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PART 0 POWER DENSITY CHAR REPORT

Applicant Name: **SAMSUNG Electronics Co., Ltd.** 129, Samsung-ro, Yeongtong-gu, Suwon-Si, Gyeonggi-do, 16677 Rep. of Korea	**Date of Issue:** Jul 02, 2020 **Test Report No.:** HCT-SR-2006-FC009-R2 **Test Site: HCT CO., LTD.**

FCC ID: A3LSMA516V

Report Type:	**Part 0 Power Density Characterization**
Equipment Type:	**Mobile Phone**
Application Type	**Certification**
FCC Rule Part(s):	**CFR §2.1093**
Model Name:	**SM-A516V**

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I attest to the accuracy of data. All measurements reported herein were performed by me or were made under my supervision and are correct to the best of my knowledge and belief. I assume full responsibility for the completeness of these measurements and vouch for the qualifications of all persons taking them.

Tested By	Reviewed By
이다솔	
Da-Sol Lee Test Engineer SAR Team Certification Division	Yun-jeang, Heo Technical Manager SAR Team Certification Division

REVISION HISTORY

The revision history for this test report is shown in table.

Revision No.	Date of Issue	Description
0	Jun. 22, 2020	Initial Release
R1	Jun. 25, 2020	Revised page 3
R2	Jul. 02, 2020	Revised page 25

This test results were applied only to the test methods required by the standard.

The above Test Report is not related to the accredited test result by (KS Q) ISO/IEC 17025 and KOLAS(Korea Laboratory Accreditation Scheme), which signed the ILAC-MRA.

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1. Test Location

1.1 Test Laboratory

Company Name	HCT Co., Ltd.
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1.2 Test Facilities

Our laboratories are accredited and approved by the following approval agencies according to ISO/IEC 17025.

Korea	National Radio Research Agency (Designation No. KR0032)
	KOLAS (Testing No. KT197)

2. Information of the EUT

2.1 General Information of the EUT

Model Name	SM-A516V
Equipment Type	Mobile Phone
FCC ID	A3LSMA516V
Application Type	Certification
Applicant	SAMSUNG Electronics Co., Ltd.

3. DEVICE UNDER TEST

3.1 Device Overview

This device uses the Qualcomm® Smart Transmit feature to control and manage transmitting power in real time and to ensure the time-averaged RF exposure is in compliance with the FCC requirement at all times for 2G/3G/4G/5G WWAN operations. Additionally, this device supports WLAN/BT/NFC/ANT+/MST technologies, but the output power of these modems is not controlled by the Smart Transmit algorithm.

3.2 Time-Averaging for SAR and 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 2G/3G/4G/5G NR WWAN is in compliance with FCC requirements. This Part 0 report shows SAR and Power Density characterization of WWAN radios for 2G/3G/4G/5G Sub-6 NR and 5G mmW NR respectively. Characterization is achieved by determining P_{Limit} for 2G/3G/4G/5G Sub-6 NR and input.power.limit for 5G mmW NR that correspond to the exposure design targets after accounting for all device design related uncertainties, i.e., SAR_design_target (< FCC SAR limit) for sub-6 radio and PD_design_target (< FCC PD limit) for mmW radio. The SAR characterization and PD characterization are denoted as SAR Char and PD Char in this report. Section 3.3 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 (report SN could be found in Section 3.4 – Bibliography).

3.3 Nomenclature for Part 0 Report

Technology	Term	Description
5G mmW NR	*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 PD 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

3.4 Bibliography

Report Type	Report Serial Number
Part 1 SAR Test Report	HCT-SR-2006-FC007-R1
Part 1 Power Density Test Report	HCT-SR-2006-FC010-R1
Part2 RF Exposure Report	HCT-SR-2006-FC012-R1
Power Density Simulation Report	Power Density Simulation Report Revision A

4. POWER DENSITY CHARACTERIZATION

4.1 Exposure Scenarios in Power Density Evaluation

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

As showed in Figure 4-1, the surfaces near-by each mmW antenna module for PD characterization are identified and listed in Table 4-1.

Note: The J Patch antenna, located on the back surface, is constructed with its dedicated ground plane behind the entire patch array and can only propagate outward.

