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NEAR-FIELD POWER DENSITY PART 0 REPORT

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APPLICANT:	**SAMSUNG ELECTRONICS CO., LTD.**

DUT Type: Portable Tablet
Report Type: Part 0 Power Density Characterization
Model: SM-T978U

Note: This revised Test Report (S/N: 1M2004230075-23-R1.A3L) supersedes and replaces the previously issued test report on the same subject device for the same type of testing as indicated. Please discard or destroy the previously issued test report(s) and dispose of it accordingly.

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. Test results reported herein relate only to the item(s) tested.

Randy Ortanez
President

ACCREDITED
CERT #2041.01

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1 DEVICE UNDER TEST

1.1 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.

1.2 Time-Averaging Algorithm for RF Exposure Compliance

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 Power Density characterization of WWAN radios for mmW NR. Characterization is achieved by determining input.power.limit for 5G mmW NR that correspond to the exposure design target after accounting for all device design related uncertainties, i.e., PD_design_target (< FCC PD limit) for mmW radio. The PD characterization is denoted as PD Char 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.

1.3 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
	Δ_{min}	Housing material influence
	PD Char	Table containing *input.power.limit* for all beams and bands

2 MEASUREMENT SYSTEM

2.1 Measurement Setup

Peak spatially averaged power density (psPD) measurements for mmWave frequencies were performed using the DASY6 with cDASY6 5G module. The DASY6 is made by Schmid & Partner Engineering AG (SPEAG) in Zurich, Switzerland and consists of a high precision robotics system (Staubli), robot controller, desktop computer, near-field probe, probe alignment sensor, and the 5G phantom. The robot is a six-axis industrial robot, performing precise movements to position the probe to the location (points) of maximum electromagnetic field (EMF).

2.2 SPEAG EUmmWV3 Probe / E-Field 5G Probe

The EUmmWV3 probe consists of two dipoles optimally arranged to obtain pseudo-vector information.

Frequency Range	750 MHz – 110 GHz
Dynamic Range	< 20 V/m – 10,000 V/m with PRE-10 (min < 50 V/m – 3,000 V/m)
Position Precision	< 0.2 mm (cDASY6)
Dimensions	Probe Overall Length: 320 mm Probe Body Diameter: 8 mm Probe Tip Length: 23 mm Probe Tip Diameter: Encapsulation 8 mm Distance from Probe Tip to Sensor X Calibration Point: 1.5 mm Distance from Probe Tip to Sensor Y Calibration Point: 1.5 mm
Applications	E-field measurements of 5G devices and other mm-wave transmitters operating above 10 GHz in < 2 mm distance from device (free-space) Power density, H-field and far-field analysis using total field reconstruction
Compatibility	cDASY6 + 5G-Module SW 2.0.2.34

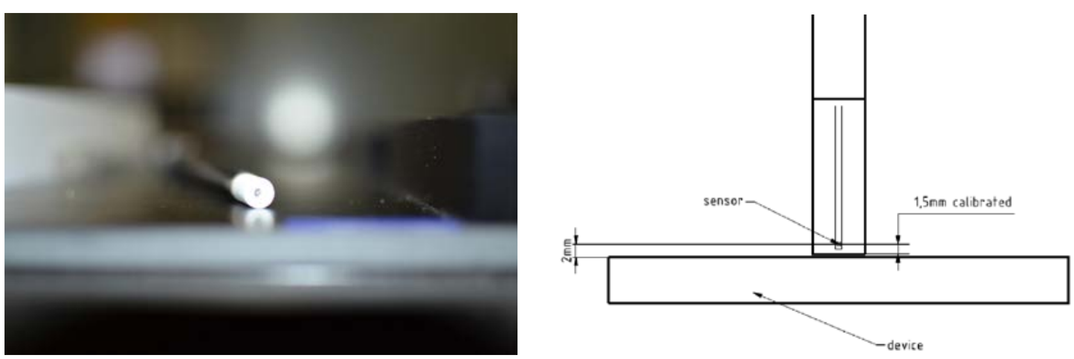

Figure 2-1
EUmmWV3 Probe

2.3 Peak Spatially Averaged Power Density Assessment Based on E-field Measurements

Within a short distance from the transmitting source, power density was determined based on both electric and magnetic fields. Generally, the magnitude and phase of two components of either the E-field or H-field were needed on a sufficiently large surface to fully characterize the total E-field and H-field distributions. Nevertheless, solutions based on direct measurement of E-field and H-field can be used to compute power density. The general measurement approach used for this device was:

a) The local E field on the measurement surface was measured at a reference location where the field is well above the noise level. This reference level was used at the end of this procedure to assess output power drift of the DUT during the measurement.

