FCC ID : ZNFF100VM

Part 0 Power Density Char Report

Rev. A (Ver. 1.0)

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LG Electronics

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1. INTRODUCTION

Qualcomm Smart Transmit cannot operate without PD characterization at the device level, beforehand. The parameters obtained from PD characterization (referred to as PD char, respectively) will be used as input for Smart Transmit. PD char will be entered via the Embedded File System (EFS) to enable the Smart Transmit feature.

2. DEVICE UNDER TEST

2.1. Time-Averaging for Power Density

This device is enabled with Qualcomm® Smart Transmit algorithm to control and manage transmitting power in real time and to ensure that the time-averaged RF exposure from 5G NR mmW WWAN is in compliance with FCC requirements. This Part 0 report shows Power Density characterization of WWAN radios for 5G NR mmW. Characterization is achieved by determining input.power.limit for 5G NR mmW that correspond to the exposure design targets after accounting for all device design related uncertainties, i.e., PD_design_target (< FCC PD limit) for mmW radio. The PD characterization are denoted as PD Char in this report. Section 2.2 includes a nomenclature of the specific terms used in this report.

The compliance test under the static transmission scenario and simultaneous transmission analysis are reported in Part 1 report. The validation of the time-averaging algorithm and compliance under the dynamic (time- varying) transmission scenario for WWAN technologies are reported in Part 2 report

2.2 Nomenclature for Part 0 Report

Technology	Term	Description
5G NR mmW	input.power.limit	Power level at antenna element for each beam corresponding to the exposure design target (PD_design_target)
	PD_design_target	Target PD level < FCC SAR limit after accounting for all device design related uncertainties
	Δmin	Housing material influence
	PD Char	Table containing input.power.limit for all beams and bands

3. POWER DENSITY CHARACTERIZATION

3.1. Exposure Scenarios in Power Density Evaluation

For a portable handset at frequencies > 6 GHz, the power density (PD) is required to be assessed for all antenna configurations (beams) from all mmW antenna modules installed inside the device. This device has 3 patch antenna arrays (QTM#0, QTM#1, QTM#2). Per each supported band, there are a total of 135 beams: 90 SISO beams and 45 MIMO beam pairs.

As showed in Figure 3-1, the surfaces near-by each mmW antenna module for PD characterization are identified and listed in Table 3-1.

Table 3-1 Evaluation Surfaces for PD Characterization

Band & Mode	Antenna	Back S2	Front S1	Top S5	Bottom S6	Right S4	Left S3
5G NR Band n261/n260	QTM#0	Yes	Yes	No	No	Yes	No
	QTM#1	Yes	No	Yes	No	No	No
	QTM#2	Yes	Yes	No	No	No	Yes

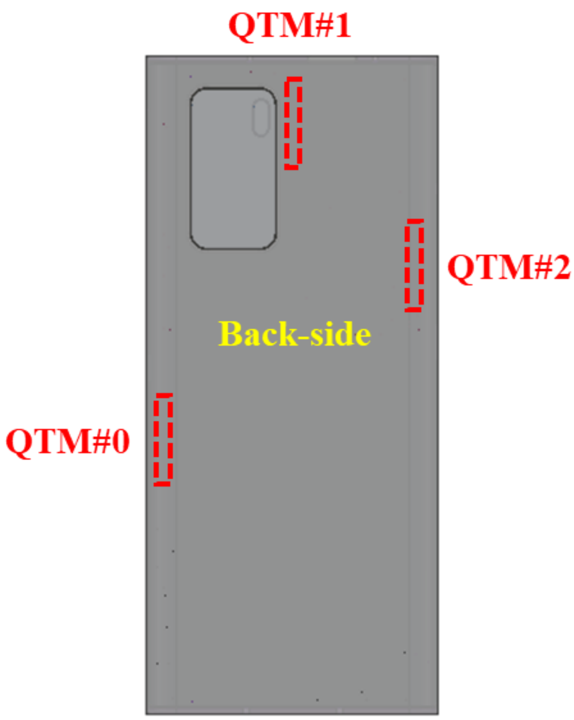

Figure 3-1: Location of mmW antenna modules looking from back of the DUT

3.2. Power Density Characterization Method

An overview of power density characterization method could be found in Figure 3-2 below.

