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Part 0 PD Characterization

1. Power Density (PD) Characterization

1.1 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 modules installed inside the device. This device has 5 patch antenna arrays (ANT#0, ANT#1).
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

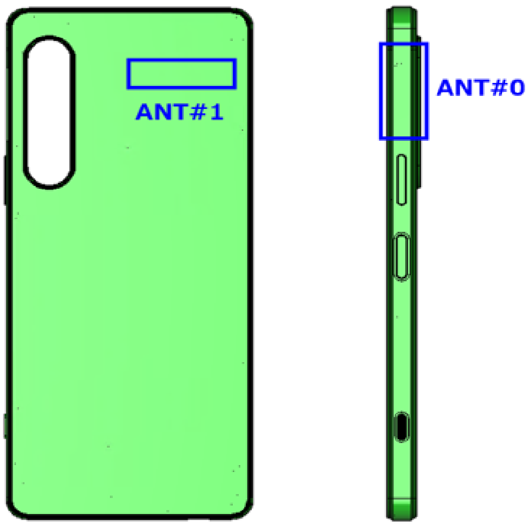
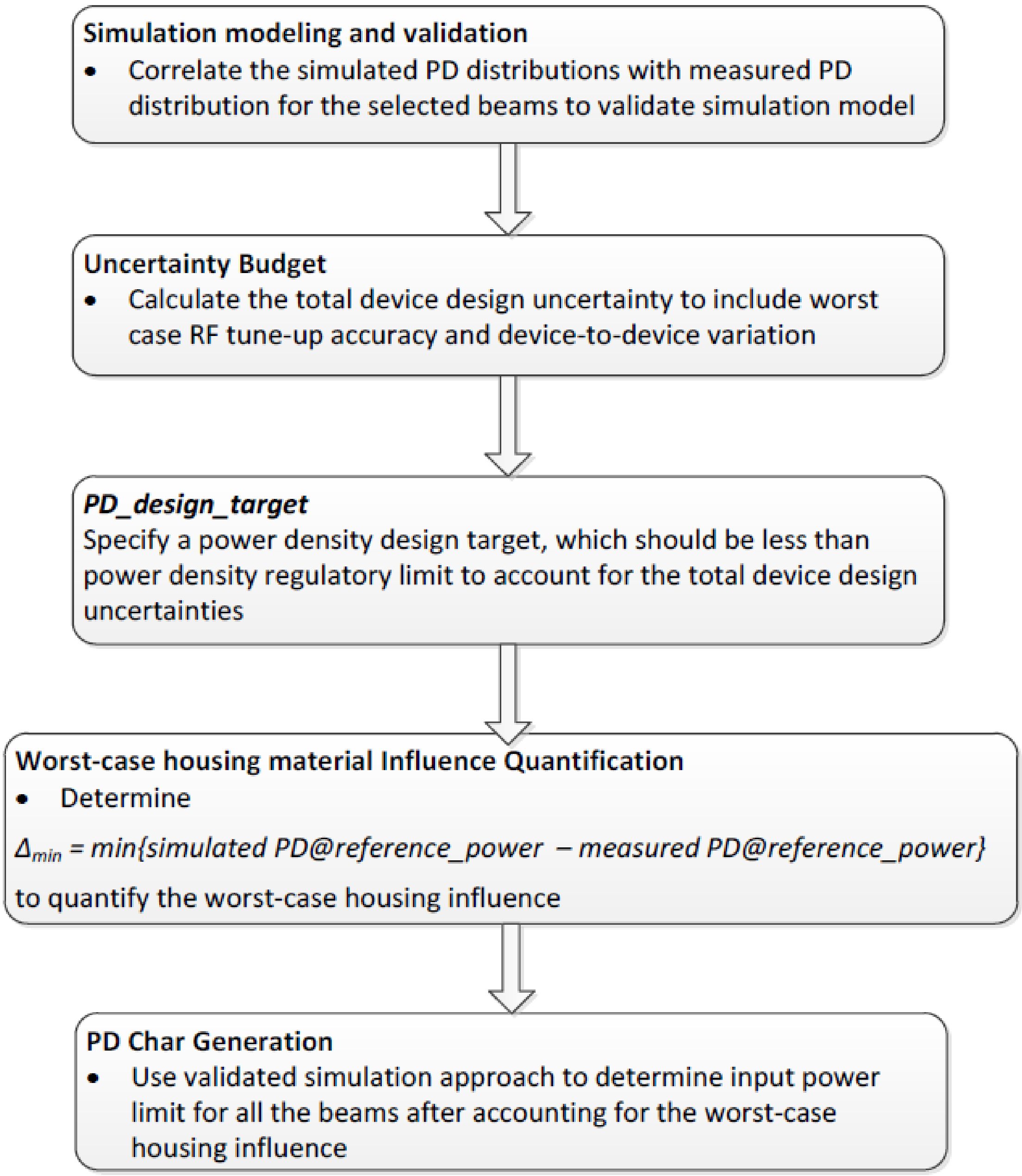


Figure 1: Location of mmWave modules

1.2 Power Density Characterization Method



1.3 Codebook for all supported beams

Table 2
5G mmW NR Band n261 ANT#0 Codebook

Band	Beam ID	Antenna	Ant_Type	Paired_With	# of Ant Feed
261	1	0	PATCH	129	1
261	3	0	PATCH	131	1
261	5	0	PATCH	133	1
261	7	0	PATCH	135	1
261	9	0	PATCH	137	1
261	14	0	PATCH	142	2
261	15	0	PATCH	143	2
261	16	0	PATCH	144	2
261	17	0	PATCH	145	2
261	21	0	PATCH	149	2
261	22	0	PATCH	150	2
261	23	0	PATCH	151	2
261	29	0	PATCH	157	5
261	30	0	PATCH	158	5
261	31	0	PATCH	159	5
261	32	0	PATCH	160	5
261	33	0	PATCH	161	5
261	38	0	PATCH	166	5
261	39	0	PATCH	167	5
261	40	0	PATCH	168	5
261	41	0	PATCH	169	5

