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NEAR-FIELD POWER DENSITY PART 0 REPORT

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Date of Testing
01/20/2021 – 02/24/2021
Test Site/Location
PCTEST, Columbia, MD, USA
Document Serial No:
1M2101040001-26.A3L (Rev 1)

FCC ID:	**A3LSMA426U**
APPLICANT:	**SAMSUNG ELECTRONICS CO., LTD.**

DUT Type:	Portable Handset
Report Type:	Part 0 Power Density Characterization
Model:	SM-A426U
Additional Model(s):	SM-A426U1/DS, SM-S426DL, SM-A426U1

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Note: This revised Test Report 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

ilac-MRA
ACCREDITED
CERTIFICATE # 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

1.4 Bibliography

Table 1-1
Bibliography

Report Type	Report Serial Number
FCC SAR Evaluation Report (Part 1)	1M2101040001-01.A3L
Power Density Part 1 Test Report	1M2101040001-20.A3L
RF Exposure Part 2 Test Report	1M2101040001-21.A3L
RF Exposure Compliance Summary Report	1M2101040001-22.A3L
Power Density Simulation Report	

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 and EUmmWV4 Probe / E-Field 5G Probe

The EUmmWV3 and EUmmWV4 probes 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

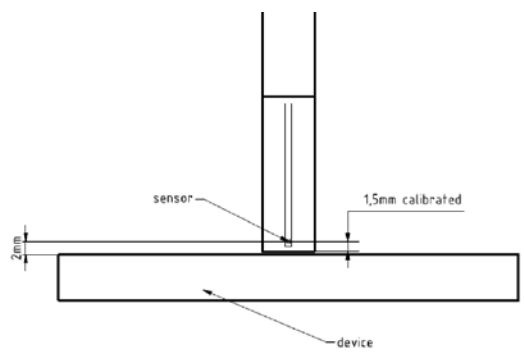

Figure 2-1
EUmmWV3 and EUmmWV4 Probe

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 and EUmmWV4 probes.

3 POWER DENSITY CHARACTERIZATION

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 Module	Back	Front	Top	Bottom	Right	Left
NR n261	**R**	Yes	Yes	No	No	No	Yes
NR n261	**L**	Yes	Yes	Yes	No	Yes	No
NR n260	**R**	Yes	Yes	No	No	No	Yes
NR n260	**L**	Yes	Yes	Yes	No	Yes	No

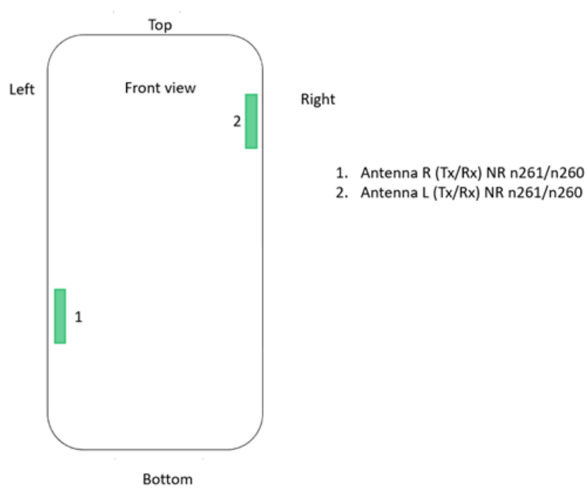

Figure 3-1
Location of mmW antenna modules

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.