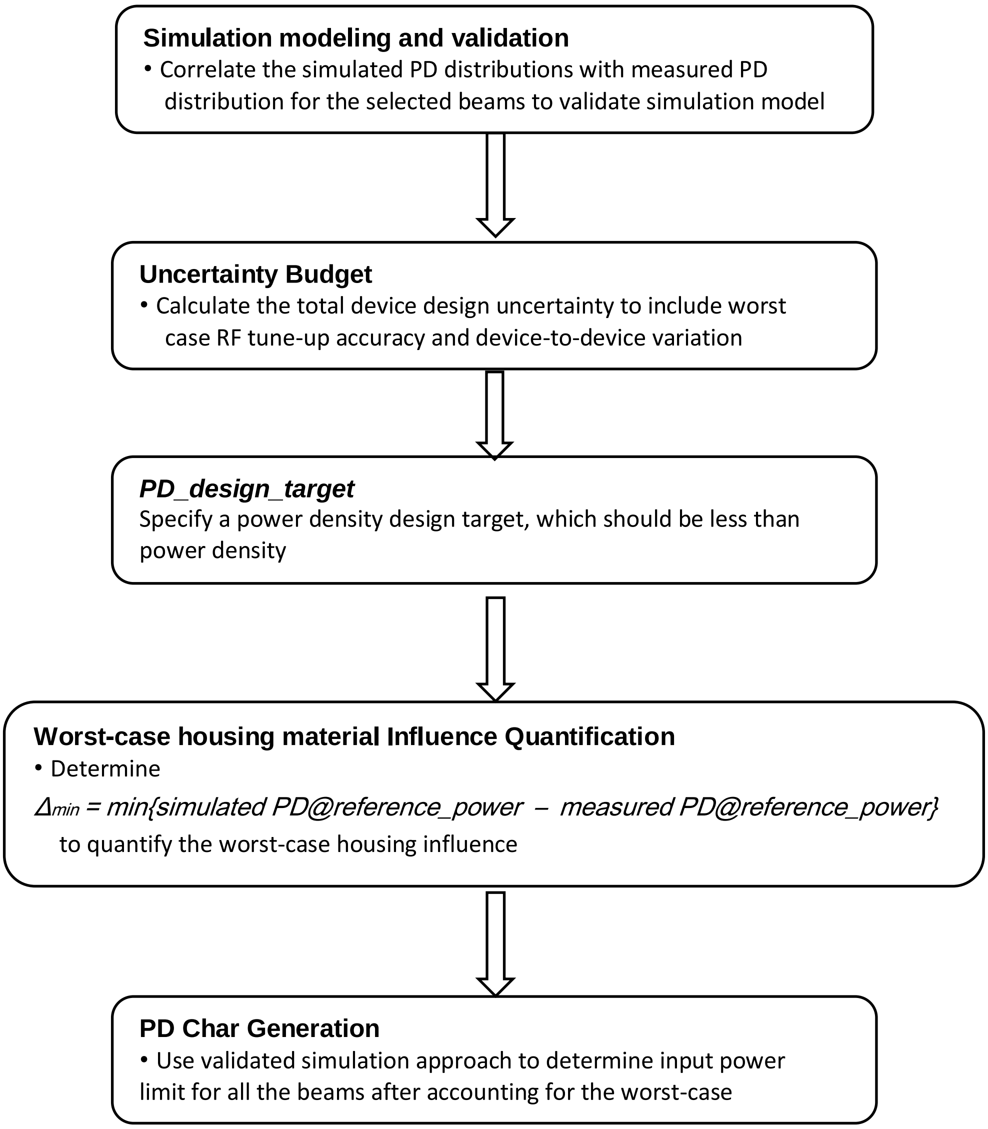

Figure 3-2 High level flow Chart for Power Density Characterization

3.3. Codebook for all supported beams

All the beams that the DUT supports are specified in the pre-defined codebook. The codebook for this device is specified as below.

Table 3-2 5G mmW NR Band n261 QTM#0 Codebook

Band	Beam ID	Ant Module ID	Ant Type	Paired With	# of Ant Feed
261	1	0	PATCH	129	1
261	6	0	PATCH	134	2
261	7	0	PATCH	135	2
261	8	0	PATCH	136	2
261	14	0	PATCH	142	2
261	15	0	PATCH	143	2
261	23	0	PATCH	151	4
261	24	0	PATCH	152	4
261	25	0	PATCH	153	4
261	26	0	PATCH	154	4
261	27	0	PATCH	155	4
261	37	0	PATCH	165	4
261	38	0	PATCH	166	4
261	39	0	PATCH	167	4
261	40	0	PATCH	168	4
261	129	0	PATCH	1	1
261	134	0	PATCH	6	2
261	135	0	PATCH	7	2
261	136	0	PATCH	8	2
261	142	0	PATCH	14	2
261	143	0	PATCH	15	2
261	151	0	PATCH	23	4
261	152	0	PATCH	24	4
261	153	0	PATCH	25	4
261	154	0	PATCH	26	4
261	155	0	PATCH	27	4
261	165	0	PATCH	37	4
261	166	0	PATCH	38	4
261	167	0	PATCH	39	4
261	168	0	PATCH	40	4

Table 3-3 5G mmW NR Band n261 QTM#1 Codebook

Band	Beam ID	Ant Module ID	Ant Type	Paired With	# of Ant Feed
261	0	1	PATCH	128	1
261	3	1	PATCH	131	2
261	4	1	PATCH	132	2
261	5	1	PATCH	133	2
261	12	1	PATCH	140	2
261	13	1	PATCH	141	2
261	18	1	PATCH	146	4
261	19	1	PATCH	147	4
261	20	1	PATCH	148	4
261	21	1	PATCH	149	4
261	22	1	PATCH	150	4
261	33	1	PATCH	161	4
261	34	1	PATCH	162	4
261	35	1	PATCH	163	4
261	36	1	PATCH	164	4
261	128	1	PATCH	0	1
261	131	1	PATCH	3	2
261	132	1	PATCH	4	2
261	133	1	PATCH	5	2
261	140	1	PATCH	12	2
261	141	1	PATCH	13	2
261	146	1	PATCH	18	4
261	147	1	PATCH	19	4
261	148	1	PATCH	20	4
261	149	1	PATCH	21	4
261	150	1	PATCH	22	4
261	161	1	PATCH	33	4
261	162	1	PATCH	34	4
261	163	1	PATCH	35	4
261	164	1	PATCH	36	4

Table 3-4 5G mmW NR Band n261 QTM#2 Codebook

Band	Beam ID	Ant Module ID	Ant Type	Paired With	# of Ant Feed
261	2	2	PATCH	130	1
261	9	2	PATCH	137	2
261	10	2	PATCH	138	2
261	11	2	PATCH	139	2
261	16	2	PATCH	144	2
261	17	2	PATCH	145	2
261	28	2	PATCH	156	4
261	29	2	PATCH	157	4
261	30	2	PATCH	158	4
261	31	2	PATCH	159	4
261	32	2	PATCH	160	4
261	41	2	PATCH	169	4
261	42	2	PATCH	170	4
261	43	2	PATCH	171	4
261	44	2	PATCH	172	4
261	130	2	PATCH	2	1
261	137	2	PATCH	9	2
261	138	2	PATCH	10	2
261	139	2	PATCH	11	2
261	144	2	PATCH	16	2
261	145	2	PATCH	17	2
261	156	2	PATCH	28	4
261	157	2	PATCH	29	4
261	158	2	PATCH	30	4
261	159	2	PATCH	31	4
261	160	2	PATCH	32	4
261	169	2	PATCH	41	4
261	170	2	PATCH	42	4
261	171	2	PATCH	43	4
261	172	2	PATCH	44	4

