ELECTRONICS

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Part #0 Power Density Report

Power Density Characterization

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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 mmWave antenna modules installed inside the device. This device has a patch antenna arrays

As showed in Figure 1 and 2, 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	condition	Back	Front	Top	Bottom	Right	Left
NR n258	J	Closed	Yes	Yes	Yes	No	Yes	No
NR n260	J	Closed	Yes	Yes	Yes	No	Yes	No
NR n261	J	Closed	Yes	Yes	Yes	No	Yes	No
NR n258	J	Open	Yes	Yes	Yes	No	Yes	No
NR n260	J	Open	Yes	Yes	Yes	No	Yes	No
NR n261	J	Open	Yes	Yes	Yes	No	Yes	No

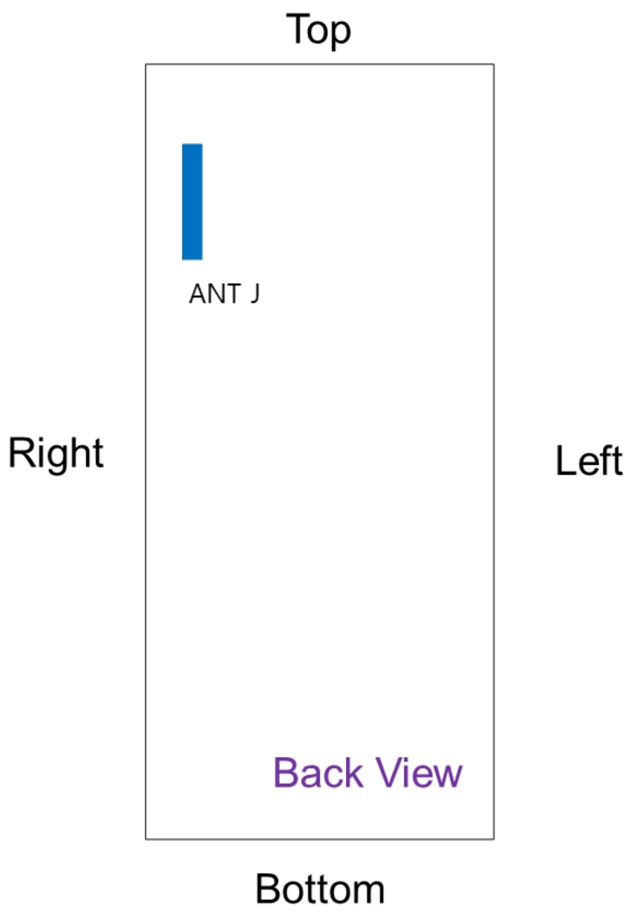

Figure 1: Location of mmW antenna modules looking from back of the DUT - Closed

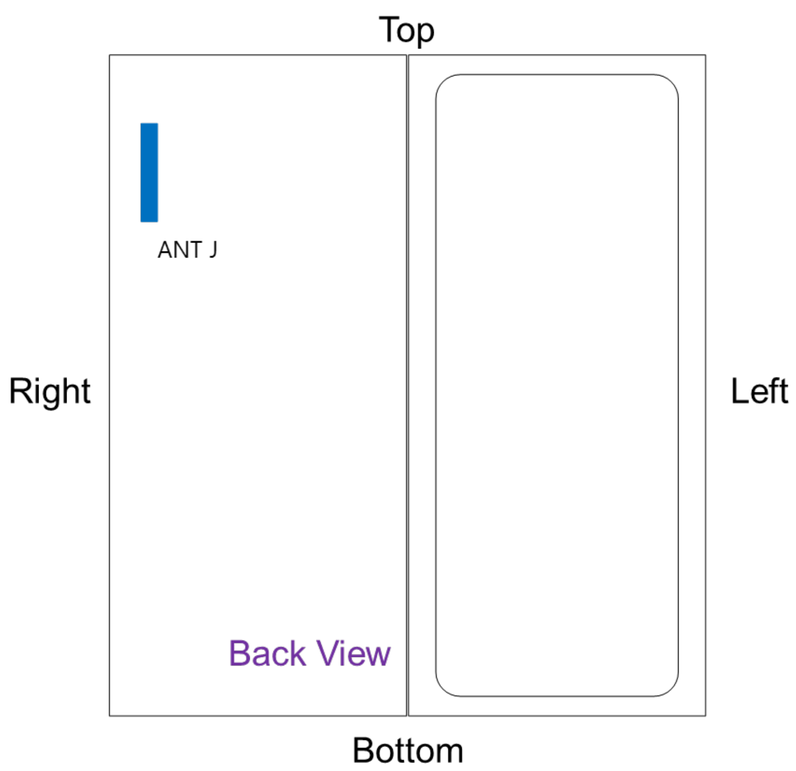

Figure 2: Location of mmW antenna modules looking from back of the DUT – Open

2. Power Density Characterization Method

Simulation modeling and validation

- Correlate the simulated PD distributions with measured PD distribution for the selected beams to validate simulation model