Table 3
5G mmW NR Band n261 ANT#1 Codebook

Band	Beam ID	Antenna	Ant_Type	Paired_With	# of Ant Feed
261	0	1	PATCH	128	1
261	2	1	PATCH	130	1
261	4	1	PATCH	132	1
261	6	1	PATCH	134	1
261	8	1	PATCH	136	1
261	10	1	PATCH	138	2
261	11	1	PATCH	139	2
261	12	1	PATCH	140	2
261	13	1	PATCH	141	2
261	18	1	PATCH	146	2
261	19	1	PATCH	147	2
261	20	1	PATCH	148	2
261	24	1	PATCH	152	5
261	25	1	PATCH	153	5
261	26	1	PATCH	154	5
261	27	1	PATCH	155	5
261	28	1	PATCH	156	5
261	34	1	PATCH	162	5
261	35	1	PATCH	163	5
261	36	1	PATCH	164	5
261	37	1	PATCH	165	5

Table 4
5G mmW NR Band n260 ANT#0 Codebook

Band	Beam ID	Antenna	Ant_Type	Paired_With	# of Ant Feed
260	1	0	PATCH	129	1
260	3	0	PATCH	131	1
260	5	0	PATCH	133	1
260	7	0	PATCH	135	1
260	9	0	PATCH	137	1
260	14	0	PATCH	142	2
260	15	0	PATCH	143	2
260	16	0	PATCH	144	2
260	17	0	PATCH	145	2
260	21	0	PATCH	149	2
260	22	0	PATCH	150	2
260	23	0	PATCH	151	2
260	29	0	PATCH	157	5
260	30	0	PATCH	158	5
260	31	0	PATCH	159	5
260	32	0	PATCH	160	5
260	33	0	PATCH	161	5
260	38	0	PATCH	166	5
260	39	0	PATCH	167	5
260	40	0	PATCH	168	5
260	41	0	PATCH	169	5

Table 5
5G mmW NR Band n260 ANT#1 Codebook

Band	Beam ID	Antenna	Ant_Type	Paired_With	# of Ant Feed
260	0	1	PATCH	128	1
260	2	1	PATCH	130	1
260	4	1	PATCH	132	1
260	6	1	PATCH	134	1
260	8	1	PATCH	136	1
260	10	1	PATCH	138	2
260	11	1	PATCH	139	2
260	12	1	PATCH	140	2
260	13	1	PATCH	141	2
260	18	1	PATCH	146	2
260	19	1	PATCH	147	2
260	20	1	PATCH	148	2
260	24	1	PATCH	152	5
260	25	1	PATCH	153	5
260	26	1	PATCH	154	5
260	27	1	PATCH	155	5
260	28	1	PATCH	156	5
260	34	1	PATCH	162	5
260	35	1	PATCH	163	5
260	36	1	PATCH	164	5
260	37	1	PATCH	165	5

1.4 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 per antenna module (ANT#0, ANT#1) 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

					4㎠ ave. PD(W/㎡)		Delta=Sim.-Meas.
Band	Beam ID	Antenna	Surface	Channel	Meas.	Sim.	(dB)
n261	39	ANT#0	Right(S4)	Mid	13.7	20.06	1.66
	168		Right(S4)	Mid	13.1	20.53	1.95
	34	ANT#1	Back(S2)	MId	9.31	11.92	1.07
	163		Back(S2)	Mid	9.03	14.3	2.00
n260	30	ANT#0	Right(S4)	Mid	7.97	13.2	2.19
	160		Right(S4)	Mid	11	16.82	1.84
	24	ANT#1	Back(S2)	MId	5.81	8.83	1.81
	154		Back(S2)	Mid	7.38	11.73	2.01

1.5 PD_design_target

Table 7

PD_design_target	
$PD\_design\_target < PD\_regulatory\_limit \times 10^{\frac{-Total\ Uncertainty}{10}}$	
psPD over 4 cm^2 Averaging Area (mW/cm^2)	
Total Uncertainty	2.1 dB
PD_regulatory_limit	1.0 mW/cm^2
PD_design_target	0.6166 mW/cm^2

1.6 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 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 $4cm^2$ 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 ≥ 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 Table 2 - Table 5 in Sony PD simulation report, the worst-surface(s) having highest $4cm^2$ 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 ANT#0 patch: Right (S4)

b. for ANT#1 patch: Back (S2)

Thus, when comparing a simulated $4cm^2$-averaged PD and measured 4 cm^2-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 10. Thus, the worst-case housing influence, denoted as Δmin = Sim. PD − Meas. PD , is determined as

					4㎠ ave. PD(W/㎡)		Delta=Sim.-Meas.
Band	Beam ID	Antenna	Surface	Channel	Meas.	Sim.	(dB)
n261	39	ANT#0	Right(S4)	Mid	13.7	20.06	1.66
	160		Right(S4)	Mid	9.72	23.2	3.78
	168		Right(S4)	Mid	13.1	20.53	1.95
	28	ANT#1	Back(S2)	MId	5.74	18.38	5.05
	34		Back(S2)	Mid	9.31	11.92	1.07
	153		Back(S2)	Mid	3.82	14.5	5.79
	163		Back(S2)	Mid	9.03	14.3	2.00
n260	30	ANT#0	Right(S4)	Mid	7.97	13.2	2.19
	40		Right(S4)	Mid	9.42	18.64	2.96
	160		Right(S4)	Mid	11	16.82	1.84
	168		Right(S4)	Mid	11	19.37	2.46
	24	ANT#1	Back(S2)	MId	5.81	8.83	1.81
	26		Back(S2)	MId	4.66	11.53	3.93
	154		Back(S2)	Mid	7.38	11.73	2.01

$\boldsymbol{\Delta min}$ for ANT#0, ANT#1

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 1.7.