Table 4-1 Evaluation Surfaces for PD Characterization

Band & Mode	Antenna	Back (S2)	Front (S1)	Top (S5)	Bottom (S6)	Right (S4)	Left (S3)
5G NR Band n261	L Patch	Yes	Yes	No	No	No	Yes
	K Patch	Yes	Yes	No	No	Yes	No
5G NR Band n260	L Patch	Yes	Yes	No	No	No	Yes
	K Patch	Yes	Yes	No	No	Yes	No

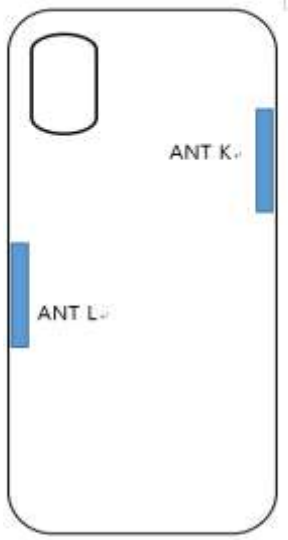

Figure 4-1: Location of mmW antenna modules looking from front of the DUT

Particular DUT edges were not required to be evaluated for power density if the edges were greater than 2.5 cm from the transmitting antenna according to FCC KDB Publication 941225 D06v02r01 Section III and FCC KDB Publication 648474 D04v01r03. The distances between the transmit antennas and the edges of the device are included in the filing. Per FCC guidance, additional edges with negligible psPD results could be excluded from testing towards Δ_{min} calculations.

4.2 Power Density Characterization Method

An overview of power density characterization method could be found in Figure 4-2 below.