Table 3-5 5G mmW NR Band n260 QTM#0 Codebook

Band	Beam ID	Ant Module ID	Ant Type	Paired With	# of Ant Feed
260	1	0	PATCH	129	1
260	6	0	PATCH	134	2
260	7	0	PATCH	135	2
260	8	0	PATCH	136	2
260	14	0	PATCH	142	2
260	15	0	PATCH	143	2
260	23	0	PATCH	151	4
260	24	0	PATCH	152	4
260	25	0	PATCH	153	4
260	26	0	PATCH	154	4
260	27	0	PATCH	155	4
260	37	0	PATCH	165	4
260	38	0	PATCH	166	4
260	39	0	PATCH	167	4
260	40	0	PATCH	168	4
260	129	0	PATCH	1	1
260	134	0	PATCH	6	2
260	135	0	PATCH	7	2
260	136	0	PATCH	8	2
260	142	0	PATCH	14	2
260	143	0	PATCH	15	2
260	151	0	PATCH	23	4
260	152	0	PATCH	24	4
260	153	0	PATCH	25	4
260	154	0	PATCH	26	4
260	155	0	PATCH	27	4
260	165	0	PATCH	37	4
260	166	0	PATCH	38	4
260	167	0	PATCH	39	4
260	168	0	PATCH	40	4

Table 3-6 5G mmW NR Band n260 QTM#1 Codebook

Band	Beam ID	Ant Module ID	Ant Type	Paired With	# of Ant Feed
260	0	1	PATCH	128	1
260	3	1	PATCH	131	2
260	4	1	PATCH	132	2
260	5	1	PATCH	133	2
260	12	1	PATCH	140	2
260	13	1	PATCH	141	2
260	18	1	PATCH	146	4
260	19	1	PATCH	147	4
260	20	1	PATCH	148	4
260	21	1	PATCH	149	4
260	22	1	PATCH	150	4
260	33	1	PATCH	161	4
260	34	1	PATCH	162	4
260	35	1	PATCH	163	4
260	36	1	PATCH	164	4
260	128	1	PATCH	0	1
260	131	1	PATCH	3	2
260	132	1	PATCH	4	2
260	133	1	PATCH	5	2
260	140	1	PATCH	12	2
260	141	1	PATCH	13	2
260	146	1	PATCH	18	4
260	147	1	PATCH	19	4
260	148	1	PATCH	20	4
260	149	1	PATCH	21	4
260	150	1	PATCH	22	4
260	161	1	PATCH	33	4
260	162	1	PATCH	34	4
260	163	1	PATCH	35	4
260	164	1	PATCH	36	4

Table 3-7 5G mmW NR Band n260 QTM#2 Codebook

Band	Beam ID	Ant Module ID	Ant Type	Paired With	# of Ant Feed
260	2	2	PATCH	130	1
260	9	2	PATCH	137	2
260	10	2	PATCH	138	2
260	11	2	PATCH	139	2
260	16	2	PATCH	144	2
260	17	2	PATCH	145	2
260	28	2	PATCH	156	4
260	29	2	PATCH	157	4
260	30	2	PATCH	158	4
260	31	2	PATCH	159	4
260	32	2	PATCH	160	4
260	41	2	PATCH	169	4
260	42	2	PATCH	170	4
260	43	2	PATCH	171	4
260	44	2	PATCH	172	4
260	130	2	PATCH	2	1
260	137	2	PATCH	9	2
260	138	2	PATCH	10	2
260	139	2	PATCH	11	2
260	144	2	PATCH	16	2
260	145	2	PATCH	17	2
260	156	2	PATCH	28	4
260	157	2	PATCH	29	4
260	158	2	PATCH	30	4
260	159	2	PATCH	31	4
260	160	2	PATCH	32	4
260	169	2	PATCH	41	4
260	170	2	PATCH	42	4
260	171	2	PATCH	43	4
260	172	2	PATCH	44	4

3.4. Simulation and modeling validation

Power density simulations of all beams and surfaces were performed by the manufacturer. Details of these simulations and modeling validation can be found in the Power Density Simulation Report Rev. A. Table 3-8 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 both n261 and n260 band, PD measurements are conducted for at least one single beam per antenna type and per antenna module (QTM#0,#1,#2) on worst-surface(s) listed in Section 3.6. PD measurements are performed at mid channel of each mmW band and with CW modulation. All measured PD values are listed in Table 3-8 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 3-8 Measured and Simulated 4cm^2 avg. PD for Selected Beams with 6 dBm Input Power for both n261 and n260

6dBm input measurement / simulation							4cm^2 avg. PD(W/m^2)		
Band	Ant Type	Module	Ant Group (Ant Polarization)	beam ID	Surface	Channel	Measured	Simulated	Delta [dB]
n261	Patch	QTM0	AG0(V)	39	Right	Mid	**4.54**	**9.73**	**3.31**
					Back	Mid	**3.89**	**8.46**	**3.37**
			AG1(H)	153	Right	Mid	**3.7**	**9.33**	**4.02**
					Back	Mid	**2.94**	**8.81**	**4.77**
		QTM1	AG0(V)	19	Back	Mid	**8.18**	**11.42**	**1.45**
			AG1(H)	149	Back	Mid	**7.73**	**11.06**	**1.56**
		QTM2	AG0(V)	30	Back	Mid	**5.2**	**11.36**	**3.39**
					Left	Mid	**2.81**	**8.55**	**4.83**
			AG1(H)	157	Back	Mid	**4.38**	**10.59**	**3.84**
					Left	Mid	**2.8**	**8.14**	**4.63**
n260	Patch	QTM0	AG0(V)	40	Right	Mid	**4.65**	**7.83**	**2.26**
					Back	Mid	**3.2**	**7.58**	**3.75**
			AG1(H)	166	Right	Mid	**4.62**	**7.48**	**2.09**
					Back	Mid	**3.44**	**6.51**	**2.77**
		QTM1	AG0(V)	33	Back	Mid	**7.44**	**13.13**	**2.47**
			AG1(H)	150	Back	Mid	**5.66**	**10.78**	**2.80**
		QTM2	AG0(V)	28	Back	Mid	**7.63**	**14.81**	**2.88**
					Left	Mid	**4.87**	**9.66**	**2.97**
			AG1(H)	172	Back	Mid	**6.47**	**15.30**	**3.74**
					Left	Mid	**4.39**	**10.41**	**3.75**

3.5. *PD_design_target*

PD_design_target is determined by ensuring that it is less than FCC PD limit after accounting for total device design uncertainties including TxAGC and device-to-device variation, specified by the manufacturer (see Table 3-9).