b) The electric field on the measurement surface was scanned. Measurements are conducted according to the instructions provided by the measurement system manufacturer. Measurement spatial resolution can depend on the measured field characteristic and measurement methodology used by the system. The planar scan step size was configured at λ/4.

c) For cDASY6, H-field was calculated from the measured E-field using a reconstruction algorithm. As the power density calculation requires knowledge of both amplitude and phase, reconstruction algorithms can also be used to obtain field information from the measured E-field data (e.g. the phase from the amplitude if only the amplitude is measured). H-field and phase data was reconstructed from repeated measurements (three per measurement point) on two measurement planes separated by λ/4.

d) The total Peak spatially averaged power density (psPD) distribution on the evaluation surface is determined per the below equation. The spatial averaging area, *A*, is specified by the applicable exposure limits or regulatory requirements. A circular shape was used.

$$psPD = \frac{1}{2A_{av}} \iint_{A_{av}} || Re\{E \times H^*\} || \, dA$$

e) The maximum spatial-average on the evaluation surface is the final quantity to determine compliance against applicable limits.

f) The local E field reference value, at the same location as step 2, was re-measured after the scan was complete to calculate the power drift. If the drift deviated by more than 5%, the power density test and drift measurements were repeated.

2.4 Reconstruction Algorithm

Computation of the power density in general requires measurement information from the both E-field and H-field amplitudes and phases in the plane of incidence. Reconstruction of these quantities from pseudo-vector E-field measurements is feasible according to the manufacturer, as they are determined via Maxwell's equations. As such, the SPEAG reconstruction approach was based on the Gerchberg-Saxton algorithm, which benefits from the availability of the E-field polarization ellipse information obtained with the EUmmWV3 probe.

3 POWER DENSITY CHARACHTERIZATION

3.1 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.

The surfaces near-by each mmW antenna module for PD characterization are identified below.

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	0	Yes	No	No	No	Yes	No
	1	No	Yes	No	No	Yes	No
5G NR Band n260	0	Yes	No	No	No	Yes	No
	1	No	Yes	No	No	Yes	No

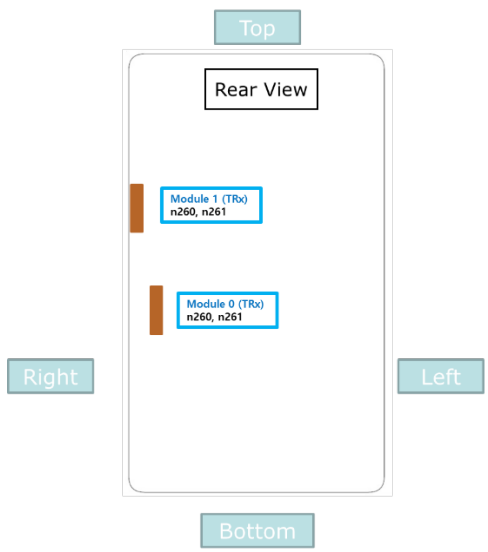

Figure 3-1
Location of mmW antenna modules

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.

3.2 Power Density Characterization Method

An overview of power density characterization method could be found below.