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.

Determine the worst beam for each of non-selected surface(s), i.e.,

a. for ANT#0 patch: Rear

b. for ANT#1 patch: Left

Then perform PD measurement for all determined worst-case beams, highlighted in orange in Tables 9 – 12, on the corresponding surface. Measurement is performed in the mid channel of each band with CW modulation. The evaluation distance is at 2 mm. The test results in Table 13 shows that the all measured 4cm2 PD values are less than PD_design_target of 0.6166 mW/cm2, thus, the non-selected surfaces have no influence on the determined Δmin and input.power.limit in Section 1.7.

Table 9
n261/mid channel, ANT#0 Patch simulated 4cm^2 PD at PD_Design_Target (if simulation performed with correct housing material properties) (Δmin)

Module	Type	BID	Simulated 4cm2 PD(W/m^{2}) corresponding to PD Design Target					
			Front(S1)	Back(S2)	Left(S3)	Right(S4)	Top(S5)	Bottom(S6)
ANT#0	Patch	1	1.05	2.22	0.02	5.54	0.14	0.40
		3	1.24	1.86	0.04	5.99	0.12	0.31
		5	1.33	1.84	0.01	6.17	0.10	0.28
		7	1.46	1.19	0.01	6.15	0.20	0.21
		9	2.26	2.13	0.17	5.61	0.06	0.58
		14	1.51	1.41	0.02	6.08	0.31	0.40
		15	1.93	1.42	0.06	6.04	0.09	0.14
		16	1.44	2.27	0.03	6.17	0.03	0.25
		17	1.17	1.61	0.04	5.92	0.22	0.59
		21	1.56	2.05	0.03	5.96	0.13	0.22
		22	1.81	1.58	0.07	5.92	0.07	0.30
		23	1.45	2.07	0.04	6.08	0.08	0.41
		29	1.67	1.54	0.06	5.35	0.49	0.25
		30	1.68	1.91	0.04	5.96	0.04	0.21
		31	1.58	2.17	0.04	6.05	0.06	0.13
		32	1.50	2.29	0.04	5.45	0.04	0.17
		33	1.58	1.89	0.04	5.85	0.05	0.95
		38	1.71	1.73	0.02	5.81	0.16	0.25
		39	1.67	2.01	0.04	6.04	0.06	0.10
		40	1.70	2.21	0.04	6.07	0.02	0.12
		41	1.53	2.09	0.03	5.25	0.04	0.70
		129	1.43	1.38	0.04	6.06	0.16	0.42
		131	1.27	1.35	0.03	5.82	0.14	0.12
		133	1.31	1.53	0.03	5.87	0.11	0.23
		135	1.55	1.34	0.01	6.17	0.17	0.22
		137	1.44	2.26	0.10	6.07	0.10	0.74
		142	0.96	1.56	0.04	5.31	0.35	0.40
		143	1.39	1.77	0.01	6.15	0.07	0.08
		144	1.59	1.54	0.02	6.17	0.05	0.23
		145	1.52	1.52	0.04	5.92	0.20	0.42
		149	1.13	1.98	0.02	5.70	0.19	0.14
		150	1.55	1.54	0.01	6.13	0.01	0.12
		151	1.60	1.37	0.04	5.65	0.16	0.32
		157	0.86	2.14	0.04	5.35	0.47	0.35
		158	1.45	1.92	0.03	6.09	0.04	0.22
		159	1.53	1.61	0.02	6.06	0.03	0.15
		160	1.88	1.71	0.02	6.17	0.04	0.36
		161	2.07	1.46	0.08	5.76	0.08	0.86
		166	1.06	2.19	0.03	5.76	0.17	0.25
		167	1.45	1.73	0.02	6.02	0.02	0.10
		168	1.61	1.74	0.03	6.09	0.06	0.17
		169	2.06	1.64	0.06	6.16	0.05	0.74

Please note the above scaled simulation values correspond to PD_design_target if the simulation was performed with correct housing material properties.

Table 10
n261/mid channel, ANT#1 Patch simulated 4cm^2 PD at PD_Design_Target
(if simulation performed with correct housing material properties) (Δmin)