Table 3-9 *PD_design_target* Calculations

PD_design_target	
$PD\_design\_target < PD\_regulatory\_limit \times 10^{-\text{Total Uncertainty}/10}$	
PD over 4 cm^2 Averaging Area (W/m^2)	
Total Uncertainty	2.1 dB
PD_regulatory_limit	10 W/m^2
PD_design_target	6.166 W/m^2

3.6. Worst-case Housing Influence Determination: 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 location as shown in Figure 3-1, 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 4cm^{2}PD for all the single beams per antenna module and per antenna type in the mid channel of each band.
2. For identified worst surface(s) per antenna module and per antenna type group,
    a. First determine Δ_{min} based on identified worst surface(s), and derive *input.power.limit*
    b. Then prove all other near-by surface(s), i.e., non-selected surface(s), is not required for housing material loss quantification (in other words, these non-evaluated surfaces have no influence on the determined *input.power.limit*) by:
        i. re-scale all simulated 4cm^{2}PD values to *input.power.limit* to identify the worst-PD beam per each non-evaluated surface.
        ii. Measure 4cm^{2}PD at *input.power.limit* on identified worst-PD beam per each non-evaluated surface
        iii. Demonstrate all measured 4cm^{2}PD values are below *PD_design_target*.
3. If any of the above surface(s) in Step (2.b.iii) have measured 4cm^{2}PD ≥ *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 7 in 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 QTM#0: Back (S2) & Front (S1) & Right (S4)
b. for QTM#1: Back (S2) & Top (S5)
c. for QTM#2: Back (S2) & Front (S1) & Left (S3)

Thus, when comparing a simulated 4 cm^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 3-8. Thus, the worst-case housing influence, denoted as Δ_{min} = Sim. PD − Meas. PD , is determined as

Table 3-10 Δ_{min} for QTM#0, QTM#1 and QTM#2

Band	Ant Module	Δ_{min} (dB)
n261	QTM#0 (Patch Beam)	3.31
	QTM#1 (Patch Beam)	1.45
	QTM#2 (Patch Beam)	3.39
n260	QTM#0 (Patch Beam)	2.09
	QTM#1 (Patch Beam)	2.47
	QTM#2 (Patch Beam)	2.88

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

The detail *input.power.limit* derivation is described in Section 3.7.

Simulated 4cm^2PD values in Table 2 ~ Table 7 in Power Density Simulation Report are scaled to *input.power.limit* and are listed in Tables 3-11 – 3-16 for all single beams for all identified surfaces (shown in Table 3-1), 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 QTM#0*: Front (S1), Left (S3)
b. for QTM#1: Front (S1), Left (S3), Right (S4)
c. for QTM#2: Front (S1), Right (S4), Top (S5)

Then perform PD measurement for all determined worst-case beams, highlighted in red in Tables 3-11 – 3-16, 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 3-17 shows that the all measured 4 cm^2PD values are less than *PD_design_target* of 6.166 W/m^2, thus, the non-selected surfaces have no influence on the determined Δ_{min} and *input.power.limit* in Section 3.7.

(QTM#0* : PD evaluation surfaces were determined based on Table 1 of the PD Simulation Report. In QTM#0, 5 evaluation surfaces except top side are set up. QTM#0 is placed at the lower of the device and the top side is excluded from the worst case because the distance from the top side is more than 10λ at 28 GHz and 39 GHz.)

Table 3-11: n261/mid channel, QTM#0 simulated 4cm^2 avg.PD (W/m^2) at *PD_Design_Target* (if simulation performed with correct housing material properties) (*Δmin*)

LG HFSS PD Simulation						
Band	Beam_ID	Module	Ant_Type	Front (S1)	Right (S4)	Left (S3)
n261	1	QTM0	PATCH	0.69	5.79	0.03
	6	QTM0	PATCH	0.60	5.96	0.03
	7	QTM0	PATCH	0.87	5.65	0.10
	8	QTM0	PATCH	0.31	5.58	0.08
	14	QTM0	PATCH	0.86	5.77	0.05
	15	QTM0	PATCH	0.72	5.55	0.08
	23	QTM0	PATCH	0.76	5.84	0.09
	24	QTM0	PATCH	0.95	6.00	0.06
	25	QTM0	PATCH	0.77	5.80	0.05
	26	QTM0	PATCH	0.48	5.73	0.02
	27	QTM0	PATCH	0.31	5.67	0.06
	37	QTM0	PATCH	0.94	5.58	0.06
	38	QTM0	PATCH	0.87	6.02	0.04
	39	QTM0	PATCH	0.65	5.91	0.03
	40	QTM0	PATCH	0.38	5.85	0.03
	129	QTM0	PATCH	0.02	5.45	0.05
	134	QTM0	PATCH	0.33	5.43	0.04
	135	QTM0	PATCH	0.28	5.90	0.03
	136	QTM0	PATCH	0.62	6.03	0.09
	142	QTM0	PATCH	0.22	5.74	0.03
	143	QTM0	PATCH	0.37	5.91	0.03
	151	QTM0	PATCH	0.28	4.38	0.08
	152	QTM0	PATCH	0.15	5.43	0.04
	153	QTM0	PATCH	0.60	5.74	0.02
	154	QTM0	PATCH	0.79	5.52	0.09
	155	QTM0	PATCH	0.83	4.75	0.09
	165	QTM0	PATCH	0.12	4.65	0.05
	166	QTM0	PATCH	0.44	5.77	0.03
	167	QTM0	PATCH	0.76	5.74	0.04
	168	QTM0	PATCH	0.84	5.19	0.11