Simulation modeling and validation

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

↓

Uncertainty Budget

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

↓

PD_design_target

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

↓

Worst-case housing material Influence Quantification

- Determine

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

to quantify the worst-case housing influence

↓

PD Char Generation

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

Figure 3-2
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 Ant 0 Codebook

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

Table 3-3
5G mmW NR Band n261 Ant 1 Codebook

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

Table 3-4
5G mmW NR Band n260 Ant 0 Codebook

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

Table 3-5
5G mmW NR Band n260 Ant 1 Codebook

Band	Antenna Module	Beam ID	Paired With	Antenna Type	# of Antenna Feed
n260	1	1	129	Patch	1
		5	133	Patch	2
		6	134	Patch	2
		7	135	Patch	2
		10	138	Patch	2
		11	139	Patch	2
		17	145	Patch	4
		18	146	Patch	4
		19	147	Patch	4
		20	148	Patch	4
		21	149	Patch	4
		26	154	Patch	4
		27	155	Patch	4
		28	156	Patch	4
		29	157	Patch	4
		129	1	Patch	1
		133	5	Patch	2
		134	6	Patch	2
		135	7	Patch	2
		138	10	Patch	2
		139	11	Patch	2
		145	17	Patch	4
		146	18	Patch	4
		147	19	Patch	4
		148	20	Patch	4
		149	21	Patch	4
		154	26	Patch	4
		155	27	Patch	4
		156	28	Patch	4
		157	29	Patch	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. A summary of the validation results to support worst-case housing influence quantification in power density characterization for this model can be seen below.

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 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 below along with corresponding simulated PD values for the same configuration. Beams are chosen based on worst case simulation value of mid channel only.

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

Table 3-6
Measured and Simulated 4cm^2 psPD for Selected Beams
with 6 dBm Input Power for n261 and 6 dBm Input Power for n260

Band	Antenna	Beam ID	Surface	Meas.	Sim	Delta = Sim. - Meas. (dB)
				4cm^2 psPD (mW/cm^2)		
n261	0	14	Back	0.82	1.89	3.64
		150	Back	0.94	2.07	**3.42**
	1	28	Front	0.86	1.48	2.37
		149	Front	1.08	1.67	**1.90**
n260	0	22	Back	0.83	1.70	**3.13**
		140	Back	0.79	1.82	3.62
	1	18	Front	1.09	2.20	3.05
		145	Front	1.05	2.06	**2.92**

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.

Table 3-7
***PD_design_target* Calculations**

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

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 locations, only surrounding material/housing has impact on EM field propagation, and in turn power density. Furthermore, depending on the type of antenna array, i.e., dipole antenna array or patch antenna array, the nature of EM field propagation in the near field is different. Therefore, the worst-case housing influence is determined per antenna module and per antenna type.

For this DUT, the below procedure was used to determine worst-case housing influence, *Δmin*:

1. Based on PD simulation, for each module and antenna type, determine one or more worst-surface(s) that has highest $4cm^2$ 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, the worst-surface(s) having highest 4cm^2 psPD 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 Antenna 0: Back

b. for Antenna 1: Front

Thus, when comparing a simulated 4cm^2-averaged psPD and measured 4 cm^2-averaged psPD 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 are chosen for Δ_{min}. Thus, the worst-case housing influence, denoted as $\Delta_{min} = \mathrm{Sim.PD} - \mathrm{Meas.PD}$, is determined as

Table 3-8
Δ_{min} for all antennas

Band	Antenna	Δmin (dB)
n261	0	3.42
	1	1.90
n260	0	3.13
	1	2.92

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.

Simulated 4cm^2 psPD values in Power Density Simulation Report are scaled to *input.power.limit* and are listed in tables below 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 antenna 0: Right

b. for antenna 1: Right

Then perform PD measurement for all determined worst-case beams, highlighted in orange in tables below, 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 show that the all measured 4cm^2 psPD values are less than *PD_design_target* of 0.6166 mW/cm^2, thus, the non-selected surfaces have no influence on the determined Δ_{min} and *input.power.limit*..

