260 Ant L Code book

Band	Module (Ant)	Ant_Type	Beam ID_1	Bema ID_2
n260	L	Patch	1	
			3	
			4	
			9	
			10	
			11	
			12	
			16	
			17	
			18	
			24	
			25	
			26	
			27	
			28	
			33	
			34	
			35	
			36	
				129
				131
				132
				137
				138
				139
				140
				144
				145
				146
				152
				153
				154
				155
				156
				161
				162
				163
				164
			1	129
			3	131
			4	132
			9	137
			10	138
			11	139
			12	140
			16	144
			17	145
			18	146
			24	152
			25	153
			26	154
			27	155
			28	156
			33	161
			34	162
			35	163
			36	164

Table 5

5G NR band n260 Ant K Code book

Band	Module (Ant)	Ant_Type	Beam ID_1	Bema ID_2
n260	K	Patch	0	
			2	
			5	
			6	
			7	
			8	
			13	
			14	
			15	
			19	
			20	
			21	
			22	
			23	
			29	
			30	
			31	
			32	
				128
				130
				133
				134
				135
				136
				141
				142
				143
				147
				148
				149
				150
				151
				157
				158
				159
				160
			0	128
			2	130
			5	133
			6	134
			7	135
			8	136
			13	141
			14	142
			15	143
			19	147
			20	148
			21	149
			22	150
			23	151
			29	157
			30	158
			31	159
			32	160

6. 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 n261 band and 6 dBm for n260 band, PD measurements are conducted for at least one single beam per antenna (patch) and per antenna module (K, L) 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 6

Band	Beam ID	Antenna	Surface	4cm2 psPD		Delta = Simulated - Measured
				Measured	Simulated	
				(mW/cm2)		(dB)
n261	29	K (patch)	Front (S1)	0.44	0.92	3.19
	150			0.12	0.34	4.70
	29		Rear (S2)	0.42	0.69	2.20
	157			0.47	0.96	3.09
	19		Right (S3)	0.73	1.18	2.09
	148			0.58	0.91	**1.99**
	24	L (patch)	Front (S1)	0.28	1.09	5.85
	161			0.22	0.35	1.99
	25		Rear (S2)	0.28	0.54	2.85
	162			0.42	0.87	3.23
	24		Left (S4)	0.67	1.33	2.99
	153			0.54	0.84	**1.98**
n260	21	K (patch)	Front (S1)	0.27	0.63	3.67
	157			0.34	0.68	3.03
	30		Rear (S2)	0.19	0.44	3.55
	151			0.36	0.76	3.22
	23		Right (S3)	0.61	0.82	**1.28**
	151			0.38	0.75	2.98
	34	L (patch)	Front (S1)	0.37	0.74	3.00
	155			0.38	0.68	2.49
	25		Rear (S2)	0.46	0.47	0.15
	163			0.41	0.71	2.42
	34		Left (S4)	0.86	0.82	**-0.18**
	155			0.42	0.73	2.40

7. PD_design_target

Table 7

PD_design_target	
$PD\_design\_target < PD\_regulatory\_limit \times 10^{\frac{-Total\ Uncertainty}{10}}$	
psPD over 4 cm2 Averaging Area (mW/cm2)	
Total Uncertainty	2.1 dB
PD_regulatory_limit	1.0 mW/cm2
PD_design_target	0.6166 mW/cm2

8. △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,

Δmin:

1. Based on PD simulation, for each module and antenna type, determine one or more worst-surface(s) that has highest 4cm2 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 Δmin 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 4cm2 PD values to input.power.limit to identify the worst-PD beam per each non-evaluated surface

ii. Measure 4cm2 PD at input.power.limit on identified worst-PD beam per each non-evaluated surface

iii. Demonstrate all measured 4cm2 PD values are below PD_design_target

3. If any of the above surface(s) in Step (2.b.iii) have measured 4cm2 PD ≥ PD_design_target, then those surfaces must be included in the Δmin determination in Step (2.a), and re-evaluate input.power.limit with these added surfaces.