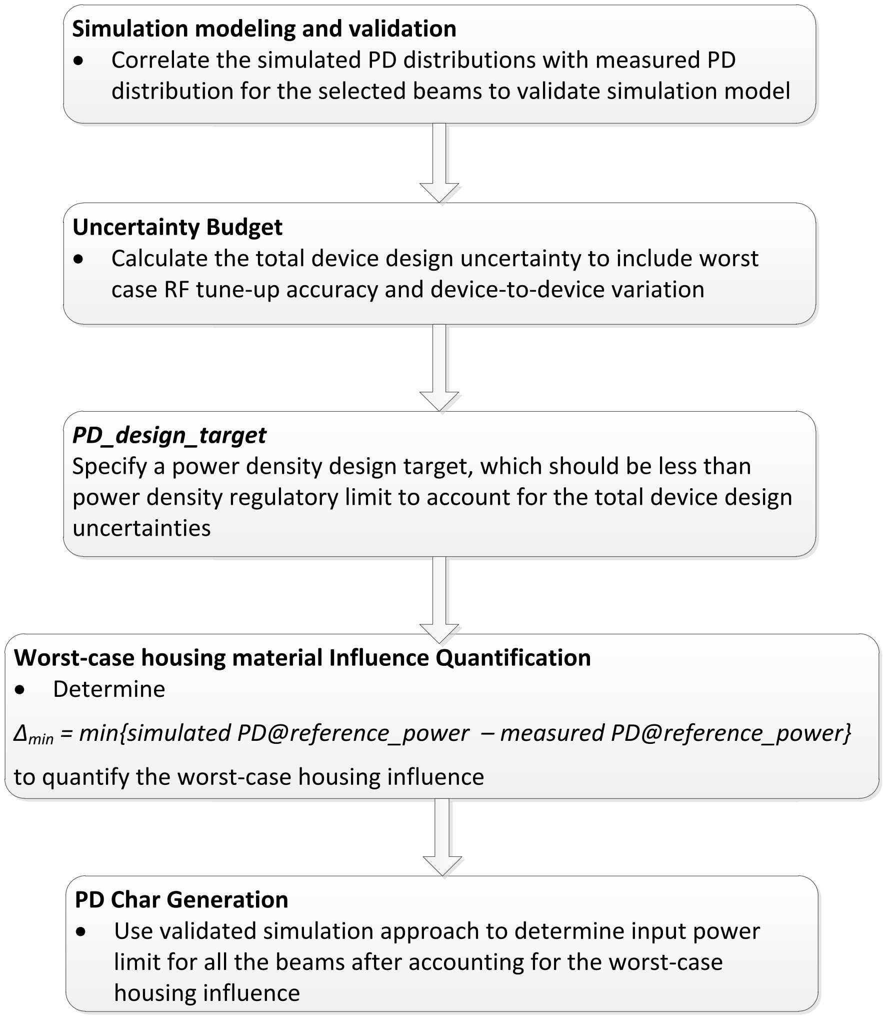

Figure 3-2
Flow Chart for Power Density Characterization

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 R Codebook

Band	Antenna Module	Antenna Type	Beam ID	Feed no.	Paired With
n261	R	Patch	2	1	130
n261	R	Patch	6	2	134
n261	R	Patch	7	2	135
n261	R	Patch	8	2	136
n261	R	Patch	11	2	139
n261	R	Patch	12	2	140
n261	R	Patch	18	4	146
n261	R	Patch	19	4	147
n261	R	Patch	20	4	148
n261	R	Patch	21	4	149
n261	R	Patch	22	4	150
n261	R	Patch	27	4	155
n261	R	Patch	28	4	156
n261	R	Patch	29	4	157
n261	R	Patch	30	4	158
n261	R	Patch	130	1	2
n261	R	Patch	134	2	6
n261	R	Patch	135	2	7
n261	R	Patch	136	2	8
n261	R	Patch	139	2	11
n261	R	Patch	140	2	12
n261	R	Patch	146	4	18
n261	R	Patch	147	4	19
n261	R	Patch	148	4	20
n261	R	Patch	149	4	21
n261	R	Patch	150	4	22
n261	R	Patch	155	4	27
n261	R	Patch	156	4	28
n261	R	Patch	157	4	29
n261	R	Patch	158	4	30

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

Band	Antenna Module	Antenna Type	Beam ID	Feed no.	Paired With
n261	L	Patch	0	1	128
n261	L	Patch	1	1	129
n261	L	Patch	3	2	131
n261	L	Patch	4	2	132
n261	L	Patch	5	2	133
n261	L	Patch	9	2	137
n261	L	Patch	10	2	138
n261	L	Patch	13	4	141
n261	L	Patch	14	4	142
n261	L	Patch	15	4	143
n261	L	Patch	16	4	144
n261	L	Patch	17	4	145
n261	L	Patch	23	4	151
n261	L	Patch	24	4	152
n261	L	Patch	25	4	153
n261	L	Patch	26	4	154
n261	L	Patch	128	1	0
n261	L	Patch	129	1	1
n261	L	Patch	131	2	3
n261	L	Patch	132	2	4
n261	L	Patch	133	2	5
n261	L	Patch	137	2	9
n261	L	Patch	138	2	10
n261	L	Patch	141	4	13
n261	L	Patch	142	4	14
n261	L	Patch	143	4	15
n261	L	Patch	144	4	16
n261	L	Patch	145	4	17
n261	L	Patch	151	4	23
n261	L	Patch	152	4	24
n261	L	Patch	153	4	25
n261	L	Patch	154	4	26