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

Table 3-12: n261/mid channel QTM#1 simulated 4cm² avg.PD (W/m²) at *PD_Design_Target* (if simulation performed with correct housing material properties) (*Δmin*)

Band	Beam_ID	Module	Ant_Type	Front (S1)	Back (S2)	Right (S4)	Left (S3)	Top (S5)
n261	0	QTM1	PATCH	0.04	6.07	0.06	0.08	0.50
	3	QTM1	PATCH	0.02	5.94	0.04	0.17	0.49
	4	QTM1	PATCH	0.02	5.86	0.03	0.24	0.07
	5	QTM1	PATCH	0.08	6.17	0.08	0.06	1.76
	12	QTM1	PATCH	0.01	5.93	0.04	0.24	0.01
	13	QTM1	PATCH	0.02	5.74	0.03	0.22	0.20
	18	QTM1	PATCH	0.11	6.13	0.07	0.35	1.49
	19	QTM1	PATCH	0.04	6.03	0.08	0.19	0.34
	20	QTM1	PATCH	0.03	6.10	0.13	0.17	0.14
	21	QTM1	PATCH	0.02	6.17	0.07	0.11	0.70
	22	QTM1	PATCH	0.11	5.50	0.12	0.15	1.32
	33	QTM1	PATCH	0.09	6.03	0.08	0.34	0.75
	34	QTM1	PATCH	0.03	5.71	0.04	0.16	0.25
	35	QTM1	PATCH	0.01	6.12	0.14	0.14	0.42
	36	QTM1	PATCH	0.04	6.17	0.09	0.13	1.08
	128	QTM1	PATCH	0.01	6.13	0.06	0.11	0.04
	131	QTM1	PATCH	0.08	5.89	0.06	0.12	0.24
	132	QTM1	PATCH	0.01	6.00	0.07	0.07	0.02
	133	QTM1	PATCH	0.01	6.02	0.11	0.14	0.10
	140	QTM1	PATCH	0.01	5.99	0.09	0.08	0.03
	141	QTM1	PATCH	0.02	6.02	0.09	0.10	0.06
	146	QTM1	PATCH	0.14	6.14	0.14	0.29	0.64
	147	QTM1	PATCH	0.07	5.77	0.10	0.07	0.11
	148	QTM1	PATCH	0.04	5.98	0.09	0.21	0.09
	149	QTM1	PATCH	0.06	6.17	0.08	0.16	0.07
	150	QTM1	PATCH	0.09	5.94	0.17	0.15	1.19
	161	QTM1	PATCH	0.12	6.06	0.19	0.14	0.25
	162	QTM1	PATCH	0.03	5.97	0.12	0.14	0.26
	163	QTM1	PATCH	0.06	6.17	0.07	0.14	0.11
	164	QTM1	PATCH	0.08	6.17	0.17	0.21	0.13

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

Table 3-13: n261/mid channel, QTM#2 simulated 4cm^2 avg.PD (W/m^2) at *PD_Design_Target* (if simulation performed with correct housing material properties) (*Δmin*)

Band	Beam_ID	Module	Ant_Type	Front (S1)	Back (S2)	Right (S4)	Top (S5)
n261	2	QTM2	PATCH	0.07	6.17	0.03	0.11
	9	QTM2	PATCH	0.12	6.17	0.10	0.03
	10	QTM2	PATCH	0.13	6.11	0.12	0.01
	11	QTM2	PATCH	0.17	6.17	0.01	0.10
	16	QTM2	PATCH	0.08	6.08	0.10	0.01
	17	QTM2	PATCH	0.16	6.17	0.11	0.06
	28	QTM2	PATCH	0.08	5.66	0.03	0.08
	29	QTM2	PATCH	0.13	6.03	0.14	0.04
	30	QTM2	PATCH	0.13	6.04	0.01	0.04
	31	QTM2	PATCH	0.22	6.00	0.01	0.02
	32	QTM2	PATCH	0.37	6.17	0.02	0.22
	41	QTM2	PATCH	0.16	5.86	0.08	0.07
	42	QTM2	PATCH	0.10	6.05	0.02	0.03
	43	QTM2	PATCH	0.19	6.14	0.01	0.03
	44	QTM2	PATCH	0.28	6.01	0.01	0.15
	130	QTM2	PATCH	0.16	6.17	0.02	0.15
	137	QTM2	PATCH	0.31	5.69	0.03	0.03
	138	QTM2	PATCH	0.02	6.15	0.01	0.08
	139	QTM2	PATCH	0.19	6.17	0.02	0.02
	144	QTM2	PATCH	0.20	5.84	0.14	0.01
	145	QTM2	PATCH	0.18	6.17	0.15	0.02
	156	QTM2	PATCH	0.39	5.76	0.02	0.05
	157	QTM2	PATCH	0.17	5.91	0.10	0.04
	158	QTM2	PATCH	0.14	6.07	0.02	0.05
	159	QTM2	PATCH	0.11	6.12	0.01	0.05
	160	QTM2	PATCH	0.14	5.57	0.03	0.19
	169	QTM2	PATCH	0.23	5.48	0.03	0.06
	170	QTM2	PATCH	0.15	5.71	0.17	0.03
	171	QTM2	PATCH	0.13	5.50	0.01	0.05
	172	QTM2	PATCH	0.01	5.86	0.02	0.09

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

Table 3-14: n260/mid channel, QTM#0 simulated 4cm^2 avg.PD (W/m^2) at *PD_Design_Target* (if simulation performed with correct housing material properties) (*Δmin*)