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Uncertainty Budget

- Calculate the total device design uncertainty to include worst case RF tune-up accuracy and device-to-device variation

↓

PD_design_target

Specify a power density design target, which should be less than power density regulatory limit to account for the total device design uncertainties

↓

Worst-case housing material Influence Quantification

- Determine

Δ_{min} = *min{simulated PD@reference_power – measured PD@reference_power}*

to quantify the worst-case housing influence

↓

PD Char Generation

- Use validated simulation approach to determine input power limit for all the beams after accounting for the worst-case housing influence

3. Codebook for all supported beams

Table 2. 5G mmW NR Band n258 Ant J Codebook

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

Table 3. 5G mmW NR Band n260 Ant J Codebook

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

Table 4. 5G mmW NR Band n261 Ant J Codebook

Band	Module	Type(P or D)	Beam ID	Feed no.	Paried With
n261	J	Patch	0	1	256
			1	1	257
			2	1	258
			3	1	259
			4	1	260
			5	2	261
			6	2	262
			7	2	263
			8	2	264
			9	2	265
			10	2	266
			11	2	267
			12	5	268
			13	5	269
			14	5	270
			15	5	271
			16	5	272
			17	5	273
			18	5	274
			19	5	275
			20	5	276
			256	1	0
			257	1	1
			258	1	2
			259	1	3
			260	1	4
			261	2	5
			262	2	6
			263	2	7
			264	2	8
			265	2	9
			266	2	10
			267	2	11
			268	5	12
			269	5	13
			270	5	14
			271	5	15
			272	5	16
			273	5	17
			274	5	18
			275	5	19
			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 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 cannel 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. Simulated and Measure PD

Condition	Band	Channel	Module	Side	Beam ID	Sim. PD (mW/cm2)	Meas. PD (mW/cm2)	Delta=Sim. - Meas. (dB)
Folder Closed	n261	Mid Ch. 2077915 (27924.96 MHz)	J	Right	14	1.66	0.398	6.19
					271	2.01	0.597	5.26
				Back	273	1.80	0.727	3.93
	n260	Mid Ch. 2254165 (38499.96 MHz)		Right	18	1.84	0.543	5.31
					274	1.60	0.67	3.78
				Back	20	1.35	0.422	5.06
					274	0.83	0.267	4.90
				Top	12	1.02	0.334	4.84
	n258	Mid Ch. 2025833 (24800.04 MHz)		Right	19	1.41	0.641	3.41
					270	2.10	0.67	4.96
				Back	268	1.82	0.498	5.63
Condition	**Band**	**Channel**	**Module**	**Side**	**Beam ID**	**Sim. PD (mW/cm2)**	**Meas. PD (mW/cm2)**	**Delta=Sim. - Meas. (dB)**
Folder Open	n261	Mid Ch. 2077915 (27924.96 MHz)	J	Right	14	1.77	0.441	6.03
					273	2.03	0.695	4.66
				Front	14	1.34	0.283	6.76
					268	1.60	0.123	11.14
	n260	Mid Ch. 2254165 (38499.96 MHz)		Right	18	1.79	0.463	5.86
					274	1.81	0.778	3.67
				Front	18	1.46	0.176	9.19
					274	1.31	0.277	6.74
	n258	Mid Ch. 2025833 (24800.04 MHz)		Right	19	1.55	0.561	4.42
					273	1.98	0.516	5.84
				Front	19	1.15	0.353	5.14
					268	1.46	0.0689	13.27
				Back	273	1.01	0.732	1.39

5. PD design target

Table 6. PD design target

PD_design_target	
$PD\_design\_target < \mathrm{PD}_{regulatory\_limit} \times 10^{\frac{-total\ uncertainty}{10}}$	
psPD over 4 cm² Averaging Area (mW/cm²)	
Total Uncertainty	1.4 dB
PD_regulatory_limit	1.0 mW/cm²
PD_design_target	0.724 mW/cm²

6. Δmin

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 cannel of each band.
2. For identified worst surface(s) per antenna module and per antenna type group,
    a. First determine 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 4cm² PD at 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. Demonstrated all measured 4cam2 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 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 cm^2 PD for all the single beams per each antenna type and each antenna module group in the mid cannel of n258, n260 and n261 bands are identified as in following table :

Table 7. Worst-surface(s) for ANT J

Band/Mode	Antenna Module	condition	Back	Front	Top	Bottom	Right	Left
NR n258	J	Closed	Yes	No	No	No	Yes	No
NR n260	J	Closed	Yes	No	Yes	No	Yes	No
NR n261	J	Closed	Yes	No	No	No	Yes	No
NR n258	J	Open	No	Yes	No	No	Yes	No
NR n260	J	Open	No	Yes	No	No	Yes	No
NR n261	J	Open	Yes	Yes	No	No	Yes	No

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 Table 8. Thus, the worst-case housing influence, denoted as Δmin = Sim. PD − Meas. PD , is determined as

Table 8. Δmin for Ant J

Condition	Band	Antenna	Δmin (dB)
Folder Closed	NR n258	J	3.93
	NR n260	J	3.78
	NR n261	J	3.41
Folder Open	NR n258	J	4.66
	NR n260	J	3.67
	NR n261	J	1.39

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 7.