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

Band	Antenna Module	Antenna Type	Beam ID	Feed no.	Paired With
n260	R	Patch	2	1	130
n260	R	Patch	3	1	131
n260	R	Patch	7	2	135
n260	R	Patch	8	2	136
n260	R	Patch	9	2	137
n260	R	Patch	12	2	140
n260	R	Patch	13	2	141
n260	R	Patch	19	4	147
n260	R	Patch	20	4	148
n260	R	Patch	21	4	149
n260	R	Patch	22	4	150
n260	R	Patch	23	4	151
n260	R	Patch	28	4	156
n260	R	Patch	29	4	157
n260	R	Patch	30	4	158
n260	R	Patch	31	4	159
n260	R	Patch	130	1	2
n260	R	Patch	131	1	3
n260	R	Patch	135	2	7
n260	R	Patch	136	2	8
n260	R	Patch	137	2	9
n260	R	Patch	140	2	12
n260	R	Patch	141	2	13
n260	R	Patch	147	4	19
n260	R	Patch	148	4	20
n260	R	Patch	149	4	21
n260	R	Patch	150	4	22
n260	R	Patch	151	4	23
n260	R	Patch	156	4	28
n260	R	Patch	157	4	29
n260	R	Patch	158	4	30
n260	R	Patch	159	4	31

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

Band	Antenna Module	Antenna Type	Beam ID	Feed no.	Paired With
n260	L	Patch	0	1	128
n260	L	Patch	1	1	129
n260	L	Patch	4	2	132
n260	L	Patch	5	2	133
n260	L	Patch	6	2	134
n260	L	Patch	10	2	138
n260	L	Patch	11	2	139
n260	L	Patch	14	4	142
n260	L	Patch	15	4	143
n260	L	Patch	16	4	144
n260	L	Patch	17	4	145
n260	L	Patch	18	4	146
n260	L	Patch	24	4	152
n260	L	Patch	25	4	153
n260	L	Patch	26	4	154
n260	L	Patch	27	4	155
n260	L	Patch	128	1	0
n260	L	Patch	129	1	1
n260	L	Patch	132	2	4
n260	L	Patch	133	2	5
n260	L	Patch	134	2	6
n260	L	Patch	138	2	10
n260	L	Patch	139	2	11
n260	L	Patch	142	4	14
n260	L	Patch	143	4	15
n260	L	Patch	144	4	16
n260	L	Patch	145	4	17
n260	L	Patch	146	4	18
n260	L	Patch	152	4	24
n260	L	Patch	153	4	25
n260	L	Patch	154	4	26
n260	L	Patch	155	4	27

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	4cm^2 psPD Measured (mW/cm^2)	4cm^2 psPD Simulated (mW/cm^2)	Delta = Simulated - Measured (dB)
n261	R (patch)	20	Back	0.310	0.733	3.74
			Left	0.882	1.607	**2.61**
		158	Back	0.427	0.806	2.76
			Left	0.693	1.450	3.20
	L (patch)	15	Back	0.398	0.758	2.80
			Right	0.832	1.519	2.61
		143	Back	0.389	0.683	**2.44**
		153	Right	0.558	1.083	2.88
n260	R (patch)	30	Back	0.149	0.436	4.67
		19	Left	1.180	1.411	**0.78**
		157	Back	0.639	1.099	2.36
		159	Left	1.160	1.506	1.13
	L (patch)	25	Back	0.188	0.391	3.18
			Right	0.682	1.175	2.36
		154	Back	0.585	0.904	1.89
			Right	0.865	1.324	**1.85**

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 R Patch: Back (S2) & Left (S3)

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

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	R (patch)	2.61
	L (patch)	2.44
n260	R (patch)	0.78
	L (patch)	1.85

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 R Patch: Front (S1)

b. for L Patch: Front (S1) & Top (S5)

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 R simulated 4cm² PD at PD_Design_Target (if simulation performed with correct housing material properties) (Δ_{min})