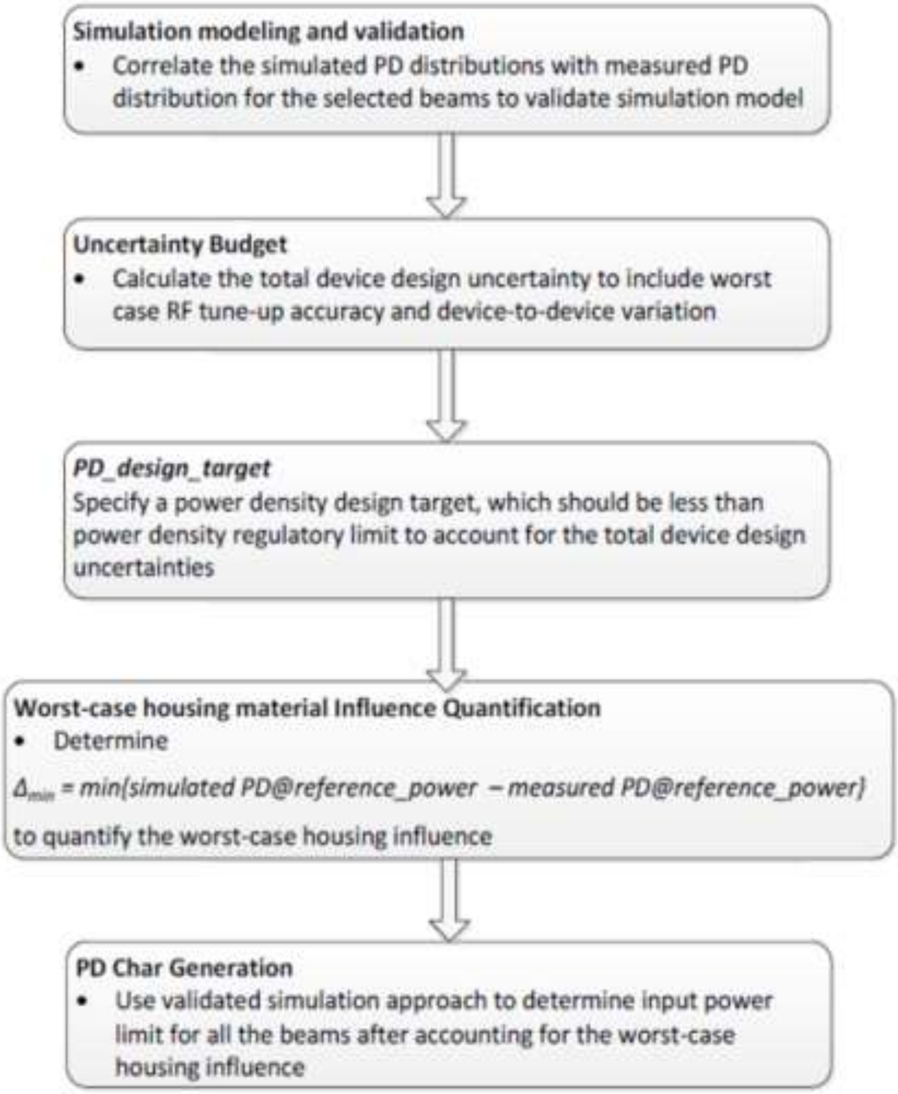

Figure 4-2: Flow chart for Power deisity characterization

4.3 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 4-2 5G mmW NR Band n261 Ant K Codebook

Band	Beam ID	Antenna	Ant_Type	Paired_With	# of Antenna Feed
n261	1	K	PATCH	129	1
n261	5	K	PATCH	135	2
n261	6	K	PATCH	133	2
n261	7	K	PATCH	134	2
n261	10	K	PATCH	138	2
n261	11	K	PATCH	139	2
n261	17	K	PATCH	148	4
n261	18	K	PATCH	147	4
n261	19	K	PATCH	146	4
n261	20	K	PATCH	145	4
n261	21	K	PATCH	149	4
n261	26	K	PATCH	156	4
n261	27	K	PATCH	155	4
n261	28	K	PATCH	154	4
n261	29	K	PATCH	157	4
n261	129	K	PATCH	1	1
n261	133	K	PATCH	5	2
n261	134	K	PATCH	6	2
n261	135	K	PATCH	7	2
n261	138	K	PATCH	10	2
n261	139	K	PATCH	11	2
n261	145	K	PATCH	17	4
n261	146	K	PATCH	18	4
n261	147	K	PATCH	19	4
n261	148	K	PATCH	20	4
n261	149	K	PATCH	21	4
n261	154	K	PATCH	26	4
n261	155	K	PATCH	27	4
n261	156	K	PATCH	28	4
n261	157	K	PATCH		4

Table 4-3 5G mmW NR Band n260 Ant K Codebook

Band	Beam ID	Antenna	Ant_Type	Paired_With	# of Antenna Feed
n260	1	K	PATCH	129	1
n260	5	K	PATCH	135	2
n260	6	K	PATCH	134	2
n260	7	K	PATCH	133	2
n260	10	K	PATCH	139	2
n260	11	K	PATCH	138	2
n260	17	K	PATCH	145	4
n260	18	K	PATCH	147	4
n260	19	K	PATCH	146	4
n260	20	K	PATCH	148	4
n260	21	K	PATCH	149	4
n260	26	K	PATCH	157	4
n260	27	K	PATCH	155	4
n260	28	K	PATCH	154	4
n260	29	K	PATCH	156	4
n260	129	K	PATCH	1	1
n260	133	K	PATCH	5	2
n260	134	K	PATCH	6	2
n260	135	K	PATCH	7	2
n260	138	K	PATCH	10	2
n260	139	K	PATCH	11	2
n260	145	K	PATCH	17	4
n260	146	K	PATCH	18	4
n260	147	K	PATCH	19	4
n260	148	K	PATCH	20	4
n260	149	K	PATCH	21	4
n260	154	K	PATCH	26	4
n260	155	K	PATCH	27	4
n260	156	K	PATCH	28	4
n260	157	K	PATCH	29	4