Table 3-9
n261, mid channel, antenna 0 simulated 4cm^2 PD at PD_Design_Target
(if simulation performed with correct housing material properties) (Δ_{min})

Module	Beam ID_1	Simulated 4cm2 PD(mW/cm2) Corresponding to PD_design_target if the simulation was performed with correct No. Module Type housing material properties	
		S4(Right)	S2(Back)
0	0	0.045	0.542
	2	0.042	0.593
	3	0.062	0.581
	4	0.033	0.567
	8	0.063	0.572
	9	0.049	0.561
	12	0.045	0.529
	13	0.063	0.505
	14	0.089	0.576
	15	0.072	0.601
	16	0.030	0.525
	22	0.049	0.525
	23	0.090	0.592
	24	0.088	0.578
	25	0.054	0.593
	128	0.034	0.608
	130	0.042	0.585
	131	0.051	0.575
	132	0.065	0.616
	136	0.043	0.571
	137	0.060	0.590
	140	0.080	0.576
	141	0.034	0.548
	142	0.051	0.563
	143	0.092	0.567
	144	0.098	0.594
	150	0.070	0.598
	151	0.048	0.563
	152	0.067	0.561
	153	0.115	0.569

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

Table 3-10
n261, mid channel, antenna 1 simulated 4cm^2 PD at PD_Design_Target
(if simulation performed with correct housing material properties) (Δ_{min})

Module	Beam ID_1	Simulated 4cm2 PD(mW/cm2) Corresponding to PD_design_target if the simulation was performed with correct No. Module Type housing material properties	
		S4(Right)	S1(Front)
1	1	0.166	0.567
	5	0.174	0.583
	6	0.277	0.577
	7	0.155	0.568
	10	0.251	0.596
	11	0.207	0.572
	17	0.199	0.592
	18	0.235	0.605
	19	0.281	0.597
	20	0.287	0.574
	21	0.242	0.582
	26	0.214	0.605
	27	0.261	0.583
	28	0.296	0.600
	29	0.247	0.548
	129	0.158	0.574
	133	0.224	0.602
	134	0.254	0.617
	135	0.161	0.591
	138	0.293	0.612
	139	0.184	0.598
	145	0.185	0.557
	146	0.274	0.605
	147	0.277	0.602
	148	0.256	0.609
	149	0.194	0.563
	154	0.239	0.565
	155	0.289	0.617
	156	0.265	0.595
	157	0.226	0.617

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

Table 3-11
n260, mid channel, antenna 0 simulated 4cm^2 PD at PD_Design_Target
(if simulation performed with correct housing material properties) (Δ_{min})

Module	Beam ID_1	Simulated 4cm2 PD(mW/cm2) Corresponding to PD_design_target if the simulation was performed with correct No. Module Type housing material properties	
		S4(Right)	S2(Back)
0	0	0.032	0.617
	2	0.074	0.617
	3	0.081	0.617
	4	0.055	0.584
	8	0.100	0.617
	9	0.044	0.586
	12	0.078	0.574
	13	0.141	0.617
	14	0.068	0.517
	15	0.060	0.562
	16	0.073	0.593
	22	0.126	0.608
	23	0.123	0.617
	24	0.043	0.458
	25	0.064	0.612
	128	0.042	0.577
	130	0.057	0.604
	131	0.061	0.561
	132	0.069	0.598
	136	0.066	0.575
	137	0.073	0.584
	140	0.110	0.616
	141	0.071	0.617
	142	0.058	0.501
	143	0.111	0.617
	144	0.100	0.617
	150	0.083	0.598
	151	0.079	0.589
	152	0.080	0.565
	153	0.117	0.617

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
n260, mid channel, antenna 1 simulated 4cm^2 PD at PD_Design_Target
(if simulation performed with correct housing material properties) (Δ_{min})

Module	Beam ID_1	Simulated 4cm2 PD(mW/cm2) Corresponding to PD_design_target if the simulation was performed with correct No. Module Type housing material properties	
		S4(Right)	S1(Front)
1	1	0.215	0.589
	5	0.204	0.617
	6	0.248	0.617
	7	0.204	0.617
	10	0.170	0.617
	11	0.268	0.617
	17	0.224	0.617
	18	0.182	0.617
	19	0.275	0.568
	20	0.292	0.617
	21	0.210	0.617
	26	0.188	0.617
	27	0.194	0.617
	28	0.302	0.615
	29	0.254	0.617
	129	0.219	0.605
	133	0.174	0.603
	134	0.334	0.617
	135	0.179	0.597
	138	0.254	0.617
	139	0.190	0.617
	145	0.210	0.617
	146	0.298	0.617
	147	0.283	0.581
	148	0.248	0.617
	149	0.231	0.617
	154	0.249	0.617
	155	0.289	0.617
	156	0.273	0.617
	157	0.206	0.617