Band	Beam_ID	Module	Ant_Type	Front (S1)	Right (S4)	Left (S3)
n260	1	QTM0	PATCH	0.58	5.73	0.05
	6	QTM0	PATCH	0.65	5.39	0.06
	7	QTM0	PATCH	0.85	6.17	0.16
	8	QTM0	PATCH	0.64	5.35	0.03
	14	QTM0	PATCH	0.60	5.44	0.04
	15	QTM0	PATCH	0.49	5.39	0.04
	23	QTM0	PATCH	0.74	5.67	0.02
	24	QTM0	PATCH	0.75	5.31	0.13
	25	QTM0	PATCH	0.67	5.33	0.04
	26	QTM0	PATCH	0.35	5.50	0.05
	27	QTM0	PATCH	0.77	5.03	0.02
	37	QTM0	PATCH	0.70	5.82	0.02
	38	QTM0	PATCH	0.64	5.29	0.11
	39	QTM0	PATCH	0.57	5.55	0.03
	40	QTM0	PATCH	0.44	5.91	0.04
	129	QTM0	PATCH	0.53	5.70	0.05
	134	QTM0	PATCH	0.66	5.99	0.13
	135	QTM0	PATCH	0.73	5.54	0.06
	136	QTM0	PATCH	0.55	5.50	0.06
	142	QTM0	PATCH	0.45	5.47	0.04
	143	QTM0	PATCH	0.70	6.17	0.14
	151	QTM0	PATCH	0.49	4.70	0.02
	152	QTM0	PATCH	0.34	5.10	0.04
	153	QTM0	PATCH	0.62	5.14	0.02
	154	QTM0	PATCH	0.65	4.17	0.13
	155	QTM0	PATCH	0.74	5.25	0.04
	165	QTM0	PATCH	0.71	5.14	0.04
	166	QTM0	PATCH	0.47	6.04	0.04
	167	QTM0	PATCH	0.55	5.57	0.12
	168	QTM0	PATCH	0.72	5.45	0.03

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

Table 3-15: n260/mid channel, QTM#1 simulated 4cm² avg.PD (W/m²) at *PD_Design_Target* (if simulation performed with correct housing material properties) (*Δmin*)

Band	Beam_ID	Module	Ant_Type	Front (S1)	Back (S2)	Right (S4)	Left (S3)	Top (S5)
n260	0	QTM1	PATCH	0.10	6.17	0.05	0.15	1.54
	3	QTM1	PATCH	0.04	6.17	0.06	0.06	0.19
	4	QTM1	PATCH	0.01	6.17	0.13	0.14	0.07
	5	QTM1	PATCH	0.01	6.17	0.05	0.04	0.25
	12	QTM1	PATCH	0.04	6.17	0.05	0.09	0.63
	13	QTM1	PATCH	0.02	6.17	0.16	0.06	0.62
	18	QTM1	PATCH	0.05	6.17	0.07	0.06	0.48
	19	QTM1	PATCH	0.02	6.17	0.06	0.06	0.48
	20	QTM1	PATCH	0.03	6.17	0.04	0.13	0.46
	21	QTM1	PATCH	0.09	6.17	0.05	0.10	0.41
	22	QTM1	PATCH	0.06	6.17	0.05	0.03	0.47
	33	QTM1	PATCH	0.05	6.17	0.06	0.06	0.33
	34	QTM1	PATCH	0.03	6.17	0.10	0.13	0.35
	35	QTM1	PATCH	0.09	6.17	0.18	0.11	0.99
	36	QTM1	PATCH	0.07	6.17	0.06	0.03	0.63
	128	QTM1	PATCH	0.02	6.17	0.08	0.08	0.22
	131	QTM1	PATCH	0.03	6.17	0.10	0.12	0.34
	132	QTM1	PATCH	0.04	6.17	0.04	0.06	0.15
	133	QTM1	PATCH	0.02	6.17	0.05	0.08	0.37
	140	QTM1	PATCH	0.03	6.17	0.16	0.11	0.46
	141	QTM1	PATCH	0.02	6.17	0.06	0.11	0.48
	146	QTM1	PATCH	0.05	6.17	0.08	0.11	0.69
	147	QTM1	PATCH	0.02	6.17	0.09	0.11	0.34
	148	QTM1	PATCH	0.08	6.17	0.13	0.08	0.47
	149	QTM1	PATCH	0.03	6.17	0.13	0.09	0.61
	150	QTM1	PATCH	0.02	6.17	0.09	0.12	0.50
	161	QTM1	PATCH	0.04	6.17	0.08	0.12	0.62
	162	QTM1	PATCH	0.02	6.17	0.09	0.09	0.15
	163	QTM1	PATCH	0.09	6.17	0.07	0.11	0.43
	164	QTM1	PATCH	0.05	6.17	0.08	0.12	0.73

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

Table 3-16: n260/mid channel, QTM#2 simulated 4cm^2 avg.PD (W/m^2) at P*D_Design_Target* (if simulation performed with correct housing material properties) (*Δmin*)