Table 4-4 5G mmW NR Band n261 Ant L Codebook

Band	Beam ID	Antenna	Ant_Type	Paired_With	# of Antenna Feed
n261	0	L	PATCH	128	1
n261	2	L	PATCH	132	2
n261	3	L	PATCH	131	2
n261	4	L	PATCH	130	2
n261	8	L	PATCH	137	2
n261	9	L	PATCH	136	2
n261	12	L	PATCH	144	4
n261	13	L	PATCH	143	4
n261	14	L	PATCH	142	4
n261	15	L	PATCH	141	4
n261	16	L	PATCH	140	4
n261	22	L	PATCH	153	4
n261	23	L	PATCH	152	4
n261	24	L	PATCH	151	4
n261	25	L	PATCH	150	4
n261	128	L	PATCH	0	1
n261	130	L	PATCH	2	2
n261	131	L	PATCH	3	2
n261	132	L	PATCH	4	2
n261	136	L	PATCH	8	2
n261	137	L	PATCH	9	2
n261	140	L	PATCH	12	4
n261	141	L	PATCH	13	4
n261	142	L	PATCH	14	4
n261	143	L	PATCH	15	4
n261	144	L	PATCH	16	4
n261	150	L	PATCH	22	4
n261	151	L	PATCH	23	4
n261	152	L	PATCH	24	4
n261	153	L	PATCH	25	4

Table 4-5 5G mmW NR Band n260 Ant L Codebook

Band	Beam ID	Antenna	Ant_Type	Paired_With	# of Antenna Feed
n260	0	L	PATCH	128	1
n260	2	L	PATCH	130	2
n260	3	L	PATCH	131	2
n260	4	L	PATCH	132	2
n260	8	L	PATCH	136	2
n260	9	L	PATCH	137	2
n260	12	L	PATCH	143	4
n260	13	L	PATCH	142	4
n260	14	L	PATCH	141	4
n260	15	L	PATCH	140	4
n260	16	L	PATCH	144	4
n260	22	L	PATCH	152	4
n260	23	L	PATCH	151	4
n260	24	L	PATCH	150	4
n260	25	L	PATCH	153	4
n260	128	L	PATCH	0	1
n260	130	L	PATCH	2	2
n260	131	L	PATCH	3	2
n260	132	L	PATCH	4	2
n260	136	L	PATCH	8	2
n260	137	L	PATCH	9	2
n260	140	L	PATCH	12	4
n260	141	L	PATCH	13	4
n260	142	L	PATCH	14	4
n260	143	L	PATCH	15	4
n260	144	L	PATCH	16	4
n260	150	L	PATCH	22	4
n260	151	L	PATCH	23	4
n260	152	L	PATCH	24	4
n260	153	L	PATCH	25	4

4.4 Simulation and modeling validation

Power density simulations of all 13 beams and surfaces were performed by the manufacturer. Details of these simulations and modeling validatio0n can be found in the Power Density Simulation Report (Power Density Simulation Report Revision A). 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 type and per antenna module (K, L) on worst-surface(s)

PD measurements are performed at mid channel of each mmW band and with CW modulation. All measured PD values are listed in table below along with corresponding simulated PD values for the same configuration. PD value will be used to determine worst-case housing influence for conservative assessment.

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

Table 4-6

					4cm^2 avg. PD (mW/cm^2)		Delta = Simulated - Measured
Band	Beam ID	Antenna	Surface	Channel	Meas.	Sim	[dB]
n261	28	K (patch)	Back (S2)	Mid	0.849	1.32	**1.93**
			Left (S3)	Mid	0.771	1.48	2.85
	155		Back (S2)	Mid	0.785	1.32	2.25
			Left (S3)	Mid	0.829	1.52	2.64
	24	L (patch)	Back (S2)	Mid	0.879	1.39	**2**
			Right (S4)	Mid	0.843	1.53	2.59
	142		Back (S2)	Mid	0.586	1.44	3.9
			Right (S4)	Mid	0.878	1.62	2.66
n260	28	K (patch)	Back (S2)	Mid	0.86	1.28	1.73
			Left (S3)	Mid	0.112	1.58	**1.48**
	157		Back (S2)	Mid	0.797	1.15	1.59
			Left (S3)	Mid	0.954	1.6	2.26
	24	L (patch)	Back (S2)	Mid	0.798	1.32	2.24
			Right (S4)	Mid	0.884	1.59	2.55
	143		Back (S2)	Mid	0.839	1.26	**1.77**
			Right (S4)	Mid	0.1	1.58	2

4.5 *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

PD_design_target Calculations

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

PD_design_target Calculations

4.6 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 surfac e
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 4-1, 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 4-2 ~ Table 4-5 in Samsung 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 K patch: Back (S2) & Left (S3)

b. for L patch: Back (S2) & Right (S4)