Simulated 4cm2 PD values in Power Density Simulation Report are scaled to input.power.limit and are listed in Tables blow 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 bleow:

Table 9. Non-Selected Surface(s) for Ant J

Band/Mode	Antenna Module	condition	Back	Front	Top	Bottom	Right	Left
NR n258	J	Closed	No	Yes	Yes	No	No	No
NR n260	J	Closed	No	Yes	No	No	No	No
NR n261	J	Closed	No	Yes	Yes	No	No	No
NR n258	J	Open	No	No	Yes	No	No	No
NR n260	J	Open	Yes	No	Yes	No	No	No
NR n261	J	Open	Yes	No	Yes	No	No	No

Then perform PD measurement for all determined worst-case beam, highlighted in orange in the tables blow, 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, J Patch simulated 4cm² PD at PD_design_Target (if simulation performed with correct housing material properties) (Δmin) - closed

Antenna	Beam ID_1	Simulated 4cm2 PD (mW/cm2) 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)
J	0	0.702	0.026	0.045	0.006	0.188	0.213
J	1	0.724	0.019	0.045	0.006	0.199	0.154
J	2	0.724	0.019	0.056	0.006	0.176	0.188
J	3	0.721	0.023	0.109	0.007	0.148	0.224
J	4	0.672	0.026	0.122	0.007	0.155	0.232
J	5	0.718	0.024	0.065	0.012	0.200	0.230
J	6	0.724	0.031	0.019	0.006	0.257	0.190
J	7	0.724	0.032	0.025	0.005	0.257	0.188
J	8	0.724	0.032	0.034	0.004	0.253	0.193
J	9	0.724	0.033	0.011	0.008	0.249	0.209
J	10	0.724	0.031	0.019	0.006	0.257	0.190
J	11	0.724	0.026	0.125	0.004	0.172	0.278
J	12	0.656	0.045	0.023	0.010	0.203	0.240
J	13	0.685	0.054	0.011	0.009	0.248	0.228
J	14	0.724	0.066	0.043	0.003	0.327	0.248
J	15	0.724	0.050	0.078	0.004	0.252	0.283
J	16	0.687	0.046	0.173	0.008	0.220	0.302
J	17	0.662	0.049	0.016	0.010	0.223	0.226
J	18	0.724	0.055	0.028	0.005	0.294	0.240
J	19	0.724	0.062	0.020	0.002	0.306	0.275
J	20	0.717	0.048	0.130	0.007	0.235	0.300
J	256	0.703	0.002	0.081	0.002	0.035	0.506
J	257	0.724	0.005	0.091	0.002	0.033	0.508
J	258	0.717	0.005	0.088	0.003	0.035	0.499
J	259	0.722	0.005	0.117	0.005	0.034	0.512
J	260	0.722	0.003	0.143	0.005	0.034	0.519
J	261	0.722	0.004	0.016	0.005	0.038	0.592
J	262	0.709	0.002	0.009	0.002	0.040	0.545
J	263	0.721	0.002	0.055	0.001	0.044	0.524
J	264	0.724	0.001	0.152	0.002	0.042	0.567
J	265	0.708	0.003	0.016	0.003	0.040	0.553
J	266	0.713	0.002	0.020	0.001	0.043	0.515
J	267	0.724	0.002	0.130	0.001	0.044	0.535
J	268	0.724	0.003	0.018	0.009	0.045	0.683
J	269	0.701	0.003	0.011	0.001	0.056	0.562
J	270	0.709	0.003	0.009	0.001	0.067	0.538
J	271	0.724	0.004	0.078	0.000	0.069	0.544
J	272	0.724	0.003	0.284	0.001	0.054	0.645
J	273	0.712	0.003	0.005	0.004	0.049	0.625
J	274	0.703	0.004	0.015	0.001	0.061	0.542
J	275	0.715	0.003	0.013	0.000	0.069	0.539
J	276	0.724	0.003	0.152	0.000	0.061	0.564

Table 11. n260/mid channel, J Patch simulated 4cm^2 PD at PD_design_Target (if simulation performed with correct housing material properties) (Δmin) - closed