Module	Type	BID	Simulated 4cm2 PD(W/m$^{2)}$ corresponding to PD Design Target					
			Front(S1)	Back(S2)	Left(S3)	Right(S4)	Top(S5)	Bottom(S6)
ANT#1	Patch	0	0.09	4.66	0.27	0.09	0.22	0.16
		2	0.11	4.39	0.32	0.09	0.19	0.11
		4	0.19	4.67	0.74	0.03	0.28	0.14
		6	0.18	4.49	0.48	0.05	0.21	0.15
		8	0.10	4.73	0.66	0.03	0.27	0.31
		10	0.11	4.35	0.21	0.12	0.22	0.11
		11	0.06	4.49	0.12	0.07	0.22	0.12
		12	0.11	4.90	0.36	0.03	0.23	0.15
		13	0.15	4.84	0.47	0.08	0.26	0.15
		18	0.15	4.73	0.21	0.02	0.22	0.26
		19	0.07	4.54	0.20	0.05	0.19	0.13
		20	0.11	4.86	0.93	0.06	0.29	0.21
		24	0.14	4.31	0.34	0.09	0.30	0.19
		25	0.13	4.52	0.23	0.03	0.35	0.28
		26	0.16	4.63	0.24	0.03	0.31	0.33
		27	0.11	4.51	0.15	0.03	0.33	0.17
		28	0.07	4.90	1.10	0.03	0.12	0.12
		34	0.13	4.73	0.25	0.04	0.37	0.25
		35	0.14	4.47	0.27	0.04	0.35	0.32
		36	0.17	4.45	0.18	0.02	0.33	0.19
		37	0.07	4.84	0.60	0.05	0.15	0.16
		128	0.09	4.60	0.17	0.12	0.22	0.12
		130	0.11	4.60	0.22	0.09	0.30	0.37
		132	0.08	4.70	0.41	0.07	0.35	0.28
		134	0.08	4.85	0.33	0.05	0.18	0.11
		136	0.21	4.78	0.79	0.03	0.40	0.17
		138	0.06	4.47	0.19	0.12	0.20	0.21
		139	0.07	4.64	0.24	0.02	0.24	0.18
		140	0.18	4.74	0.46	0.03	0.37	0.14
		141	0.16	4.40	0.27	0.15	0.46	0.32
		146	0.05	4.61	0.17	0.10	0.16	0.21
		147	0.09	4.57	0.13	0.04	0.33	0.17
		148	0.09	4.72	0.31	0.07	0.23	0.23
		152	0.08	4.69	0.33	0.06	0.27	0.19
		153	0.11	4.77	0.17	0.03	0.29	0.15
		154	0.11	4.67	0.34	0.02	0.41	0.30
		155	0.14	4.21	0.27	0.03	0.44	0.22
		156	0.17	4.65	0.80	0.10	0.37	0.16
		162	0.08	4.86	0.19	0.03	0.26	0.12
		163	0.13	4.63	0.32	0.02	0.31	0.27
		164	0.15	4.73	0.23	0.03	0.48	0.28
		165	0.11	4.81	0.50	0.05	0.46	0.21

Table 11

n260/mid channel, ANT#0 Patch simulated 4cm^2 PD at PD_Design_Target

(if simulation performed with correct housing material properties) (Δmin)

Module	Type	BID	Simulated 4cm2 PD(W/m$^{2)}$ corresponding to PD Design Target					
			Front(S1)	Back(S2)	Left(S3)	Right(S4)	Top(S5)	Bottom(S6)
ANT#0	Patch	1	0.93	1.78	0.01	5.31	0.20	0.16
		3	0.94	1.77	0.01	5.65	0.21	0.09
		5	0.93	1.65	0.01	5.19	0.22	0.17
		7	1.93	0.85	0.02	5.94	0.05	0.33
		9	1.47	0.83	0.02	5.25	0.07	0.40
		14	0.90	1.61	0.01	5.05	0.21	0.20
		15	1.12	2.00	0.01	5.69	0.19	0.08
		16	1.49	1.47	0.02	5.56	0.11	0.20
		17	0.83	1.67	0.01	5.25	0.27	0.15
		21	1.01	1.83	0.01	5.47	0.30	0.10
		22	1.56	1.42	0.02	5.49	0.09	0.15
		23	0.92	1.75	0.01	5.33	0.16	0.15
		29	1.42	1.64	0.02	4.92	0.36	0.37
		30	1.37	1.49	0.01	4.89	0.36	0.21
		31	1.23	1.65	0.01	5.92	0.06	0.09
		32	1.44	1.52	0.01	5.94	0.12	0.23
		33	1.40	1.81	0.03	4.95	0.06	0.46
		38	1.43	1.47	0.01	4.70	0.47	0.19
		39	1.28	1.44	0.01	5.41	0.13	0.12
		40	1.42	1.53	0.01	6.17	0.10	0.13
		41	1.30	1.55	0.01	5.24	0.09	0.36
		129	1.66	0.94	0.01	5.30	0.16	0.17
		131	1.75	0.91	0.01	6.14	0.19	0.09
		133	1.67	0.92	0.01	5.81	0.17	0.17
		135	0.97	1.88	0.01	5.88	0.06	0.36
		137	1.08	1.29	0.02	5.09	0.07	0.33
		142	1.45	0.85	0.02	5.43	0.29	0.15
		143	1.27	1.40	0.01	5.62	0.10	0.23
		144	1.99	1.04	0.01	5.91	0.05	0.14
		145	1.70	0.85	0.02	5.41	0.21	0.19
		149	1.20	1.36	0.01	5.61	0.14	0.30
		150	1.90	1.10	0.01	6.15	0.05	0.10
		151	1.55	1.60	0.02	6.11	0.11	0.26
		157	1.97	1.31	0.02	5.39	0.35	0.47
		158	1.43	1.40	0.02	5.63	0.22	0.11
		159	1.56	1.31	0.02	6.07	0.05	0.12
		160	1.57	1.41	0.01	5.54	0.04	0.31
		161	1.77	1.53	0.02	5.48	0.08	0.48
		166	1.45	1.41	0.02	5.52	0.45	0.15
		167	1.32	1.37	0.02	5.78	0.07	0.10
		168	1.78	1.26	0.02	6.17	0.04	0.09
		169	1.50	1.47	0.02	5.23	0.05	0.50

Table 12
n260/mid channel, ANT#1 Patch simulated 4cm^2 PD at PD_Design_Target
(if simulation performed with correct housing material properties) (Δmin)