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
4cm² psPD of the selected beams measured on the corresponding surfaces that are not selected for Δ_{min} determination

Band	Antenna	Beam ID	Surface	*input.power.limit* (dBm)	Meas. 4cm² psPD (mW/cm²)
n261	0	153	Right	4.6	0.253
	1	28	Right	3.5	0.214
n260	0	13	Right	4.4	0.278
	1	134	Right	6.5	0.378

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

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

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

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

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

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

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

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 $input.power.limit(i)$, for beam *i* can be obtained after accounting for the housing influence (Δ_{min}), given by:

- For n260 and n261

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

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*; Δ_{min} is the worst-case housing influence factor 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 5 is modified to:

If -TxAGC uncertainty < Δ_{min} < TxAGC uncertainty,

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

else if Δ_{min} < -TxAGC uncertainty,

$$input.power.limit(i) = 6\ dBm + 10 * \log\big(s(i)\big) + \ (\Delta_{min} + \text{TxAGC uncertainty}),$$

$$i \in all\ beams, \text{ for n260 and n261} \quad (7)$$

else if Δ_{min} > TxAGC uncertainty,

$$input.power.limit(i) = 6\ dBm + 10 * \log\big(s(i)\big) + (\Delta_{min} - \text{TxAGC uncertainty}),$$

$$i \in all\ beams, \text{ for n260 and n261} \quad (8)$$

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

Table 3-14
***input.power.limit* Calculation**

Band	Antenna	Δmin (dB)	TxAGC Uncertainty (dB)	*input.power.limit* (dBm)	Notes
n261	0	3.42	0.5	*input.power.limit(i) = 6 dBm + 10 x log(s(i)) + 2.92*	Using Eq.8
	1	1.90	0.5	*input.power.limit(i) = 6 dBm + 10 x log(s(i)) + 1.4*	Using Eq.8
n260	0	3.13	0.5	*input.power.limit(i) = 6 dBm + 10 x log(s(i)) + 2.63*	Using Eq.8
	1	2.92	0.5	*input.power.limit(i) = 6 dBm + 10 x log(s(i)) + 2.42*	Using Eq.8

Thus, the DUT PD Char for n261 and n260 bands is as shown in the tables below. The full simulation results used to support this calculation can be found in the Power Density Simulation Report.

Table 3-15
5G NR n261 Antenna 0 *input.power.limit*

Band	Antenna Module	Beam ID_1	Beam ID_2	input.power.limit (dBm)
n261	0	0		9.5
		2		7.0
		3		7.3
		4		7.4
		8		7.0
		9		7.5
		12		3.8
		13		3.7
		14		3.8
		15		5.0
		16		5.5
		22		3.8
		23		4.4
		24		4.0
		25		6.1
		128		11.3
		130		6.2
		131		6.5
		132		7.7
		136		6.3
		137		6.4
		140		3.6
		141		4.7
		142		4.6
		143		4.0
		144		4.0
		150		3.6
		151		5.6
		152		4.0
		153		4.6
		0	128	7.2
		2	130	4.0
		3	131	3.5
		4	132	6.1
		8	136	3.4
		9	137	3.3
		12	140	0.9
		13	141	0.9
		14	142	1.0
		15	143	1.2
		16	144	0.9
		22	150	0.7
		23	151	1.5
		24	152	0.7
		25	153	1.2

Table 3-16
5G NR n261 Antenna 1 *input.power.limit*

Band	Antenna Module	Beam ID_1	Beam ID_2	input.power.limit (dBm)
n261	1	1		9.0
		5		6.5
		6		6.5
		7		6.0
		10		6.8
		11		6.1
		17		3.5
		18		3.7
		19		3.5
		20		3.8
		21		4.4
		26		3.8
		27		3.5
		28		3.5
		29		4.0
		129		9.1
		133		5.7
		134		5.6
		135		5.2
		138		6.1
		139		4.9
		145		3.7
		146		3.8
		147		3.2
		148		3.1
		149		2.7
		154		4.1
		155		3.5
		156		3.2
		157		3.1
		1	129	7.7
		5	133	1.7
		6	134	1.9
		7	135	1.4
		10	138	2.1
		11	139	1.4
		17	145	-0.2
		18	146	-0.6
		19	147	-0.3
		20	148	-0.5
		21	149	-1.4
		26	154	-0.3
		27	155	-0.4
		28	156	-0.4
		29	157	-0.8