Thus, when comparing a simulated 4cm2averaged PD and measured 4 cm2averaged PD for the identified worstsurface(s), the worst error introduced for each antenna type and each antenna module group when using theestimated material property in the simulation is highlighted in bold numbers in Table 4-6.
Thus, the worst-case housing influence, denoted as Δmin = Sim. PD − Meas. PD , is determined as

Table 4-7.
Table Δmin for Ant K, Ant L

Band	Ant	*Δmin* (dB)
n261	K(Patch Beam)	1.93
	L(Patch Beam)	2.0
n260	K(Patch Beam)	1.48
	L(Patch Beam)	1.77

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 5-1 Simulated 4cm2 PD values in Table 4 ~ Table 5 in Power Density Simulation Report are scaled to input.power.limit and are listed in Tables 4-8 ~ 4-11 for all single beams for all identified surfaces (shown in Table 4-1), 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 L patch: Front (S1)
b. for K patch: Front (S1)

Then perform PD measurement for all determined worst-case beams, in Tables 4-8 ~4- 11 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 4-12 shows that the all measured 4cm^2 PD values are less than *PD_design_target* of 0.6166 mW/cm^2, thus, the non- selected surfaces have no influence on the determined Δmin and input.power.limit in Section 5

Table 4-8
N261/mid channel, L patch simulates 4cm² PD at PD_Design_Target
(If simulation performed with correct housing material properties) Δmin

n261, Ant L,						
Beam ID	4cm2 PD(mW/cm2)					
	S4(Right)	S3(Left)	S5(Top)	S6(Bottom)	S1(Front)	S2(Rear)
0	0.603	0.005	0.000	0.007	0.049	0.616
2	0.616	0.006	0.000	0.016	0.115	0.497
3	0.616	0.005	0.000	0.006	0.094	0.559
4	0.561	0.007	0.000	0.014	0.060	0.557
8	0.617	0.005	0.000	0.018	0.105	0.523
9	0.575	0.005	0.000	0.003	0.062	0.574
12	0.572	0.008	0.000	0.040	0.133	0.544
13	0.595	0.003	0.000	0.010	0.103	0.540
14	0.617	0.003	0.000	0.005	0.081	0.555
15	0.617	0.002	0.000	0.004	0.067	0.589
16	0.569	0.005	0.000	0.015	0.051	0.603
22	0.600	0.004	0.000	0.022	0.118	0.519
23	0.617	0.003	0.000	0.005	0.098	0.563
24	0.617	0.003	0.000	0.003	0.072	0.562
25	0.564	0.005	0.000	0.004	0.040	0.602
128	0.617	0.004	0.000	0.012	0.086	0.532
130	0.617	0.003	0.000	0.017	0.097	0.536
131	0.610	0.002	0.000	0.007	0.081	0.556
132	0.570	0.005	0.000	0.030	0.085	0.583
136	0.617	0.002	0.000	0.005	0.091	0.549
137	0.606	0.003	0.000	0.020	0.069	0.575
140	0.611	0.010	0.000	0.035	0.115	0.546
141	0.617	0.004	0.000	0.003	0.089	0.585
142	0.616	0.002	0.000	0.004	0.077	0.547
143	0.581	0.003	0.000	0.003	0.060	0.536
144	0.529	0.006	0.000	0.039	0.048	0.598
150	0.617	0.008	0.000	0.008	0.097	0.577
151	0.605	0.002	0.000	0.002	0.089	0.550
152	0.598	0.003	0.000	0.003	0.069	0.533
153	0.594	0.004	0.000	0.016	0.057	0.591

Note: Even though the worst surface having the highest 4cm^2 PD values is right surface (S3), as shown in Table 5-3, the back surface (S2) was also selected for *Δmin* determination. Therefore, the worst- case beam for remaining non-selected surfaces (identified in Table 4-1) is from front surface (S1) only.
Please note the above scaled simulation values correspond to PD_design_target if the simulation was performed with correct housing material properties.