Following above procedure, based on Table 2 ~ Table 5 in Samsung PD simulation report, the worst-surface(s) having highest 4cm2 PD for all the single beams per each antenna type and each antenna module group in the mid channel of n261 and n260 bands are identified as:

a. for K patch : Front (S1) & Rear (S2) & Right (S3)

b. for L patch : Front (S1) & Rear (S2) & Left (S4)

Thus, when comparing a simulated 4cm2-averaged PD and measured 4 cm2-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 Table 6. Thus, the worst-case housing influence, denoted as Δmin = Sim. PD − Meas. PD , is determined as

Table 8

Δmin for Ant K and Ant L

Band	Antenna	△min (dB)
n261	K (patch)	**1.99**
	L (patch)	**1.98**
n260	K (patch)	**1.28**
	L (patch)	**-0.18**

Δmin 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 Δmin 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 8.
Simulated 4cm2 PD values in Table 2 ~ Table 5 in Power Density Simulation Report are scaled to input.power.limit and are listed in Tables 9 – 12 for all single beams for all identified surfaces, when assuming the simulation is performed with correct housing influence.

Table 9
N261/mid channel, K Patch simulated 4cm^2 PD at PD_design_Target
(if simulation performed with correct housing material properties) (Δmin)

Module	Type	No.	Beam ID	Simulated 4cm2 PD(mW/cm2) Corresponding to PD_design_target if the simulation was performed with correct No. Module Type housing material properties					
				S3(Right)	S4(Left)	S5(Top)	S6(Bottom)	S1(Front)	S2(Rear)
K	Patch	1	0	0.267	0.006	0.008	0.014	0.187	0.172
		2	2	0.235	0.006	0.006	0.012	0.156	0.150
		3	4	0.454	0.018	0.022	0.022	0.331	0.286
		4	5	0.681	0.012	0.009	0.011	0.485	0.408
		5	6	0.639	0.011	0.011	0.014	0.480	0.437
		6	7	0.428	0.020	0.021	0.041	0.368	0.307
		7	12	0.611	0.014	0.019	0.024	0.432	0.317
		8	13	0.529	0.016	0.012	0.012	0.423	0.271
		9	14	0.419	0.016	0.014	0.041	0.333	0.294
		10	18	0.952	0.037	0.083	0.063	0.677	0.470
		11	19	1.177	0.032	0.016	0.011	0.909	0.641
		12	20	1.117	0.025	0.014	0.016	0.879	0.671
		13	21	1.112	0.043	0.012	0.027	0.909	0.632
		14	22	0.639	0.047	0.054	0.112	0.603	0.485
		15	28	1.124	0.031	0.048	0.036	0.826	0.552
		16	29	1.153	0.029	0.013	0.016	0.921	0.691
		17	30	1.134	0.032	0.013	0.012	0.901	0.671
		18	31	0.886	0.033	0.044	0.075	0.761	0.537
		19	128	0.244	0.005	0.010	0.011	0.098	0.285
		20	130	0.139	0.004	0.004	0.021	0.050	0.163
		21	132	0.287	0.015	0.037	0.029	0.150	0.408
		22	133	0.537	0.009	0.007	0.005	0.188	0.606
		23	134	0.527	0.009	0.013	0.031	0.184	0.584
		24	135	0.367	0.009	0.019	0.048	0.163	0.428
		25	140	0.454	0.011	0.020	0.013	0.175	0.521
		26	141	0.389	0.009	0.007	0.013	0.122	0.430
		27	142	0.406	0.011	0.020	0.050	0.167	0.430
		28	146	0.495	0.029	0.085	0.042	0.277	0.681
		29	147	0.811	0.030	0.019	0.020	0.326	0.916
		30	148	0.911	0.023	0.011	0.017	0.304	0.958
		31	149	0.757	0.014	0.014	0.05	0.281	0.828
		32	150	0.721	0.019	0.047	0.17	0.342	0.722
		33	156	0.656	0.027	0.052	0.03	0.332	0.797
		34	157	0.892	0.020	0.013	0.02	0.311	0.963
		35	158	0.874	0.022	0.012	0.01	0.302	0.925
		36	159	0.757	0.016	0.029	0.13	0.323	0.802

Table 10
N261/mid channel, L Patch simulated 4cm^2 PD at PD_design_Target
(if simulation performed with correct housing material properties) (Δmin)