Band	Beam_ID	Module	Ant_Type	Front (S1)	Back (S2)	Right (S4)	Top (S5)
n260	2	QTM2	PATCH	0.25	5.62	0.02	0.03
	9	QTM2	PATCH	0.16	6.09	0.02	0.04
	10	QTM2	PATCH	0.01	5.44	0.02	0.05
	11	QTM2	PATCH	0.11	5.18	0.02	0.06
	16	QTM2	PATCH	0.01	5.11	0.01	0.07
	17	QTM2	PATCH	0.12	5.08	0.02	0.02
	28	QTM2	PATCH	0.25	6.13	0.02	0.03
	29	QTM2	PATCH	0.28	5.75	0.02	0.03
	30	QTM2	PATCH	0.01	5.20	0.02	0.06
	31	QTM2	PATCH	0.29	5.03	0.03	0.02
	32	QTM2	PATCH	0.19	5.69	0.02	0.06
	41	QTM2	PATCH	0.37	6.02	0.03	0.05
	42	QTM2	PATCH	0.21	5.01	0.02	0.07
	43	QTM2	PATCH	0.22	6.17	0.02	0.06
	44	QTM2	PATCH	0.24	5.34	0.02	0.04
	130	QTM2	PATCH	0.24	6.17	0.02	0.01
	137	QTM2	PATCH	0.21	5.76	0.02	0.01
	138	QTM2	PATCH	0.37	5.34	0.06	0.02
	139	QTM2	PATCH	0.30	6.17	0.02	0.02
	144	QTM2	PATCH	0.21	5.54	0.01	0.03
	145	QTM2	PATCH	0.23	6.17	0.02	0.02
	156	QTM2	PATCH	0.32	6.17	0.03	0.01
	157	QTM2	PATCH	0.14	5.36	0.05	0.04
	158	QTM2	PATCH	0.22	5.37	0.02	0.06
	159	QTM2	PATCH	0.33	6.01	0.02	0.01
	160	QTM2	PATCH	0.19	6.06	0.01	0.03
	169	QTM2	PATCH	0.27	6.17	0.02	0.01
	170	QTM2	PATCH	0.20	5.57	0.01	0.02
	171	QTM2	PATCH	0.19	5.47	0.09	0.04
	172	QTM2	PATCH	0.28	6.17	0.02	0.02

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

Table 3-17: 4cm² avg.PD of the selected beams measured on the corresponding surfaces that are not selected for Δmin determination

Band	Antenna	Beam ID	Surface	input.power.limit (dBm)	Meas. 4cm² PD (W/m²)
n261	QTM#0	24	Front (S1)	7.45	1.37
		168	Left (S3)	7.64	0.540
	QTM#1	146	Front (S1)	7.49	0.746
		161	Right (S4)	6.56	0.630
		18	Left (S3)	6.17	0.575
		5	Top (S5)	6.94	1.96
	QTM#2	156	Front (S1)	7.57	1.47
		170	Right (S4)	7.02	0.374
		32	Top (S5)	7.73	0.488
n260	QTM#0	7	Front (S1)	10.38	1.65
		7	Left (S3)	10.38	0.826
	QTM#1	0	Front (S1)	11.42	1.05
		35	Right (S4)	6.96	0.188
		0	Left (S3)	11.42	0.525
		0	Top (S5)	11.42	1.53
	QTM#2	138	Front (S1)	8.23	0.874
		171	Right (S4)	5.17	0.211
		42	Top (S5)	4.21	0.457

3.7. PD Char

3.7.1. Scaling Factor for 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 6dBm input power per active port for n261 band and 6dBm input power per active port for n260 band:

1. Obtained $PD_{surface}$ value (the worst PD among all identified surfaces of the DUT) at all three channels for all single beams specified in the codebook of Table 3-1.
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, $(\boldsymbol{ii})$**,** among low, mid and high channels:

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

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

3.7.2. Scaling Factor for 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 $\varnothing$, the scaling factor was obtained by the below equation for low, mid and high channels:

$$\boldsymbol{s(i)}_{\text{low\_or\_mid\_or\_high}} = \frac{PD\ design\ target}{total\ PD\ (\varnothing(i)_{worstcase})},\ i \in \text{single beams} \qquad (3)$$

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

$$\boldsymbol{s(i)} = min\{s_{\text{low}}(i),\ s_{\text{mid}}(i),\ s_{\text{high}}(i)\},\ i \in \text{single beams} \qquad (4)$$

3.7.3. *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 $\text{input.power.limit}(i)$, for beam *i* can be obtained after accounting for the housing influence (Δ_{min}) determined in Table 3-10, given by:

- For n261

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

- For n260

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

where 6 dBm is the input powers used in simulation for n261 and n260 ; $s(i)$ is the scaling factor obtained from Eq. (2) or Eq. (4) for beam *i*; Δ_{min} is the worst-case housing influence factor (determined in Table 3-10) for beam *i*.
If simulation overestimates the housing influence, then Δ_{min} (= simulated PD – measured PD) is negative, which means that the measured PD would be higher than the simulated PD. The input power to antenna elements determined via simulation must be decreased for compliance.

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

In reality the hardware design has uncertainty which must be properly considered. The device design related uncertainty is embedded in the process of Δ_{min} determination. Since the device uncertainty is already accounted for in *PD_design_target*, it needs to be removed to avoid double counting this uncertainty. Thus, Equation 5a and 5b is modified to:

If -TxAGC uncertainty < *Δmin* < TxAGC uncertainty,

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

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

else if *Δmin* < -TxAGC uncertainty,

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

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

else if *Δmin* > TxAGC uncertainty,

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

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

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

Table 3-18 *input.power.limit* Calculation

Band	Ant Module	Δ_{min} (dB)	TxAGC Uncertainty (dB)	input.power.limit(dBm)=	Notes
n261	QTM#0 (Patch Beam)	3.31	0.5	6 dBm + 10 * log(s(i)) + 2.81	Using Eq. 8a
	QTM#1 (Patch Beam)	1.45	0.5	6 dBm + 10 * log(s(i)) + 0.95	Using Eq. 8a
	QTM#2 (Patch Beam)	3.39	0.5	6 dBm + 10 * log(s(i)) + 2.89	Using Eq. 8a
n260	QTM#0 (Patch Beam)	2.09	0.5	6 dBm + 10 * log(s(i)) + 1.59	Using Eq. 8b
	QTM#1 (Patch Beam)	2.47	0.5	6 dBm + 10 * log(s(i)) + 1.97	Using Eq. 8b
	QTM#2 (Patch Beam)	2.88	0.5	6 dBm + 10 * log(s(i)) + 2.38	Using Eq. 8b

Thus, the DUT PD Char for n261 and n260 bands is as shown in the tables 3-19 – 3-24 below. The input.power.limit for a single beam does not apply to guarantee PD margin, only the calculation of the MIMO beam input.power.limit. The full simulation results used to support this calculation can be found in the Power Density Simulation Report.