Table 4-9
N261/mid channel, K patch simulates 4cm² PD at PD_Design_Target
(If simulation performed with correct housing material properties) Δmin

n261, Ant K						
Beam ID	4cm2 PD(mW/cm2)					
	S4(Right)	S3(Left)	S5(Top)	S6(Bottom)	S1(Front)	S2(Rear)
1	0.003	0.575	0.015	0.000	0.101	0.519
5	0.004	0.617	0.036	0.000	0.113	0.515
6	0.004	0.597	0.008	0.000	0.056	0.587
7	0.004	0.583	0.039	0.000	0.091	0.529
10	0.002	0.617	0.018	0.000	0.103	0.544
11	0.003	0.531	0.013	0.000	0.057	0.550
17	0.005	0.617	0.070	0.000	0.128	0.501
18	0.002	0.617	0.022	0.000	0.108	0.556
19	0.003	0.603	0.006	0.000	0.084	0.537
20	0.004	0.601	0.013	0.000	0.046	0.593
21	0.006	0.589	0.045	0.000	0.072	0.577
26	0.002	0.617	0.041	0.000	0.107	0.554
27	0.003	0.617	0.006	0.000	0.093	0.568
28	0.002	0.600	0.010	0.000	0.084	0.535
29	0.005	0.594	0.020	0.000	0.044	0.593
129	0.003	0.597	0.023	0.000	0.083	0.539
133	0.003	0.615	0.022	0.000	0.109	0.533
134	0.004	0.579	0.023	0.000	0.067	0.548
135	0.010	0.593	0.071	0.000	0.093	0.569
138	0.002	0.617	0.006	0.000	0.093	0.544
139	0.008	0.542	0.052	0.000	0.061	0.572
145	0.005	0.617	0.018	0.000	0.107	0.553
146	0.002	0.613	0.014	0.000	0.100	0.538
147	0.002	0.589	0.015	0.000	0.071	0.509
148	0.005	0.585	0.054	0.000	0.058	0.573
149	0.010	0.475	0.096	0.000	0.053	0.595
154	0.002	0.616	0.007	0.000	0.110	0.549
155	0.003	0.617	0.016	0.000	0.083	0.535
156	0.003	0.582	0.027	0.000	0.065	0.514
157	0.007	0.513	0.085	0.000	0.055	0.589

Table 4-10
N260/mid channel, L patch simulates 4cm² PD at PD_Design_Target
(If simulation performed with correct housing material properties) Δmin

n260, Ant L						
Beam ID	4cm2 PD(mW/cm2)					
	S4(Right)	S3(Left)	S5(Top)	S6(Bottom)	S1(Front)	S2(Rear)
0	0.617	0.003	0.000	0.011	0.087	0.427
2	0.617	0.006	0.000	0.017	0.093	0.412
3	0.617	0.003	0.000	0.005	0.107	0.505
4	0.617	0.004	0.000	0.021	0.114	0.370
8	0.617	0.004	0.000	0.008	0.104	0.495
9	0.617	0.004	0.000	0.009	0.082	0.416
12	0.600	0.007	0.000	0.033	0.113	0.407
13	0.583	0.004	0.000	0.012	0.107	0.501
14	0.617	0.005	0.000	0.007	0.112	0.528
15	0.617	0.007	0.000	0.006	0.120	0.489
16	0.617	0.004	0.000	0.038	0.145	0.416
22	0.599	0.006	0.000	0.021	0.106	0.475
23	0.617	0.004	0.000	0.007	0.099	0.542
24	0.617	0.007	0.000	0.007	0.111	0.513
25	0.617	0.005	0.000	0.024	0.138	0.404
128	0.617	0.003	0.000	0.009	0.068	0.433
130	0.610	0.004	0.000	0.006	0.074	0.439
131	0.617	0.005	0.000	0.008	0.097	0.486
132	0.617	0.003	0.000	0.009	0.083	0.397
136	0.613	0.003	0.000	0.007	0.093	0.509
137	0.617	0.005	0.000	0.011	0.110	0.411
140	0.569	0.008	0.000	0.009	0.128	0.386
141	0.569	0.006	0.000	0.008	0.094	0.452
142	0.617	0.004	0.000	0.004	0.106	0.518
143	0.617	0.005	0.000	0.015	0.105	0.491
144	0.608	0.006	0.000	0.018	0.127	0.416
150	0.617	0.008	0.000	0.004	0.100	0.451
151	0.617	0.004	0.000	0.006	0.088	0.545
152	0.617	0.006	0.000	0.010	0.098	0.490
153	0.617	0.004	0.000	0.023	0.119	0.452