Module	Type	No.	Beam ID	Simulated 4cm2 PD(mW/cm2) Corresponding to PD_design_target if the simulation was performed with correct No. Module Type housing material properties					
				S3(Right)	S4(Left)	S5(Top)	S6(Bottom)	S1(Front)	S2(Rear)
L	Patch	55	1	0.010	0.367	0.009	0.008	0.239	0.138
		56	3	0.008	0.290	0.011	0.011	0.225	0.110
		57	8	0.024	0.612	0.031	0.033	0.488	0.205
		58	9	0.021	0.725	0.013	0.025	0.567	0.297
		59	10	0.019	0.774	0.019	0.009	0.660	0.275
		60	11	0.016	0.592	0.030	0.025	0.368	0.207
		61	15	0.019	0.632	0.021	0.034	0.445	0.268
		62	16	0.023	0.790	0.009	0.015	0.664	0.300
		63	17	0.015	0.670	0.028	0.015	0.527	0.235
		64	23	0.043	0.985	0.075	0.075	0.659	0.413
		65	24	0.049	1.333	0.020	0.030	1.088	0.516
		66	25	0.038	1.272	0.016	0.014	1.058	0.541
		67	26	0.035	1.258	0.027	0.013	1.062	0.468
		68	27	0.041	1.020	0.079	0.064	0.777	0.406
		69	32	0.047	1.268	0.050	0.047	0.923	0.475
		70	33	0.044	1.302	0.014	0.018	1.043	0.538
		71	34	0.035	1.244	0.020	0.015	1.058	0.514
		72	35	0.035	1.196	0.057	0.033	0.960	0.446
		73	129	0.008	0.233	0.027	0.012	0.085	0.262
		74	131	0.005	0.148	0.011	0.016	0.074	0.177
		75	136	0.014	0.357	0.021	0.046	0.180	0.407
		76	137	0.020	0.481	0.009	0.026	0.204	0.531
		77	138	0.016	0.362	0.072	0.015	0.136	0.370
		78	139	0.018	0.288	0.104	0.038	0.142	0.323
		79	143	0.018	0.413	0.027	0.046	0.193	0.471
		80	144	0.020	0.492	0.016	0.011	0.196	0.523
		81	145	0.017	0.382	0.061	0.019	0.143	0.393
		82	151	0.029	0.618	0.049	0.185	0.339	0.754
		83	152	0.035	0.709	0.015	0.063	0.334	0.850
		84	153	0.035	0.845	0.017	0.018	0.329	0.864
		85	154	0.036	0.784	0.046	0.027	0.314	0.840
		86	155	0.035	0.548	0.232	0.047	0.278	0.560
		87	160	0.030	0.633	0.039	0.166	0.324	0.796
		88	161	0.040	0.819	0.013	0.019	0.346	0.868
		89	162	0.029	0.832	0.022	0.013	0.311	0.873
		90	163	0.035	0.591	0.159	0.035	0.258	0.651

Table 11
N260/mid channel, K Patch simulated 4cm^2 PD at PD_design_Target
(if simulation performed with correct housing material properties) (Δmin)

Module	Type	No.	Beam ID	Simulated 4cm2 PD(mW/cm2) Corresponding to PD_design_target if the simulation was performed with correct No. Module Type housing material properties					
				S3(Right)	S4(Left)	S5(Top)	S6(Bottom)	S1(Front)	S2(Rear)
K	Patch	1	0	0.192	0.004	0.013	0.016	0.141	0.102
		2	2	0.258	0.008	0.017	0.015	0.130	0.130
		3	5	0.482	0.011	0.037	0.025	0.265	0.266
		4	6	0.416	0.013	0.039	0.022	0.287	0.211
		5	7	0.453	0.015	0.010	0.051	0.266	0.218
		6	8	0.455	0.007	0.039	0.011	0.279	0.210
		7	13	0.423	0.017	0.029	0.013	0.197	0.219
		8	14	0.345	0.012	0.041	0.034	0.278	0.177
		9	15	0.416	0.014	0.016	0.033	0.280	0.235
		10	19	0.765	0.019	0.045	0.079	0.406	0.431
		11	20	0.692	0.031	0.096	0.019	0.418	0.405
		12	21	0.737	0.022	0.061	0.042	0.626	0.408
		13	22	0.601	0.028	0.017	0.086	0.433	0.361
		14	23	0.821	0.019	0.090	0.033	0.493	0.410
		15	29	0.760	0.028	0.105	0.014	0.431	0.392
		16	30	0.700	0.025	0.060	0.048	0.499	0.437
		17	31	0.635	0.029	0.036	0.088	0.490	0.377
		18	32	0.649	0.018	0.027	0.082	0.427	0.382
		19	128	0.207	0.007	0.006	0.020	0.236	0.214
		20	130	0.185	0.004	0.003	0.010	0.129	0.192
		21	133	0.267	0.009	0.005	0.028	0.213	0.310
		22	134	0.342	0.010	0.007	0.013	0.235	0.339
		23	135	0.324	0.012	0.007	0.050	0.309	0.357
		24	136	0.358	0.022	0.015	0.029	0.400	0.359
		25	141	0.408	0.022	0.023	0.017	0.469	0.392
		26	142	0.328	0.011	0.004	0.024	0.211	0.304
		27	143	0.358	0.022	0.015	0.029	0.400	0.359
		28	147	0.647	0.024	0.025	0.090	0.603	0.746
		29	148	0.722	0.028	0.029	0.028	0.671	0.689
		30	149	0.631	0.028	0.030	0.074	0.588	0.536
		31	150	0.579	0.028	0.018	0.097	0.469	0.521
		32	151	0.750	0.026	0.031	0.075	0.631	0.763
		33	157	0.699	0.025	0.023	0.075	0.677	0.718
		34	158	0.688	0.025	0.032	0.037	0.622	0.671
		35	159	0.610	0.029	0.020	0.108	0.537	0.521
		36	160	0.541	0.026	0.023	0.100	0.508	0.742