Table 3-17
5G NR n260 Antenna 0 *input.power.limit*

Band	Antenna Module	Beam ID_1	Beam ID_2	input.power.limit (dBm)
n261	0	0		10.4
		2		6.5
		3		8.0
		4		6.5
		8		7.0
		9		7.0
		12		4.1
		13		4.4
		14		6.0
		15		5.2
		16		4.1
		22		4.2
		23		5.2
		24		5.6
		25		4.5
		128		10.0
		130		6.3
		131		7.6
		132		6.5
		136		6.8
		137		7.1
		140		4.0
		141		4.4
		142		5.8
		143		5.5
		144		4.0
		150		3.9
		151		5.0
		152		6.0
		153		4.9
		0	128	6.9
		2	130	2.9
		3	131	4.7
		4	132	4.4
		8	136	3.7
		9	137	3.5
		12	140	0.7
		13	141	1.1
		14	142	2.8
		15	143	1.8
		16	144	0.9
		22	150	0.6
		23	151	2.0
		24	152	2.3
		25	153	1.5

Table 3-18
5G NR n260 Antenna 1 *input.power.limit*

Band	Antenna Module	Beam ID_1	Beam ID_2	input.power.limit (dBm)
n261	1	1		8.0
		5		6.2
		6		6.5
		7		6.2
		10		5.5
		11		6.9
		17		3.8
		18		2.9
		19		4.5
		20		4.1
		21		3.7
		26		3.3
		27		3.6
		28		4.3
		29		3.9
		129		8.7
		133		5.3
		134		6.5
		135		5.3
		138		5.6
		139		5.5
		145		3.2
		146		3.7
		147		4.4
		148		3.8
		149		3.3
		154		3.5
		155		4.3
		156		3.9
		157		3.4
		1	129	5.2
		5	133	2.4
		6	134	3.1
		7	135	2.4
		10	138	3.8
		11	139	2.9
		17	145	0.1
		18	146	-0.1
		19	147	0.8
		20	148	0.6
		21	149	-0.2
		26	154	-0.1
		27	155	0.8
		28	156	0.6
		29	157	0.4

4 EQUIPMENT LIST

Manufacturer	Model	Description	Cal Date	Cal Interval	Cal Due	Serial Number
-	WL25-1	Conducted Cable Set (25GHz)	10/30/2019	Annual	10/30/2020	WL25-1
-	WL40-1	Conducted Cable Set (40GHz)	10/30/2019	Annual	10/30/2020	WL40-1
Agilent	N9038A	MXE EMI Receiver	07/17/2019	Annual	07/17/2020	MY51210133
Agilent	N9030A	PXA Signal Analyzer (44GHz)	06/12/2019	Annual	06/12/2020	MY52350166
EMCO	3160-09	Small Horn (18 - 26.5GHz)	08/09/2018	Biennial	08/09/2020	135427
Emco	3116.00	Horn Antenna (18 - 40GHz)	06/07/2018	Triennial	06/07/2021	9203-2178
Rohde & Schwarz	ESU40	EMI Test Receiver (40GHz)	09/23/2019	Annual	09/23/2020	100348
Rohde & Schwarz	SFUNIT-Rx	Shielded Filter Unit	07/08/2019	Annual	07/08/2020	102133
SPEAG	EUmmWV3	EUmmWV3 Probe	02/14/2020	Annual	02/14/2021	9415
SPEAG	EUmmWV3	EUmmWV3 Probe	12/10/2019	Annual	12/10/2021	9407
SPEAG	SM 003 100 AA	30GHz System Verification Ka- Band Source Antenna	02/12/2020	Annual	02/12/2021	1035
SPEAG	DAE4	Dasy Data Acquisition Electronics	03/12/2020	Annual	03/12/2021	1415
SPEAG	DAE4	Dasy Data Acquisition Electronics	02/20/2020	Annual	02/20/2021	1272
Agilent	N9030A	PXA Signal Analyzer (44GHz)	06/12/2019	Annual	06/12/2020	MY52350166
Rohde & Schwarz	180-442-KF	Horn (Small)	08/21/2018	Bienniel	08/21/2020	U157403-01
Rohde & Schwarz	ESU26	EMI Test Receiver (26.5GHz)	06/05/2019	Annual	06/05/2020	100342
Rohde & Schwarz	SFUNIT-Rx	Shielded Filter Unit	07/11/2019	Annual	07/11/2020	102134
Virginia Diodes Inc	SAX252	Spectrum Analyzer Extension Module	09/30/2019	Annual	09/30/2020	SAX252
Virginia Diodes Inc	SAX253	Spectrum Analyzer Extension Module	09/30/2019	Annual	09/30/2020	SAX253
Virginia Diodes Inc	SAX254	Spectrum Analyzer Extension Module	09/30/2019	Annual	09/30/2020	SAX254