Antenna	Beam ID_1	Simulated 4cm2 PD (mW/cm2) 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)
J	0	0.724	0.007	0.074	0.002	0.060	0.414
J	1	0.722	0.009	0.088	0.004	0.062	0.390
J	2	0.724	0.006	0.156	0.004	0.045	0.425
J	3	0.724	0.011	0.238	0.002	0.057	0.416
J	4	0.724	0.007	0.226	0.002	0.042	0.426
J	5	0.720	0.006	0.270	0.006	0.051	0.468
J	6	0.706	0.009	0.166	0.001	0.071	0.474
J	7	0.721	0.007	0.110	0.004	0.064	0.467
J	8	0.673	0.010	0.182	0.004	0.056	0.428
J	9	0.724	0.009	0.421	0.003	0.053	0.523
J	10	0.724	0.007	0.081	0.001	0.073	0.488
J	11	0.719	0.007	0.328	0.005	0.057	0.555
J	12	0.724	0.005	0.478	0.004	0.083	0.628
J	13	0.607	0.010	0.093	0.001	0.072	0.426
J	14	0.724	0.015	0.018	0.000	0.101	0.501
J	15	0.724	0.011	0.274	0.007	0.083	0.513
J	16	0.724	0.004	0.458	0.005	0.086	0.611
J	17	0.715	0.010	0.595	0.002	0.046	0.724
J	18	0.724	0.007	0.014	0.000	0.084	0.513
J	19	0.706	0.019	0.120	0.001	0.099	0.490
J	20	0.724	0.004	0.341	0.008	0.094	0.571
J	256	0.699	0.012	0.022	0.005	0.132	0.252
J	257	0.679	0.013	0.045	0.005	0.124	0.293
J	258	0.687	0.013	0.053	0.004	0.103	0.296
J	259	0.724	0.013	0.109	0.005	0.142	0.282
J	260	0.653	0.013	0.141	0.002	0.132	0.215
J	261	0.699	0.012	0.138	0.005	0.086	0.328
J	262	0.617	0.016	0.038	0.001	0.150	0.299
J	263	0.688	0.018	0.107	0.010	0.108	0.275
J	264	0.670	0.014	0.086	0.009	0.087	0.280
J	265	0.716	0.011	0.035	0.002	0.156	0.319
J	266	0.633	0.015	0.034	0.007	0.144	0.289
J	267	0.716	0.015	0.138	0.008	0.094	0.303
J	268	0.636	0.012	0.230	0.007	0.110	0.343
J	269	0.690	0.010	0.058	0.002	0.172	0.339
J	270	0.578	0.021	0.030	0.002	0.147	0.290
J	271	0.714	0.026	0.320	0.023	0.174	0.344
J	272	0.686	0.015	0.241	0.004	0.131	0.368
J	273	0.724	0.027	0.233	0.003	0.153	0.410
J	274	0.636	0.037	0.012	0.001	0.170	0.327
J	275	0.573	0.020	0.106	0.002	0.150	0.237
J	276	0.603	0.012	0.241	0.018	0.115	0.337

Table 12. n261/mid channel, J Patch simulated 4cm² PD at PD_design_Target (if simulation performed with correct housing material properties) (Δmin) - closed

Antenna	Beam ID_1	Simulated 4cm2 PD (mW/cm2) 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)
J	0	0.703	0.024	0.040	0.005	0.178	0.202
J	1	0.703	0.016	0.042	0.005	0.178	0.199
J	2	0.645	0.016	0.065	0.008	0.147	0.223
J	3	0.724	0.016	0.079	0.005	0.144	0.233
J	4	0.724	0.021	0.109	0.006	0.171	0.222
J	5	0.724	0.040	0.140	0.010	0.150	0.238
J	6	0.717	0.023	0.016	0.003	0.239	0.248
J	7	0.724	0.033	0.165	0.004	0.204	0.298
J	8	0.674	0.025	0.115	0.007	0.157	0.277
J	9	0.714	0.025	0.009	0.003	0.236	0.249
J	10	0.719	0.024	0.043	0.002	0.232	0.244
J	11	0.708	0.022	0.181	0.007	0.186	0.305
J	12	0.667	0.034	0.096	0.022	0.115	0.265
J	13	0.724	0.037	0.015	0.008	0.250	0.247
J	14	0.674	0.041	0.013	0.002	0.257	0.315
J	15	0.710	0.051	0.134	0.005	0.241	0.316
J	16	0.693	0.031	0.288	0.006	0.163	0.278
J	17	0.707	0.030	0.032	0.013	0.196	0.244
J	18	0.724	0.047	0.016	0.002	0.254	0.273
J	19	0.674	0.053	0.054	0.004	0.252	0.309
J	20	0.700	0.037	0.228	0.004	0.188	0.280
J	256	0.718	0.002	0.097	0.002	0.035	0.515
J	257	0.724	0.004	0.103	0.004	0.033	0.484
J	258	0.722	0.004	0.099	0.004	0.040	0.484
J	259	0.724	0.004	0.134	0.007	0.033	0.475
J	260	0.718	0.002	0.132	0.005	0.036	0.491
J	261	0.718	0.006	0.228	0.016	0.034	0.574
J	262	0.724	0.003	0.023	0.003	0.047	0.525
J	263	0.724	0.003	0.059	0.000	0.048	0.511
J	264	0.724	0.007	0.235	0.007	0.040	0.570
J	265	0.724	0.004	0.041	0.005	0.039	0.573
J	266	0.724	0.003	0.091	0.000	0.047	0.510
J	267	0.724	0.009	0.267	0.009	0.040	0.573
J	268	0.721	0.004	0.043	0.015	0.036	0.705
J	269	0.724	0.003	0.011	0.002	0.058	0.623
J	270	0.724	0.003	0.019	0.001	0.070	0.523
J	271	0.724	0.002	0.144	0.000	0.063	0.546
J	272	0.724	0.005	0.443	0.003	0.042	0.676
J	273	0.724	0.003	0.025	0.009	0.046	0.686
J	274	0.724	0.003	0.013	0.001	0.071	0.553
J	275	0.724	0.003	0.046	0.001	0.072	0.524
J	276	0.724	0.002	0.276	0.001	0.048	0.605