Module	Type	BID	Simulated 4cm2 PD(W/m^2) corresponding to PD Design Target					
			Front(S1)	Back(S2)	Left(S3)	Right(S4)	Top(S5)	Bottom(S6)
ANT#1	Patch	0	0.09	4.68	0.07	0.06	0.24	0.18
		2	0.13	4.42	0.15	0.06	0.17	0.24
		4	0.18	4.48	0.21	0.10	0.18	0.16
		6	0.17	4.22	0.55	0.02	0.17	0.48
		8	0.29	4.68	0.54	0.04	0.45	0.16
		10	0.14	4.68	0.11	0.06	0.36	0.11
		11	0.04	4.68	0.05	0.03	0.17	0.18
		12	0.21	4.61	0.33	0.08	0.17	0.32
		13	0.19	4.23	0.17	0.07	0.33	0.18
		18	0.12	4.48	0.25	0.06	0.25	0.19
		19	0.27	4.57	0.40	0.02	0.45	0.39
		20	0.17	4.11	0.16	0.07	0.22	0.21
		24	0.22	4.08	0.60	0.07	0.36	0.26
		25	0.13	4.68	0.30	0.04	0.25	0.23
		26	0.11	4.68	0.24	0.04	0.28	0.34
		27	0.30	4.24	0.12	0.07	0.25	0.28
		28	0.15	3.50	0.31	0.08	0.21	0.22
		34	0.15	4.64	0.47	0.04	0.28	0.23
		35	0.14	4.68	0.24	0.04	0.27	0.23
		36	0.19	4.68	0.10	0.04	0.23	0.32
		37	0.27	3.77	0.18	0.09	0.25	0.21
		128	0.07	4.68	0.13	0.07	0.25	0.33
		130	0.05	4.68	0.12	0.05	0.16	0.29
		132	0.09	4.66	0.20	0.05	0.27	0.31
		134	0.24	4.29	0.39	0.04	0.32	0.17
		136	0.10	4.50	0.37	0.02	0.17	0.29
		138	0.06	4.68	0.12	0.08	0.16	0.38
		139	0.16	4.61	0.22	0.04	0.38	0.28
		140	0.07	4.65	0.19	0.07	0.22	0.51
		141	0.16	4.60	0.32	0.04	0.28	0.24
		146	0.05	4.68	0.08	0.05	0.18	0.37
		147	0.14	4.68	0.23	0.04	0.39	0.32
		148	0.14	4.68	0.31	0.03	0.33	0.28
		152	0.14	4.50	0.35	0.08	0.18	0.34
		153	0.15	4.04	0.22	0.05	0.31	0.35
		154	0.10	4.68	0.15	0.02	0.24	0.37
		155	0.14	4.41	0.22	0.07	0.25	0.47
		156	0.10	4.34	0.32	0.09	0.22	0.31
		162	0.14	4.61	0.27	0.05	0.20	0.40
		163	0.13	4.39	0.18	0.04	0.35	0.43
		164	0.13	4.68	0.22	0.05	0.21	0.46
		165	0.14	4.33	0.31	0.09	0.29	0.53

Table 13
$4cm^2$ PD of the selected beams measured on the corresponding surfaces that are not selected for Δmin determination

Band	Antenna	BID	Surface	Input Power Limit (dBm)	Meas. $4cm^2$ PD (W/m^2)
n261	Ant#0	32	Back(S2)	1.6	1.42
	Ant#0	9	Front(S1)	10.3	1.56
	Ant#1	28	Left(S4)	1.4	0.75
	Ant#1	164	Top(S5)	2.6	0.53
n260	Ant#0	15	Back(S2)	6.0	1.24
	Ant#0	144	Front(S1)	6.1	1.48
	Ant#1	24	Left(S4)	4.0	0.52
	Ant#1	8	Top(S5)	10.3	0.27
	Ant#1	19	Top(S5)	7.9	0.33

Some of the test cases above were tested at a higher power level than input.power.limit representing a more conservative evaluation.

1. 7 PD Char

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

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, $\boldsymbol{s(i)}$, among low, mid and high channels:

$$S(i) = min\{s_{low}(i), s_{mid}(i), s_{higt}(i)\}, i \in single\ beams \quad (2)$$

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

1.7.2 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 Ø, the scaling factor was obtained by the below equation for low, mid and high channels:

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

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:

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

1.7.3 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 (Δmin) determined in Table 10, given by:

For n260 and n261

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

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 10) 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,

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

else if Δmin < -TxAGC uncertainty,

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

else if Δmin > TxAGC uncertainty,

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

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	Δ min (dB)	TxAGC Uncertainty (dB)	input.power.limit= (dBm)	Notes
n261	Ant #0	1.66	0.63	6 dBm + 10*log(s(i))+1.16	Using Eq.8
	Ant #1	1.07	0.63	6 dBm + 10*log(s(i))+0.57	Using Eq.8
n260	Ant #0	1.84	0.63	6 dBm + 10*log(s(i))+1.34	Using Eq.8
	Ant #1	1.81	0.63	6 dBm + 10*log(s(i))+1.31	Using Eq.8

Table 15

Permanent Backoff applied to calculated input.power.limit

Band	Antenna	backoff(dB)
n261	ANT#0	0
n260	ANT#0	0
n261	ANT#1	1.0
n260	ANT#1	1.2

Table 16
5G NR n261 ANT#0 Patch input.power.limit

BID	Paired_BID	input.power.limit (dBm)
1		9.5
3		8.5
5		8.1
7		8.2
9		10.3
14		5.8
15		5.9
16		5.4
17		5.8
21		5.5
22		5.8
23		5.8
29		2.3
30		2.0
31		2.1
32		1.4
33		1.8
38		2.0
39		1.8
40		2.0
41		1.5
	129	9.6
	131	8.4
	133	8.3
	135	7.9
	137	9.9
	142	7.1
	143	5.1
	144	5.4
	145	6.5
	149	5.6
	150	5.1
	151	5.8
	157	2.6
	158	1.7
	159	1.5
	160	1.3
	161	1.9
	166	2.0
	167	1.3
	168	1.8
	169	1.8