Table 4-11
N260/mid channel, K patch simulates 4cm² PD at PD_Design_Target
(If simulation performed with correct housing material properties) Δmin

n260, Ant K						
Beam ID	4cm2 PD(mW/cm2)					
	S4(Right)	S3(Left)	S5(Top)	S6(Bottom)	S1(Front)	S2(Rear)
1	0.007	0.617	0.014	0.000	0.110	0.440
5	0.008	0.617	0.045	0.000	0.122	0.428
6	0.011	0.617	0.020	0.000	0.099	0.477
7	0.006	0.617	0.050	0.000	0.101	0.372
10	0.007	0.617	0.034	0.000	0.102	0.410
11	0.012	0.617	0.022	0.000	0.092	0.442
17	0.009	0.617	0.069	0.000	0.120	0.471
18	0.011	0.610	0.074	0.000	0.106	0.476
19	0.010	0.617	0.015	0.000	0.096	0.507
20	0.012	0.617	0.044	0.000	0.112	0.485
21	0.004	0.617	0.076	0.000	0.134	0.375
26	0.006	0.617	0.083	0.000	0.137	0.408
27	0.011	0.617	0.039	0.000	0.097	0.513
28	0.012	0.617	0.008	0.000	0.113	0.501
29	0.006	0.617	0.073	0.000	0.118	0.419
129	0.006	0.617	0.022	0.000	0.069	0.438
133	0.009	0.617	0.030	0.000	0.086	0.396
134	0.011	0.617	0.017	0.000	0.102	0.493
135	0.006	0.617	0.033	0.000	0.082	0.393
138	0.013	0.617	0.011	0.000	0.095	0.508
139	0.006	0.617	0.024	0.000	0.115	0.419
145	0.009	0.617	0.057	0.000	0.114	0.399
146	0.011	0.617	0.019	0.000	0.102	0.487
147	0.011	0.617	0.014	0.000	0.104	0.526
148	0.006	0.617	0.041	0.000	0.108	0.498
149	0.007	0.617	0.058	0.000	0.116	0.403
154	0.013	0.616	0.012	0.000	0.106	0.468
155	0.011	0.617	0.015	0.000	0.108	0.523
156	0.010	0.617	0.013	0.000	0.086	0.491
157	0.006	0.617	0.046	0.000	0.108	0.441

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Table 4-12
4cm² PD of the selected Beam ids measured on the corresponding surfaces that are not selected for Δmin determination

Band	Antenna	Beam ID_1	Surface	Input.power.limit (dBm)	Meas.4 c ㎠ cm PD(Mw/㎠)
n261	L (Patch)	12	Front	6.0	0.163
	K (Patch)	17	Front	4.0	0.188
n260	L (Patch)	16	Front	3.6	0.193
	K (Patch)	26	Front	3.5	0.160

5 PD Char

5.1 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 6 dBm input power per active port for n261 band and 6 dBm input power per active port for n260 band:

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

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

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

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

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

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

5.2 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.

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

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*:

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

5.3 *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 4-7, given by:

For n260 and n261

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

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

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 [illegible] 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 < Δ_{min} < TxAGC uncertainty,

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

else if Δ_{min} < -TxAGC uncertainty,

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

else if Δ_{min} > TxAGC uncertainty,

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

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

Input.power.limit Calculation

Band	Antenna	Δmin (dB)	TxAGC Uncertainty (dB)	*input.power.limit* (dBm)	Notes
n261	K (patch beam)	1.93	0.5	input.power.limit (i)=6dB+10*log(s(i)+1.43	Using Eq. 8
	L (patch beam)	2	0.5	input.power.limit (i)=6dB+10*log(s(i)+1.5	Using Eq. 8
n261	K (patch beam)	1.48	0.5	input.power.limit (i)=6dB+10*log(s(i)+0.98	Using Eq. 8
	L (patch beam)	1.77	0.5	input.power.limit (i)=6dB+10*log(s(i)+1.27	Using Eq. 8