Table 12
N260/mid channel, L Patch simulated 4cm^2 PD at PD_design_Target
(if simulation performed with correct housing material properties) (Δmin)

Module	Type	No.	Beam ID	Simulated 4cm2 PD(mW/cm2) Corresponding to PD_design_target if the simulation was performed with correct No. Module Type housing material properties					
				S3(Right)	S4(Left)	S5(Top)	S6(Bottom)	S1(Front)	S2(Rear)
L	Patch	55	1	0.005	0.162	0.015	0.011	0.096	0.110
		56	3	0.005	0.246	0.009	0.018	0.124	0.149
		57	4	0.009	0.263	0.013	0.025	0.229	0.130
		58	9	0.018	0.463	0.019	0.041	0.386	0.246
		59	10	0.013	0.372	0.045	0.043	0.409	0.169
		60	11	0.010	0.454	0.022	0.022	0.437	0.199
		61	12	0.011	0.399	0.021	0.016	0.277	0.249
		62	16	0.014	0.394	0.041	0.053	0.384	0.191
		63	17	0.010	0.508	0.033	0.042	0.412	0.256
		64	18	0.014	0.494	0.025	0.025	0.418	0.246
		65	24	0.039	0.732	0.030	0.063	0.573	0.396
		66	25	0.018	0.823	0.062	0.099	0.656	0.472
		67	26	0.020	0.784	0.070	0.104	0.647	0.377
		68	27	0.023	0.681	0.084	0.027	0.588	0.410
		69	28	0.031	0.747	0.047	0.063	0.596	0.399
		70	33	0.046	0.706	0.029	0.103	0.528	0.435
		71	34	0.016	0.824	0.099	0.097	0.738	0.397
		72	35	0.026	0.717	0.056	0.039	0.610	0.373
		73	36	0.025	0.754	0.060	0.058	0.603	0.410
		74	129	0.010	0.192	0.026	0.010	0.227	0.216
		75	131	0.011	0.248	0.003	0.018	0.168	0.225
		76	132	0.007	0.156	0.003	0.022	0.159	0.166
		77	137	0.022	0.338	0.006	0.059	0.253	0.290
		78	138	0.026	0.428	0.007	0.053	0.318	0.376
		79	139	0.024	0.383	0.008	0.024	0.356	0.435
		80	140	0.024	0.391	0.029	0.018	0.371	0.407
		81	144	0.017	0.363	0.026	0.039	0.333	0.352
		82	145	0.026	0.453	0.031	0.039	0.367	0.394
		83	146	0.028	0.432	0.032	0.013	0.380	0.415
		84	152	0.033	0.516	0.035	0.059	0.434	0.504
		85	153	0.033	0.569	0.026	0.141	0.461	0.487
		86	154	0.051	0.686	0.041	0.056	0.588	0.661
		87	155	0.049	0.730	0.036	0.026	0.677	0.704
		88	156	0.029	0.580	0.036	0.072	0.607	0.594
		89	161	0.035	0.559	0.031	0.094	0.449	0.481
		90	162	0.047	0.608	0.032	0.126	0.522	0.543
		91	163	0.048	0.717	0.045	0.022	0.625	0.709
		92	164	0.034	0.656	0.027	0.049	0.636	0.605