BID	Paired_BID	input.power.limit (dBm)
1	129	5.9
3	131	5.2
5	133	5.0
7	135	4.8
9	137	6.2
14	142	3.7
15	143	2.5
16	144	2.2
17	145	3.0
21	149	2.2
22	150	2.9
23	151	2.8
29	157	-0.9
30	158	-1.5
31	159	-1.4
32	160	-1.8
33	161	-1.5
38	166	-1.2
39	167	-1.6
40	168	-1.4
41	169	-1.6

Table 17
5G NR n261 ANT#1 Patch input.power.limit

BID	Paired_BID	input.power.limit (dBm)
0		9.0
2		8.9
4		8.8
6		8.6
8		7.6
10		5.3
11		5.7
12		6.5
13		6.5
18		4.8
19		6.1
20		5.4
24		2.8
25		1.9
26		2.1
27		1.3
28		0.7
34		2.5
35		1.9
36		2.0
37		1.2
	128	8.8
	130	9.8
	132	8.6
	134	8.6
	136	7.7
	138	6.1
	139	5.6
	140	4.5
	141	6.7
	146	6.1
	147	6.0
	148	5.5
	152	2.0
	153	1.6
	154	1.8
	155	1.5
	156	2.3
	162	1.8
	163	1.6
	164	2.1
	165	1.8

BID	Paired_BID	input.power.limit (dBm)
0	128	4.3
2	130	4.7
4	132	4.2
6	134	4.0
8	136	4.4
10	138	1.5
11	139	2.4
12	140	2.6
13	141	2.0
18	146	2.8
19	147	0.9
20	148	1.8
24	152	-2.1
25	153	-2.3
26	154	-2.3
27	155	-3.0
28	156	-3.1
34	162	-2.4
35	163	-2.3
36	164	-2.4
37	165	-3.0

Table 18
5G NR n260 ANT#0 Patch input.power.limit

BID	Paired_BID	input.power.limit (dBm)
1		8.8
3		8.3
5		8.0
7		9.0
9		9.4
14		5.1
15		5.9
16		6.0
17		5.3
21		5.5
22		6.0
23		5.6
29		2.1
30		2.9
31		2.4
32		2.5
33		3.0
38		2.4
39		2.7
40		2.4
41		2.7
	129	8.8
	131	8.5
	133	8.1
	135	8.6
	137	9.3
	142	5.4
	143	5.5
	144	6.1
	145	5.6
	149	5.4
	150	6.1
	151	6.0
	157	2.2
	158	2.6
	159	2.3
	160	2.4
	161	3.2
	166	2.4
	167	2.5
	168	2.2
	169	3.1

BID	Paired_BID	input.power.limit (dBm)
1	129	5.1
3	131	5.1
5	133	4.7
7	135	5.5
9	137	5.7
14	142	2.1
15	143	2.8
16	144	3.0
17	145	2.2
21	149	2.8
22	150	2.9
23	151	2.8
29	157	-1.4
30	158	-1.4
31	159	-1.0
32	160	-0.8
33	161	-0.7
38	166	-1.7
39	167	-1.1
40	168	-0.9
41	169	-0.6

Table 19
5G NR n260 ANT#1 Patch input.power.limit

BID	Paired_BID	input.power.limit (dBm)
0		9.8
2		9.8
4		9.2
6		10.6
8		10.3
10		7.1
11		6.5
12		7.0
13		7.4
18		6.4
19		7.9
20		7.2
24		3.8
25		3.8
26		3.3
27		3.6
28		3.1
34		4.1
35		3.4
36		3.4
37		3.5
	128	9.4
	130	9.7
	132	9.2
	134	9.9
	136	10.0
	138	6.1
	139	7.0
	140	7.3
	141	6.4
	146	6.0
	147	6.9
	148	6.5
	152	3.3
	153	3.2
	154	3.2
	155	3.4
	156	3.7
	162	3.4
	163	3.2
	164	3.3
	165	3.6

BID	Paired_BID	input.power.limit (dBm)
0	128	6.3
2	130	6.3
4	132	6.0
6	134	6.4
8	136	7.0
10	138	3.2
11	139	4.1
12	140	3.6
13	141	3.8
18	146	2.9
19	147	3.8
20	148	3.8
24	152	-0.1
25	153	0.2
26	154	-0.2
27	155	-0.7
28	156	-0.3
34	162	0.3
35	163	-0.1
36	164	-0.6
37	165	-0.4

2. SAR Characterization

2.1 DSI and SAR Determination

This device uses different Device State Index (DSI) to configure different time averaged power levels based on certain exposure scenarios. Depending on the detection scheme implemented in the smartphone, the worst-case SAR was determined by measurements for the relevant exposure conditions for that DSI. Detailed descriptions of the detection mechanisms are included in the operational description.

When 1g SAR and 10g SAR exposure comparison is needed, the worst-case was determined from SAR normalized to 1g or 10g SAR limit.

The device state index (DSI) conditions used in Table 20 represent different exposure scenarios.