Table 13. n258/mid channel, J Patch simulated 4cm² PD at PD_design_Target (if simulation performed with correct housing material properties) (Δmin) - open

Antenna	Beam ID_1	Simulated 4cm2 PD (mW/cm2) 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)
J	0	0.684	0.003	0.029	0.003	0.513	0.283
J	1	0.687	0.003	0.031	0.003	0.519	0.261
J	2	0.682	0.003	0.045	0.003	0.485	0.273
J	3	0.684	0.003	0.078	0.003	0.502	0.273
J	4	0.671	0.003	0.106	0.000	0.452	0.305
J	5	0.672	0.002	0.052	0.004	0.527	0.299
J	6	0.693	0.002	0.012	0.001	0.505	0.299
J	7	0.696	0.002	0.019	0.001	0.507	0.300
J	8	0.698	0.002	0.028	0.000	0.510	0.300
J	9	0.689	0.002	0.005	0.001	0.505	0.299
J	10	0.693	0.002	0.012	0.001	0.505	0.299
J	11	0.689	0.003	0.099	0.000	0.487	0.319
J	12	0.662	0.005	0.025	0.004	0.504	0.307
J	13	0.680	0.005	0.009	0.002	0.498	0.301
J	14	0.700	0.004	0.029	0.000	0.523	0.342
J	15	0.697	0.004	0.067	0.000	0.493	0.325
J	16	0.688	0.004	0.161	0.001	0.471	0.342
J	17	0.670	0.004	0.020	0.003	0.498	0.299
J	18	0.693	0.005	0.022	0.000	0.506	0.311
J	19	0.701	0.004	0.010	0.000	0.521	0.345
J	20	0.693	0.005	0.119	0.001	0.481	0.333
J	256	0.713	0.000	0.032	0.005	0.507	0.290
J	257	0.720	0.000	0.048	0.005	0.489	0.292
J	258	0.717	0.000	0.071	0.002	0.489	0.291
J	259	0.708	0.000	0.095	0.002	0.491	0.288
J	260	0.705	0.000	0.121	0.005	0.490	0.296
J	261	0.709	0.001	0.026	0.006	0.519	0.331
J	262	0.724	0.001	0.004	0.003	0.507	0.334
J	263	0.724	0.001	0.037	0.000	0.501	0.322
J	264	0.715	0.001	0.074	0.002	0.537	0.322
J	265	0.722	0.001	0.006	0.004	0.512	0.336
J	266	0.724	0.001	0.019	0.001	0.491	0.324
J	267	0.720	0.000	0.108	0.000	0.493	0.326
J	268	0.713	0.001	0.008	0.008	0.548	0.368
J	269	0.723	0.001	0.009	0.001	0.506	0.370
J	270	0.724	0.000	0.008	0.001	0.512	0.372
J	271	0.723	0.001	0.051	0.000	0.506	0.358
J	272	0.702	0.000	0.209	0.001	0.525	0.337
J	273	0.724	0.001	0.005	0.003	0.517	0.368
J	274	0.724	0.001	0.010	0.001	0.512	0.373
J	275	0.724	0.001	0.009	0.000	0.509	0.368
J	276	0.713	0.000	0.129	0.000	0.498	0.339

Table 14. n260/mid channel, J Patch simulated 4cm² PD at PD_design_Target (if simulation performed with correct housing material properties) (Δmin) - open