9. PD Char

9.1. 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 n261 band and 6 dBm input power per active port for n260 band:

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

Derived a scaling factor at low, mid and high channel, $s(i)low\_or\_mid\_or\_high$, by:

$$s(i)_{low\_or\_mid\_or\_high} = \frac{PD\ design\ target}{sim.PD_{surface}(i)},\ i \in single\ beams \qquad (1)$$

Determined the worst-case scaling factor, $\boldsymbol{s(i)}$, among low, mid and high channels:

$$\boldsymbol{s(i)} = min\{s_{low}(i), s_{mid}(i), s_{high}(i)\},\ i \in single\ beams \qquad (2)$$

and this scaling factor applies to the input power at each antenna port.

9.2. 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 ∅, the scaling factor was obtained by the below equation for low, mid and high channels:

$$s(i)_{low\_or\_mid\_or\_high} = \frac{PD\ design\ target}{total\ PD\ (\emptyset(i)_{worstcase})}, i \in beam\ pairs \qquad (3)$$

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:

$$\boldsymbol{s(i)} = min\{s_{low}(i), s_{mid}(i), s_{high}(i)\},\ i \in beam\ pairs \qquad (4)$$

9.3. *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 (Δmin) determined in Table 8, given by:

For n260 and n261

$$input.power.limit(i) = 6\ dBm + 10 * \log(s(i)) + \ \Delta_{min},\ i \in all\ beams \qquad (5)$$

where 6 dBm is the input power used in simulation for n261 and n260, respectively; $s(i)$ is the scaling factor obtained from Eq. (2) or Eq. (4) for beam i; Δmin is the worst-case housing influence factor (determined in Table 8) for beam i.

If simulation overestimates the housing influence, then Δmin (= 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 Δmin 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 Δmin 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 < Δmin < TxAGC uncertainty,

$$input.power.limit(i) = 6\ dBm + 10 * \log(s(i)),\ i \in all\ beams, \text{ for n260 and n261} \quad (6)$$

else if Δmin < -TxAGC uncertainty,

$$input.power.limit(i) = 6\ dBm + 10 * \log(s(i)) + (\Delta_{min} + \text{TxAGC uncertainty}),$$
$$i \in all\ beams, \text{ for n260 and n261} \quad (7)$$

else if Δmin > TxAGC uncertainty,

$$input.power.limit(i) = 6\ dBm + 10 * \log(s(i)) + (\Delta_{min} - \text{TxAGC uncertainty}),$$
$$i \in all\ beams, \text{ for n260 and n261} \quad (8)$$

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	△min (dB)	TxAGC Uncertainty (dB)	*input.power.limit* (dBm)	Notes
n261	K (patch)	1.99	0.50	*input.power.limit(i)* = 6 dBm + 10 x log(S(i)) + 1.49	Using Eq.6
	L (patch)	1.98	0.50	*input.power.limit(i)* = 6 dBm + 10 x log(S(i)) + 1.48	Using Eq.8
n260	K (patch)	1.28	0.50	*input.power.limit(i)* = 6 dBm + 10 x log(S(i)) + 0.78	Using Eq.8
	L (patch)	-0.18	0.50	*input.power.limit(i)* = 6 dBm + 10 x log(S(i))	Using Eq.8

Table 15
5G NR n261 K patch *input.power.limit*

Antenna	Beam ID_1	Beam ID_2	input.power.limit (dBm)
K patch	0		10.8
	2		11.5
	4		8.7
	5		6.8
	6		7.1
	7		8.9
	12		7.2
	13		7.9
	14		9.0
	18		5.3
	19		4.3
	20		4.8
	21		4.8
	22		7.1
	28		4.5
	29		4.5
	30		4.7
	31		5.7
		128	10.6
		130	13.1
		132	9.0
		133	7.4
		134	7.5
		135	8.5
		140	8.2
		141	8.8
		142	8.6
		146	7.1
		147	5.5
		148	5.3
		149	5.8
		150	6.3
		156	6.3
		157	5.2
		158	5.5
		159	6.0
	0	128	7.7
	2	130	9.0
	4	132	6.3
	5	133	4.0
	6	134	4.1
	7	135	5.5
	12	140	4.5
	13	141	6.0
	14	142	5.8
	18	146	2.4
	19	147	1.9
	20	148	1.8
	21	149	1.6
	22	150	3.0
	28	156	1.9
	29	157	2.0
	30	158	1.6
	31	159	2.3