Note:
1. Each equipment item was used solely within its respective calibration period.

5 MEASUREMENT UNCERTAINTIES

a	b	c	d	e	f = b x e/d	g
Uncertainty Component	Unc. (± dB)	Prob. Dist.	Div.	ci	ui (± dB)	vi
Calibration	0.49	N	1	1.0	0.49	∞
Probe correction	0	R	1.73	1.0	0.00	∞
Frequency Response (BW ≤ 1 GHz)	0.20	R	1.73	1.0	0.12	∞
Sensor cross coupling	0	R	1.73	1.0	0.00	∞
Isotropy	0.50	R	1.73	1.0	0.29	∞
Linearity	0.20	R	1.73	1.0	0.12	∞
Probe Scattering	0	R	1.73	1.0	0	∞
Probe Positioning Offset	0.30	R	1.73	1.0	0.17	∞
Probe Positioning Repeatability	0.04	R	1.73	1.0	0.02	∞
Sensor Mechanical Offset	0	R	1.73	1.0	0	∞
Probe Spatial Resolution	0	R	1.73	1.0	0	∞
Field Impedance Dependence	0	R	1.73	1.0	0	∞
Amplitude and phase drift	0	R	1.73	1.0	0	∞
Amplitude and phase noise	0.04	R	1.73	1.0	0.02	∞
Measurement area truncation	0	R	1.73	1.0	0	∞
Data acquisition	0.03	N	1	1.0	0.03	∞
Sampling	0	R	1.73	1.0	0	∞
Field Reconstruction	0.60	R	1.73	1.0	0.35	∞
Forward Transformation	0	R	1.73	1.0	0	∞
Power Density Scaling	-	R	1.73	1.0	-	∞
Spatial Averaging	0.10	R	1.73	1.0	0.06	∞
System Detection Limit	0.04	R	1.73	1.0	0.02	∞
Test Sample and Environmental Factors						
Probe Coupling with DUT	0	R	1.73	1.0	0	∞
Modulation Response	0.40	R	1.73	1.0	0.23	∞
Integration Time	0	R	1.73	1.0	0	∞
Response Time	0	R	1.73	1.0	0	∞
Device Holder Influence	0.10	R	1.73	1.0	0.06	∞
DUT Alignment	0	R	1.73	1.0	0	∞
RF Ambient Conditions	0.04	R	1.73	1.0	0.02	∞
Ambient Reflections	0.04	R	1.73	1.0	0.02	∞
Immunity / Secondary Reception	0	R	1.73	1.0	0	∞
Drift of the DUT	0.22	R	1.73	1.0	0.13	∞
Combined Standard Uncertainty (k=1)		RSS			0.76	∞
(95% CONFIDENCE LEVEL)	**k=2**				**1.53**	

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[10] October 2018 Telecommunications Certification Body Council (TCBC) Workshop Notes

[11] April 2019 Telecommunications Certification Body Council (TCBC) Workshop Notes

[12] November 2019 Telecommunications Certification Body Council (TCBC) Workshop Notes

[13] SPEAG DASY6 System Handbook (September 2019)