Antenna	Beam ID_1	Simulated 4cm2 PD (mW/cm2) 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)
J	0	0.724	0.000	0.039	0.003	0.543	0.279
J	1	0.724	0.002	0.054	0.004	0.557	0.264
J	2	0.724	0.002	0.111	0.004	0.540	0.254
J	3	0.724	0.002	0.201	0.002	0.595	0.267
J	4	0.724	0.000	0.205	0.002	0.510	0.275
J	5	0.673	0.001	0.155	0.006	0.489	0.223
J	6	0.724	0.002	0.163	0.000	0.638	0.246
J	7	0.719	0.001	0.086	0.005	0.555	0.312
J	8	0.673	0.001	0.090	0.004	0.522	0.241
J	9	0.724	0.003	0.361	0.003	0.648	0.274
J	10	0.724	0.001	0.063	0.001	0.586	0.289
J	11	0.660	0.001	0.238	0.004	0.528	0.336
J	12	0.724	0.001	0.356	0.004	0.604	0.392
J	13	0.615	0.002	0.116	0.001	0.539	0.212
J	14	0.724	0.001	0.013	0.001	0.588	0.308
J	15	0.675	0.001	0.217	0.007	0.497	0.333
J	16	0.724	0.000	0.334	0.004	0.602	0.378
J	17	0.707	0.003	0.539	0.001	0.656	0.349
J	18	0.724	0.001	0.013	0.000	0.593	0.289
J	19	0.724	0.001	0.083	0.001	0.541	0.364
J	20	0.724	0.000	0.267	0.008	0.555	0.353
J	256	0.703	0.000	0.017	0.002	0.506	0.264
J	257	0.708	0.000	0.028	0.005	0.454	0.294
J	258	0.669	0.000	0.042	0.002	0.441	0.271
J	259	0.724	0.002	0.074	0.004	0.460	0.290
J	260	0.646	0.000	0.116	0.002	0.406	0.279
J	261	0.724	0.001	0.118	0.006	0.427	0.280
J	262	0.642	0.001	0.026	0.000	0.459	0.293
J	263	0.703	0.001	0.074	0.008	0.434	0.272
J	264	0.714	0.001	0.080	0.007	0.390	0.278
J	265	0.713	0.000	0.028	0.002	0.484	0.268
J	266	0.672	0.001	0.019	0.005	0.473	0.293
J	267	0.722	0.001	0.118	0.008	0.407	0.254
J	268	0.724	0.001	0.225	0.007	0.406	0.323
J	269	0.691	0.001	0.056	0.000	0.503	0.305
J	270	0.618	0.001	0.023	0.001	0.445	0.290
J	271	0.724	0.001	0.244	0.019	0.483	0.327
J	272	0.724	0.001	0.216	0.004	0.435	0.329
J	273	0.724	0.001	0.172	0.002	0.494	0.315
J	274	0.656	0.001	0.012	0.000	0.474	0.297
J	275	0.639	0.002	0.085	0.002	0.459	0.294
J	276	0.724	0.001	0.274	0.019	0.447	0.343

Table 15. n261/mid channel, J Patch simulated 4cm² PD at PD_design_Target (if simulation performed with correct housing material properties) (Δmin) – open

Antenna	Beam ID_1	Simulated 4cm2 PD (mW/cm2) 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)
J	0	0.699	0.000	0.026	0.002	0.476	0.256
J	1	0.696	0.000	0.037	0.000	0.481	0.243
J	2	0.701	0.000	0.048	0.000	0.491	0.252
J	3	0.698	0.000	0.073	0.000	0.485	0.248
J	4	0.699	0.000	0.111	0.000	0.482	0.252
J	5	0.678	0.002	0.120	0.002	0.449	0.245
J	6	0.712	0.001	0.012	0.000	0.515	0.292
J	7	0.702	0.001	0.161	0.000	0.510	0.297
J	8	0.692	0.002	0.096	0.002	0.508	0.289
J	9	0.709	0.001	0.006	0.000	0.513	0.293
J	10	0.710	0.001	0.036	0.000	0.512	0.290
J	11	0.694	0.002	0.143	0.002	0.503	0.294
J	12	0.652	0.003	0.042	0.006	0.465	0.260
J	13	0.703	0.003	0.012	0.001	0.513	0.295
J	14	0.714	0.002	0.012	0.000	0.542	0.328
J	15	0.708	0.003	0.138	0.000	0.525	0.322
J	16	0.667	0.001	0.242	0.001	0.462	0.268
J	17	0.682	0.002	0.017	0.002	0.482	0.274
J	18	0.713	0.003	0.012	0.000	0.533	0.310
J	19	0.714	0.003	0.036	0.000	0.541	0.327
J	20	0.682	0.001	0.229	0.001	0.476	0.283
J	256	0.724	0.000	0.048	0.005	0.510	0.287
J	257	0.724	0.002	0.052	0.004	0.491	0.266
J	258	0.724	0.000	0.067	0.004	0.494	0.276
J	259	0.724	0.000	0.098	0.004	0.490	0.271
J	260	0.724	0.000	0.124	0.004	0.490	0.286
J	261	0.724	0.001	0.204	0.011	0.548	0.296
J	262	0.724	0.001	0.016	0.003	0.506	0.320
J	263	0.724	0.001	0.043	0.000	0.494	0.315
J	264	0.723	0.001	0.140	0.006	0.506	0.311
J	265	0.724	0.001	0.019	0.005	0.527	0.324
J	266	0.724	0.001	0.069	0.000	0.492	0.314
J	267	0.724	0.001	0.192	0.007	0.496	0.317
J	268	0.724	0.001	0.020	0.015	0.584	0.359
J	269	0.724	0.001	0.013	0.002	0.521	0.361
J	270	0.724	0.000	0.015	0.001	0.499	0.331
J	271	0.724	0.000	0.114	0.000	0.503	0.347
J	272	0.724	0.002	0.329	0.002	0.539	0.352
J	273	0.724	0.001	0.024	0.009	0.556	0.361
J	274	0.724	0.001	0.014	0.001	0.523	0.358
J	275	0.724	0.001	0.031	0.001	0.506	0.338
J	276	0.724	0.000	0.200	0.001	0.509	0.331