Table 3-19 5G NR n261 QTM#0 *input.power.limit*

Band	Beam_ID	Paired with Beam_ID	Input.Power.Limit
n261	1		13.41
	6		10.59
	7		9.40
	8		10.42
	14		9.92
	15		9.50
	23		8.68
	24		7.45
	25		6.91
	26		6.89
	27		8.10
	37		7.96
	38		7.34
	39		6.65
	40		7.67
	129		13.76
	134		10.63
	135		9.54
	136		10.06
	142		10.14
	143		10.21
	151		7.59
	152		8.17
	153		6.70
	154		7.30
	155		7.68
	165		7.76
	166		8.13
	167		7.07
	168		7.64
	1	129	10.72
	6	134	7.58
	7	135	6.76
	8	136	7.42
	14	142	7.52
	15	143	6.74
	23	151	5.18
	24	152	4.80
	25	153	4.49
	26	154	4.22
	27	155	4.70
	37	165	4.95
	38	166	4.70
	39	167	4.49
	40	168	4.65

Table 3-20 5G NR n261 QTM#1 *input.power.limit*

Band	Beam_ID	Paired with Beam_ID	Input.Power.Limit
n261	0		9.19
	3		7.09
	4		6.46
	5		6.94
	12		6.72
	13		6.57
	18		6.17
	19		4.17
	20		4.45
	21		4.48
	22		5.75
	33		5.39
	34		4.06
	35		4.54
	36		4.71
	128		9.62
	131		7.48
	132		6.61
	133		7.51
	140		6.99
	141		6.90
	146		7.49
	147		4.66
	148		5.01
	149		4.41
	150		4.96
	161		6.56
	162		4.66
	163		4.93
	164		4.68
	0	128	7.80
	3	131	4.82
	4	132	4.66
	5	133	6.08
	12	140	4.59
	13	141	4.91
	18	146	4.15
	19	147	2.17
	20	148	2.11
	21	149	2.10
	22	150	3.02
	33	161	3.34
	34	162	2.11
	35	163	2.02
	36	164	2.49

Table 3-21 5G NR n261 QTM#2 *input.power.limit*

Band	Beam_ID	Paired with Beam_ID	Input.Power.Limit
n261	2		13.53
	9		9.37
	10		8.68
	11		9.53
	16		8.95
	17		9.07
	28		7.20
	29		6.71
	30		6.15
	31		6.57
	32		7.73
	41		6.97
	42		6.28
	43		6.53
	44		7.19
	130		12.86
	137		10.53
	138		8.89
	139		10.60
	144		9.66
	145		10.01
	156		7.57
	157		6.36
	158		7.08
	159		6.81
	160		7.69
	169		7.03
	170		7.02
	171		6.69
	172		7.17
	2	130	12.38
	9	137	8.01
	10	138	7.09
	11	139	7.60
	16	144	7.17
	17	145	7.18
	28	156	4.75
	29	157	4.38
	30	158	4.27
	31	159	4.39
	32	160	5.10
	41	169	4.40
	42	170	4.34
	43	171	4.31
	44	172	4.88

Table 3-22 5G NR n260 QTM#0 *input.power.limit*

Band	Beam_ID	Paired with Beam_ID	Input.Power.Limit
n260	1		11.28
	6		8.52
	7		10.38
	8		8.27
	14		8.44
	15		8.92
	23		6.73
	24		6.58
	25		6.60
	26		7.13
	27		5.89
	37		6.55
	38		6.10
	39		6.97
	40		6.37
	129		11.81
	134		9.26
	135		9.60
	136		8.96
	142		8.98
	143		9.76
	151		6.09
	152		6.47
	153		6.20
	154		6.64
	155		6.43
	165		6.27
	166		6.66
	167		7.19
	168		6.73
	1	129	9.92
	6	134	6.51
	7	135	8.65
	8	136	6.33
	14	142	6.18
	15	143	7.48
	23	151	4.55
	24	152	3.97
	25	153	4.21
	26	154	4.64
	27	155	3.95
	37	165	4.32
	38	166	4.16
	39	167	5.00
	40	168	4.43

Table 3-23 5G NR n260 QTM#1 *input.power.limit*

Band	Beam_ID	Paired with Beam_ID	Input.Power.Limit
n260	0		11.42
	3		7.12
	4		8.75
	5		7.37
	12		8.01
	13		8.68
	18		4.71
	19		4.82
	20		6.13
	21		6.70
	22		4.69
	33		4.68
	34		5.79
	35		6.96
	36		4.87
	128		11.23
	131		8.03
	132		8.75
	133		8.47
	140		8.61
	141		9.27
	146		5.68
	147		5.71
	148		7.25
	149		5.99
	150		5.54
	161		5.56
	162		6.22
	163		7.22
	164		5.73
	0	128	10.15
	3	131	5.37
	4	132	7.17
	5	133	5.53
	12	140	6.02
	13	141	6.46
	18	146	3.00
	19	147	3.02
	20	148	4.38
	21	149	4.46
	22	150	2.91
	33	161	2.90
	34	162	3.66
	35	163	4.59
	36	164	3.15

Table 3-24 5G NR n260 QTM#2 *input.power.limit*

Band	Beam_ID	Paired with Beam_ID	Input.Power.Limit
n260	2		9.72
	9		7.58
	10		6.85
	11		6.91
	16		6.78
	17		6.30
	28		4.55
	29		4.31
	30		4.60
	31		4.23
	32		4.76
	41		4.66
	42		4.21
	43		5.19
	44		4.29
	130		10.66
	137		6.90
	138		8.23
	139		8.64
	144		6.99
	145		7.62
	156		5.13
	157		4.78
	158		5.45
	159		4.68
	160		4.82
	169		4.88
	170		4.98
	171		5.17
	172		4.43
	2	130	7.83
	9	137	4.36
	10	138	5.23
	11	139	5.02
	16	144	4.77
	17	145	5.04
	28	156	2.16
	29	157	2.11
	30	158	2.99
	31	159	2.23
	32	160	2.29
	41	169	2.42
	42	170	2.43
	43	171	2.63
	44	172	1.88