Table 20
DSI and Corresponding Exposure Scenarios

Scenario	Description	SAR Test Cases
Head (DSI = 2)	･Device positinoned next to head and a sensor is triggerd ･Ear speaker is activated	Head SAR per KDB Publication 648474 D04
Body worm (DSI = 3)	･Device being used with a body-wom accessary and a sensor is triggerd ･Ear speaker is not activated	Body-worn SAR per KDB Publication 648474 D04
Phablet Grip (DSI = 3)	･Device being used with a body-wom accessary and a sensor is triggerd ･Ear speaker is not activated	Body-worn SAR per KDB Publication 648474 D04

SAR_design_target is determined by ensuring that it is less than FCC SAR limit after accounting for total device designed related uncertainties specified by the manufacturer (see Table 21).

Table 21
SAR_design_target Calculation

SAR_design_target			
$SAR\_design\_target < SAR\_regulatory\_limit \times 10^{\frac{-Total\ Uncertainty}{10}}$			
1g SAR (W/kg)		**10g SAR (W/kg)**	
Total Uncertainty	1.0 dB	*Total Uncertainty*	1.0 dB
SAR_regulatory_limit	1.6 W/kg	*SAR_regulatory_limit*	4.0 W/kg
SAR_design_target	1.0 W/kg	*SAR_design_target*	2.5 W/kg

2.3 SAR Char

SAR test results corresponding to Pmax for each antenna/technology/band/DSI can be found in Part 1 SAR Report.

Plimit is calculated by linearly scaling with the measured SAR at the Pmax to correspond to the SAR_design_target. Plimit determination for each exposure scenario corresponding to SAR_design_target are shown in Table 22.

Table 22
Limit Determination

Device State Index (DSI)	Plimit Datermination Scenarios
2	Plimit is calculated based on the following scenarios: 1g Head SAR
3	Plimit is calculated based on the following scenarios: 1g Body-worn SAR measured at 10mm 10g Extremity SAR measured at 0mm for six surfaces

Table 23
SAR Characterizations

(1) Head (**DSI = 2**) : Power table #2

Band	Antenna	Test Distance (mm)	Measured Power* (dBm)	Measured 1g SAR (W/kg)	Position	**Calculated upper power limit*** (dBm)	**P limit* (dBm)**	**Pmax*** (dBm)
GSM 850	Main	0	23.3	0.13	Right	32.2	**23.3**	**23.3**
GSM 1900	Main	0	17.8	0.05	Left	30.7	**17.8**	**17.8**
UMTS II	Main	0	19	0.08	Left	30.0	**19.0**	**19.0**
UMTS IV	Main	0	19	0.08	Left	30.2	**19.0**	**19.0**
UMTS V	Main	0	21	0.09	Right	31.5	**21.0**	**21.0**
LTE B5	Main	0	24	0.19	Right	31.2	**24.0**	**24.0**
LTE B12	Main	0	24	0.062	Left	36.1	**24.0**	**24.0**
LTE B13	Main	0	24	0.114	Right	33.4	**24.0**	**24.0**
LTE B25/B2	Main	0	24	0.14	Right	32.6	**24.0**	**24.0**
LTE B41	Main	0	22	0.11	Left	31.6	**22.0**	**22.0**
LTE B48	Main	0	22	0.17	Left	29.6	**22.0**	**22.0**
LTE B66/B4	Main	0	24	0.17	Right	31.6	**24.0**	**24.0**
LTE B71	Main	0	24	0.06	Left	36.0	**24.0**	**24.0**
5GNR n2	Main	0	24	0.14	Right	32.7	**24.0**	**24.0**
5GNR n5	Main	0	24	0.50	Left	27.0	**24.0**	**24.0**
5GNR n41	Main	0	24	0.11	Left	33.5	**27.0**	**24.0**
5GNR n41 HPUE	Main	0	24	0.11	Left	33.5	**27.0**	**26.0**
5GNR n66	Main	0	24	0.18	Right	31.4	**24.0**	**24.0**
5GNR n71	Main	0	24	0.06	Left	35.9	**24.0**	**24.0**
5GNR n77	Main	0	24	0.05	Left	36.8	**27.0**	**24.0**
5GNR n77 HPUE	Main	0	24	0.05	Left	36.8	**27.0**	**26.0**
LTE2	Sub(ENDC)	0	24	2.08	Left	20.8	**19.0**	**23.0**
LTE66	Sub(ENDC)	0	24	1.51	Left	22.2	**19.0**	**23.0**
n41(Sub)	Sub(ULMIMO)	0	24	1.99	Left	21.0	**17.0**	**19.5**
n77(Sub)	Sub(ULMIMO)	0	24	2.93	Left	19.3	**15.0**	**19.5**