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 and input.power.limit in Section 7.

Table 16. 4cm² PD of the selected beams measured on the corresponding surfaces that are not selected for Δmin determination – closed

Band	Antenna	Beam ID	Surface	Tested Power Level (dBm)	input.power.limit (dBm)	Meas. 4cm2 PD (mW/cm2)
n258	J	14	Front	6.3	6.3	0.298
		272	Top	5.2	5.2	0.189
n260		271	Front	7.9	7.9	0.104
n261		14	Front	5.6	5.6	0.204
		272	Top	6.4	6.4	0.239

Table 17. 4cm² PD of the selected beams measured on the corresponding surfaces that are not selected for Δmin determination - open

Band	Antenna	Beam ID	Surface	Tested Power Level (dBm)	input.power.limit (dBm)	Meas. 4cm2 PD (mW/cm2)
n258	J	272	Top	2.9	2.9	0.105
n260		17	Top	7.3	7.3	0.218
		12	Rear	5.9	5.9	0.369
n261		272	Top	6.7	6.7	0.227
		269	Rear	6.0	6.0	0.619

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

1. 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.

Sdfgsdfg$_{sadfasdf}$

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

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

3. 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.

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 ∅, 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:

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

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 $input.power.(i)$, for beam i can be obtained after accounting for the housing influence (Δmin) given by:
For n258,n260 and n261

input.power.limit(i) = 18 dBm + 10 * log(s(i)) + △min, I ∈ all beams (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; Δmin is the worst-case housing influence factor 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 < △min < TxAGC uncertainty,

input.power.limit(i) = 18 dBm + 10 * log(s(i)) + △min, I ∈ all beams (6)

else if △min < - TxAGC uncertainty,

input.power.limit(i) = 18 dBm + 10 * log(s(i)) + (△min + TxAGC uncertainty), I ∈ all beams (7)

else if △min > TxAGC uncertainty,

input.power.limit(i) = 18 dBm + 10 * log(s(i)) + (△min - TxAGC uncertainty), I ∈ all beams (8)

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

Table 18. *input. power. limit* Calculation – closed

Band	Antenna	Δmin	TxAGC Uncertainty	*input.power.limit*	Notes
		(dB)	(dB)	(dBm)	
n258	J	3.93	0.47	*input.power.limit(i) = sim.power_limit + 3.46*	Using Eq.8
n260	J	3.78	0.47	*input.power.limit(i) = sim.power_limit + 3.31*	Using Eq.8
n261	J	3.41	0.47	*input.power.limit(i) = sim.power_limit + 2.94*	Using Eq.8

Table 19. *input. power. limit* Calculation – open

Band	Antenna	Δmin	TxAGC Uncertainty	*input.power.limit*	Notes
		(dB)	(dB)	(dBm)	
n258	J	4.66	0.47	*input.power.limit(i) = sim.power_limit + 4.19*	Using Eq.8
n260	J	3.67	0.47	*input.power.limit(i) = sim.power_limit + 3.20*	Using Eq.8
n261	J	1.39	0.47	*input.power.limit(i) = sim.power_limit + 0.92*	Using Eq.8