Table 5-1 5G NR n261 K Patch *input.power.limit*

Antenna	Beam ID_1	Beam ID_2	Input.power.limit (dBm)
K Patch	1		10.5
	5		8.2
	6		6.6
	7		8.9
	10		7.0
	11		7.6
	17		5.1
	18		4.0
	19		3.8
	20		4.1
	21		4.9
	26		4.2
	27		4.1
	28		3.5
	29		4.2
	129		9.7
	133		6.1
	134		6.1
	135		7.6
	138		5.6
	139		7.0
	145		4.5
	146		3.8
	147		3.6
	148		3.9
	149		4.3
	154		4.0
	155		3.6
	156		3.7
	157		4.0
	1	129	6.0
	5	135	4.1
	6	133	3.3
	7	134	3.4
	10	138	2.1
	11	139	4.1
	17	148	0.6
	18	147	0.0
	19	146	-0.3
	20	145	0.1
	21	149	2.1
	26	156	0.3
	27	155	-0.2
	28	154	-0.4
	29	157	2.0

Table 5-2 5G NR n261 L Patch *input.power.limit*

Antenna	Beam ID_1	Beam ID_2	Input.power.limit (dBm)
L Patch	0		9.5
	2		7.5
	3		7.2
	4		8.4
	8		8.5
	9		7.0
	12		6.0
	13		4.2
	14		3.9
	15		3.7
	16		4.2
	22		4.9
	23		3.9
	24		3.6
	25		3.9
	128		9.8
	130		6.5
	131		5.8
	132		6.9
	136		5.9
	137		6.4
	140		5.0
	141		3.8
	142		3.4
	143		3.5
	144		3.8
	150		4.1
	151		3.5
	152		3.3
	153		3.8
	0	128	6.6
	2	132	4.0
	3	131	2.2
	4	130	3.7
	8	137	3.1
	9	136	2.3
	12	144	0.8
	13	143	-0.3
	14	142	-0.7
	15	141	-0.6
	16	140	0.4
	22	153	0.2
	23	152	-0.5
	24	151	-0.7
	25	150	0.0

Table 5-3 5G NR n260 K Patch *input.power.limit*

Antenna	Beam ID_1	Beam ID_2	Input.power.limit (dBm)
K Patch	1		9.3
	5		5.5
	6		6.3
	7		5.3
	10		5.9
	11		5.6
	17		3.3
	18		4.1
	19		3.4
	20		3.2
	21		3.1
	26		3.5
	27		3.7
	28		3.0
	29		3.1
	129		8.4
	133		5.7
	134		6.0
	135		5.6
	138		6.3
	139		5.1
	145		3.3
	146		4.0
	147		3.4
	148		2.9
	149		3.0
	154		4.1
	155		3.4
	156		3.4
	157		2.9
	1	129	6.4
	5	135	1.9
	6	134	1.4
	7	133	2.3
	10	139	1.3
	11	138	1.8
	17	145	-0.7
	18	147	-0.8
	19	146	-0.8
	20	148	0.2
	21	149	-0.2
	26	157	-0.7
	27	155	-1.3
	28	154	-1.1
	29	156	0.2

Table 5-4 5G NR n260 L Patch *input.power.limit*

Antenna	Beam ID_1	Beam ID_2	Input.power.limit (dBm)
L Patch	0		8.3
	2		6.3
	3		6.3
	4		5.4
	8		6.6
	9		5.5
	12		4.0
	13		4.0
	14		3.3
	15		3.6
	16		3.6
	22		4.3
	23		3.9
	24		3.2
	25		3.5
	128		8.8
	130		5.9
	131		6.4
	132		6.2
	136		6.7
	137		5.4
	140		3.5
	141		4.3
	142		3.7
	143		3.2
	144		3.5
	150		4.3
	151		4.1
	152		3.4
	153		3.3
	0	128	4.2
	2	130	2.8
	3	131	1.9
	4	132	2.6
	8	136	2.0
	9	137	2.0
	12	143	-0.7
	13	142	-0.8
	14	141	-0.8
	15	140	-0.5
	16	144	0.0
	22	152	-0.7
	23	151	-1.0
	24	150	-0.8
	25	153	-0.3