* Frame averaged power

*Meshed cells are work with time averaging

(2) Body-Worn, Hotspot (**DSI = 3**) : Power table #3

Band	Antenna	Test Distance (mm)	Measured Power* (dBm)	Measured 1g SAR (W/kg)	Position	**Calculated upper power limit*** (dBm)	**P limit* (dBm)**	**Pmax*** (dBm)
GSM 850	Main	10	23.3	0.51	Back	26.3	**23.3**	**23.3**
GSM 1900	Main	10	17.8	0.21	Bottom	24.7	**17.8**	**17.8**
UMTS II	Main	10	19	0.28	Bottom	24.6	**19.0**	**19.0**
UMTS IV	Main	10	19	0.24	Front	25.1	**19.0**	**19.0**
UMTS V	Main	10	21	0.36	Back	25.5	**21.0**	**21.0**
LTE B5	Main	10	21	0.35	Back	25.5	**21.0**	**24.0**
LTE B12	Main	10	21	0.148	Back	29.3	**21.0**	**24.0**
LTE B13	Main	10	21	0.251	Back	27.0	**21.0**	**24.0**
LTE B25/B2	Main	10	19	0.28	Bottom	24.5	**19.0**	**24.0**
LTE B41	Main	10	17	0.14	Back	25.6	**17.0**	**22.0**
LTE B48	Main	10	17	0.51	Back	19.9	**17.0**	**22.0**
LTE B66/B4	Main	10	19	0.23	Bottom	25.3	**19.0**	**24.0**
LTE B71	Main	10	24	0.35	Back	28.6	**24.0**	**24.0**
5GNR n2	Main	10	24	0.88	Bottom	24.6	**19.0**	**24.0**
5GNR n5	Main	10	24	0.63	Back	26.0	**21.0**	**24.0**
5GNR n41	Main	10	24	0.80	Back	25.0	**19.0**	**24.0**
5GNR n41 HPUE	Main	10	24	0.80	Back	25.0	**19.0**	**26.0**
5GNR n66	Main	10	24	0.80	Back	25.0	**19.0**	**24.0**
5GNR n71	Main	10	24	0.33	Back	28.8	**24.0**	**24.0**
5GNR n77	Main	10	24	1.63	Back	21.9	**18.0**	**24.0**
5GNR n77 HPUE	Main	10	24	1.63	Back	21.9	**18.0**	**26.0**
LTE5	Sub(AsDiv)	10	24	0.12	Front	33.4	**20.5**	**23.5**
LTE12	Sub(AsDiv)	10	24	0.18	Right	31.4	**20.5**	**23.5**
LTE13	Sub(AsDiv)	10	24	0.15	Right	32.3	**20.5**	**23.5**
LTE17	Sub(AsDiv)	10	24	0.18	Right	31.4	**20.5**	**23.5**
n5	Sub(AsDiv)	10	24	0.12	Front	33.4	**20.5**	**23.5**
LTE2	Sub(ENDC)	10	24	0.28	Front	29.6	**19.0**	**23.0**
LTE66	Sub(ENDC)	10	24	0.22	Right	30.6	**19.0**	**23.0**
n41(Sub)	Sub(ULMIMO)	10	24	0.34	Right	28.7	**16.0**	**19.5**
n77(Sub)	Sub(ULMIMO)	10	24	0.49	Back	27.1	**15.0**	**19.5**
n77(4th)	4thMHB(AsDiv)	10	24	0.24	Back	30.2	**16.3**	**16.3**

* Frame averaged power

*Meshed cells are work with time averaging

(3) Extremity (**DSI = 3**) : Power table #3

Band	Antenna	Test Distance (mm)	Measured Power* (dBm)	Measured 10g SAR (W/kg)	Position	**Calculated upper power limit*** (dBm)	**P limit* (dBm)**	**Pmax*** (dBm)
GSM 850	Main	0	23.3	1.17	Front	26.6	**23.3**	**23.3**
GSM 1900	Main	0	17.8	0.60	Front	24.0	**17.8**	**17.8**
UMTS II	Main	0	19	0.87	Front	23.6	**19.0**	**19.0**
UMTS IV	Main	0	19	1.13	Front	22.4	**19.0**	**19.0**
UMTS V	Main	0	21	0.76	Front	26.2	**21.0**	**21.0**
LTE B5	Main	0	21	0.82	Front	25.8	**21.0**	**24.0**
LTE B12	Main	0	21	0.756	Front	26.2	**21.0**	**24.0**
LTE B13	Main	0	21	0.951	Front	25.2	**21.0**	**24.0**
LTE B25/B2	Main	0	19	0.82	Front	23.8	**19.0**	**24.0**
LTE B41	Main	0	17	0.49	Back	24.1	**17.0**	**22.0**
LTE B48	Main	0	17	1.02	Back	20.9	**17.0**	**22.0**
LTE B66/B4	Main	0	19	1.08	Front	22.6	**19.0**	**24.0**
LTE B71	Main	0	24	1.35	Bottom	26.7	**24.0**	**24.0**
5GNR n2	Main	0	24	2.50	Front	24.0	**19.0**	**24.0**
5GNR n5	Main	0	24	1.32	Front	26.8	**21.0**	**24.0**
5GNR n41	Main	0	24	2.83	Back	23.5	**19.0**	**24.0**
5GNR n41 HPUE	Main	0	24	2.83	Back	23.5	**19.0**	**26.0**
5GNR n66	Main	0	24	3.09	Front	23.1	**19.0**	**24.0**
5GNR n71	Main	0	24	1.43	Bottom	26.4	**24.0**	**24.0**
5GNR n77	Main	0	24	3.66	Back	22.3	**18.0**	**24.0**
5GNR n77 HPUE	Main	0	24	3.66	Back	22.3	**18.0**	**26.0**
LTE5	Sub(AsDiv)	0	24	0.54	Right	30.6	**20.5**	**23.5**
LTE12	Sub(AsDiv)	0	24	0.58	Right	30.4	**20.5**	**23.5**
LTE13	Sub(AsDiv)	0	24	0.53	Right	30.7	**20.5**	**23.5**
LTE17	Sub(AsDiv)	0	24	0.58	Right	30.4	**20.5**	**23.5**
n5	Sub(AsDiv)	0	24	0.54	Right	30.6	**20.5**	**23.5**
LTE2	Sub(ENDC)	0	24	1.97	Right	25.0	**19.0**	**23.0**
LTE66	Sub(ENDC)	0	24	1.97	Right	25.0	**19.0**	**23.0**
n41(Sub)	Sub(ULMIMO)	0	24	2.08	Right	24.8	**16.0**	**19.5**
n77(Sub)	Sub(ULMIMO)	0	24	2.24	Front	24.5	**15.0**	**19.5**
n77(4th)	4thMHB(AsDiv)	0	24	1.34	Back	26.7	**16.3**	**16.3**

* Frame averaged power

*Meshed cells are work with time averaging