Table 16
5G NR n261 L patch *input.power.limit*

Antenna	Beam ID_1	Beam ID_2	input.power.limit (dBm)
L patch	1		**9.7**
	3		**10.8**
	8		**7.5**
	9		**6.7**
	10		**6.4**
	11		**7.7**
	15		**7.4**
	16		**6.3**
	17		**7.1**
	23		**5.2**
	24		**4.1**
	25		**4.3**
	26		**4.2**
	27		**5.2**
	32		**4.4**
	33		**4.1**
	34		**4.4**
	35		**4.4**
		129	**11.2**
		131	**12.7**
		136	**9.2**
		137	**8.0**
		138	**9.5**
		139	**10.3**
		143	**8.6**
		144	**8.0**
		145	**9.3**
		151	**6.4**
		152	**5.9**
		153	**5.7**
		154	**5.9**
		155	**7.7**
		160	**6.2**
		161	**5.7**
		162	**5.7**
		163	**7.1**
	1	129	**7.2**
	3	131	**8.7**
	8	136	**5.2**
	9	137	**4.5**
	10	138	**4.4**
	11	139	**5.1**
	15	143	**4.8**
	16	144	**4.1**
	17	145	**4.4**
	23	151	**2.0**
	24	152	**2.1**
	25	153	**2.1**
	26	154	**1.6**
	27	155	**2.2**
	32	160	**1.9**
	33	161	**2.2**
	34	162	**1.9**
	35	163	**1.8**

Table 17
5G NR n260 K patch *input.power.limit*

Antenna	Beam ID_1	Beam ID_2	input.power.limit (dBm)
K patch	0		**11.8**
	2		**10.6**
	5		**7.9**
	6		**8.5**
	7		**7.9**
	8		**8.1**
	13		**8.1**
	14		**9.1**
	15		**8.2**
	19		**5.7**
	20		**6.2**
	21		**5.3**
	22		**6.7**
	23		**5.2**
	29		**5.9**
	30		**6.1**
	31		**5.7**
	32		**5.6**
		128	**10.9**
		130	**11.9**
		133	**9.8**
		134	**9.3**
		135	**8.9**
		136	**8.7**
		141	**7.8**
		142	**9.5**
		143	**8.7**
		147	**5.9**
		148	**5.6**
		149	**6.2**
		150	**7.0**
		151	**5.7**
		157	**5.6**
		158	**5.7**
		159	**6.8**
		160	**6.0**
	0	128	**7.8**
	2	130	**7.8**
	5	133	**5.5**
	6	134	**5.7**
	7	135	**5.1**
	8	136	**5.0**
	13	141	**5.0**
	14	142	**6.1**
	15	143	**4.9**
	19	147	**2.0**
	20	148	**2.4**
	21	149	**2.6**
	22	150	**2.6**
	23	151	**2.0**
	29	157	**2.4**
	30	158	**2.7**
	31	159	**2.8**
	32	160	**2.2**

Table 18
5G NR n260 L patch *input.power.limit*

Antenna	Beam ID_1	Beam ID_2	input.power.limit (dBm)
L patch	1		11.7
	3		9.7
	4		9.5
	9		7.1
	10		7.8
	11		7.2
	12		7.9
	16		7.9
	17		6.2
	18		6.8
	24		5.1
	25		4.8
	26		4.5
	27		5.1
	28		5.2
	33		4.9
	34		4.7
	35		5.1
	36		5.1
		129	10.1
		131	10.0
		132	11.2
		137	8.2
		138	7.4
		139	7.5
		140	7.8
		144	8.1
		145	7.1
		146	7.4
		152	6.3
		153	5.9
		154	5.0
		155	5.3
		156	6.0
		161	6.1
		162	5.6
		163	4.9
		164	5.7
	1	129	7.4
	3	131	6.6
	4	132	6.9
	9	137	4.4
	10	138	4.4
	11	139	3.7
	12	140	4.1
	16	144	4.5
	17	145	3.2
	18	146	4.0
	24	152	2.3
	25	153	1.9
	26	154	1.7
	27	155	1.1
	28	156	1.2
	33	161	2.3
	34	162	1.7
	35	163	1.4
	36	164	1.3

END OF REPORT