Table 20. Permanent backoff

Band	Antenna	Backoff (dB)
NR n258	J	0.50
NR n260	J	0.50
NR n261	J	1.00

Table 21. 5G NR n258 J Patch $input.power.limit$

Band	Beam ID 1	Beam ID 2	input.power.limit
n258	0		11.0
n258	1		11.3
n258	2		11.2
n258	3		11.4
n258	4		11.1
n258	5		9.5
n258	6		6.7
n258	7		6.6
n258	8		6.7
n258	9		7.2
n258	10		6.7
n258	11		7.8
n258	12		4.6
n258	13		3.2
n258	14		3.3
n258	15		3.4
n258	16		3.8
n258	17		3.9
n258	18		3.0
n258	19		3.0
n258	20		3.5
n258		256	10.1
n258		257	10.0
n258		258	10.3
n258		259	10.2
n258		260	10.3
n258		261	7.1
n258		262	6.0
n258		263	6.2
n258		264	7.2
n258		265	6.1
n258		266	5.9
n258		267	6.2
n258		268	2.1
n258		269	2.2
n258		270	2.3
n258		271	2.2
n258		272	2.4
n258		273	2.1
n258		274	2.3
n258		275	2.2
n258		276	2.2
n258	0	256	7.1
n258	1	257	7.3
n258	2	258	7.5
n258	3	259	7.4
n258	4	260	7.4
n258	5	261	4.2
n258	6	262	3.0
n258	7	263	3.1
n258	8	264	3.5
n258	9	265	3.0
n258	10	266	3.1
n258	11	267	3.4
n258	12	268	-0.8
n258	13	269	-0.7
n258	14	270	-0.4
n258	15	271	-0.6
n258	16	272	-0.6
n258	17	273	-0.8
n258	18	274	-0.5
n258	19	275	-0.6
n258	20	276	-0.7

Table 22. 5G NR n260 J Patch *input. power. limit*

Band	Beam ID 1	Beam ID 2	input.power.limit
n260	0		12.7
n260	1		12.1
n260	2		11.4
n260	3		12.3
n260	4		12.4
n260	5		9.5
n260	6		9.1
n260	7		8.2
n260	8		10.2
n260	9		10.3
n260	10		8.1
n260	11		9.0
n260	12		5.4
n260	13		5.5
n260	14		4.7
n260	15		4.7
n260	16		5.3
n260	17		6.8
n260	18		4.6
n260	19		5.0
n260	20		5.0
n260		256	12.7
n260		257	12.7
n260		258	12.1
n260		259	12.8
n260		260	12.2
n260		261	9.6
n260		262	8.5
n260		263	10.2
n260		264	9.8
n260		265	9.6
n260		266	9.4
n260		267	9.9
n260		268	6.6
n260		269	5.1
n260		270	4.8
n260		271	7.3
n260		272	6.7
n260		273	6.7
n260		274	4.7
n260		275	5.7
n260		276	6.9
n260	0	256	9.2
n260	1	257	9.0
n260	2	258	8.5
n260	3	259	9.1
n260	4	260	9.0
n260	5	261	5.7
n260	6	262	5.4
n260	7	263	5.0
n260	8	264	5.9
n260	9	265	6.6
n260	10	266	5.8
n260	11	267	5.2
n260	12	268	1.9
n260	13	269	1.6
n260	14	270	1.1
n260	15	271	1.1
n260	16	272	1.9
n260	17	273	2.1
n260	18	274	1.3
n260	19	275	1.3
n260	20	276	1.4

Table 23. 5G NR n261 J Patch $input.power.limit$

Band	Beam ID 1	Beam ID 2	input.power.limit
n261	0		12.7
n261	1		12.7
n261	2		12.8
n261	3		12.8
n261	4		13.2
n261	5		11.7
n261	6		8.6
n261	7		9.9
n261	8		10.6
n261	9		8.8
n261	10		8.8
n261	11		11.0
n261	12		8.6
n261	13		5.3
n261	14		4.6
n261	15		5.3
n261	16		7.1
n261	17		6.2
n261	18		4.9
n261	19		4.8
n261	20		6.1
n261		256	11.9
n261		257	11.9
n261		258	12.0
n261		259	11.8
n261		260	12.0
n261		261	10.5
n261		262	8.0
n261		263	7.9
n261		264	10.0
n261		265	8.3
n261		266	7.8
n261		267	9.7
n261		268	4.5
n261		269	4.3
n261		270	4.1
n261		271	4.0
n261		272	5.4
n261		273	4.3
n261		274	4.0
n261		275	4.2
n261		276	4.6
n261	0	256	9.4
n261	1	257	9.3
n261	2	258	9.4
n261	3	259	9.1
n261	4	260	9.4
n261	5	261	7.8
n261	6	262	5.6
n261	7	263	6.3
n261	8	264	7.1
n261	9	265	5.5
n261	10	266	5.7
n261	11	267	7.0
n261	12	268	2.8
n261	13	269	1.8
n261	14	270	1.5
n261	15	271	1.6
n261	16	272	2.8
n261	17	273	2.1
n261	18	274	1.5
n261	19	275	1.6
n261	20	276	2.1