Antenna	Beam ID_1	Simulated 4cm² PD(mW/cm²) Corresponding to PD_design_target if the simulation was performed with correct No. Module Type housing material properties					
		S4(Right)	S3(Left)	S5(Top)	S6(Bottom)	S1(Front)	S2(Back)
R	2	0.004	0.595	0.066	0.020	0.245	0.215
R	6	0.008	0.611	0.037	0.082	0.227	0.253
R	7	0.004	0.550	0.027	0.024	0.261	0.231
R	8	0.005	0.576	0.042	0.032	0.260	0.228
R	11	0.005	0.577	0.021	0.044	0.284	0.235
R	12	0.003	0.564	0.030	0.006	0.290	0.235
R	18	0.012	0.576	0.091	0.095	0.198	0.313
R	19	0.007	0.506	0.043	0.064	0.232	0.217
R	20	0.006	0.601	0.007	0.007	0.325	0.274
R	21	0.005	0.589	0.073	0.004	0.318	0.250
R	22	0.007	0.617	0.131	0.025	0.319	0.262
R	27	0.012	0.574	0.086	0.102	0.224	0.304
R	28	0.005	0.586	0.012	0.018	0.309	0.268
R	29	0.005	0.575	0.027	0.003	0.308	0.250
R	30	0.005	0.611	0.096	0.006	0.330	0.261
R	130	0.003	0.547	0.031	0.007	0.205	0.261
R	134	0.003	0.543	0.051	0.011	0.214	0.268
R	135	0.004	0.538	0.018	0.003	0.237	0.314
R	136	0.003	0.504	0.061	0.006	0.187	0.259
R	139	0.003	0.526	0.048	0.007	0.205	0.305
R	140	0.003	0.518	0.039	0.004	0.213	0.295
R	146	0.002	0.500	0.095	0.014	0.209	0.285
R	147	0.007	0.542	0.026	0.008	0.248	0.316
R	148	0.007	0.553	0.007	0.003	0.257	0.318
R	149	0.004	0.551	0.016	0.002	0.243	0.315
R	150	0.003	0.544	0.064	0.018	0.184	0.300
R	155	0.002	0.536	0.071	0.012	0.228	0.291
R	156	0.008	0.540	0.006	0.003	0.259	0.310
R	157	0.005	0.552	0.014	0.002	0.248	0.321
R	158	0.004	0.553	0.022	0.005	0.221	0.307

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 L simulated 4cm² PD at PD_Design_Target
(if simulation performed with correct housing material properties) (Δ_{min})

Antenna	Beam ID_1	Simulated 4cm² PD(mW/cm²) Corresponding to PD_design_target if the simulation was performed with correct No. Module Type housing material properties					
		S4(Right)	S3(Left)	S5(Top)	S6(Bottom)	S1(Front)	S2(Back)
L	0	0.589	0.005	0.048	0.008	0.226	0.220
L	1	0.571	0.006	0.037	0.004	0.246	0.192
L	3	0.553	0.008	0.047	0.020	0.198	0.227
L	4	0.587	0.003	0.029	0.005	0.275	0.279
L	5	0.617	0.007	0.091	0.008	0.282	0.231
L	9	0.562	0.009	0.027	0.008	0.247	0.256
L	10	0.585	0.003	0.044	0.015	0.244	0.262
L	13	0.585	0.027	0.098	0.039	0.207	0.281
L	14	0.552	0.005	0.030	0.002	0.291	0.253
L	15	0.567	0.003	0.010	0.003	0.295	0.283
L	16	0.600	0.004	0.084	0.008	0.286	0.242
L	17	0.617	0.005	0.132	0.013	0.256	0.245
L	23	0.571	0.015	0.059	0.013	0.256	0.233
L	24	0.547	0.003	0.011	0.003	0.294	0.270
L	25	0.565	0.003	0.017	0.003	0.285	0.256
L	26	0.611	0.004	0.116	0.012	0.256	0.257
L	128	0.501	0.003	0.017	0.007	0.232	0.256
L	129	0.551	0.005	0.034	0.007	0.203	0.371
L	131	0.540	0.006	0.042	0.023	0.248	0.311
L	132	0.495	0.004	0.010	0.003	0.263	0.219
L	133	0.540	0.004	0.046	0.016	0.172	0.271
L	137	0.501	0.004	0.010	0.009	0.270	0.208
L	138	0.482	0.004	0.018	0.003	0.246	0.216
L	141	0.483	0.005	0.017	0.023	0.233	0.223
L	142	0.526	0.006	0.020	0.008	0.286	0.292
L	143	0.517	0.005	0.011	0.003	0.248	0.327
L	144	0.527	0.004	0.056	0.004	0.207	0.327
L	145	0.524	0.005	0.088	0.020	0.180	0.315
L	151	0.512	0.006	0.013	0.012	0.266	0.270
L	152	0.519	0.006	0.012	0.005	0.278	0.309
L	153	0.511	0.004	0.021	0.002	0.223	0.311
L	154	0.533	0.004	0.078	0.009	0.181	0.338

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 R simulated $4cm^2$ PD at PD_Design_Target
(if simulation performed with correct housing material properties) (Δ_{min})

Antenna	Beam ID_1	Simulated $4cm^2$ PD(mW/cm^2) Corresponding to PD_design_target if the simulation was performed with correct No. Module Type housing material properties					
		S4(Right)	S3(Left)	S5(Top)	S6(Bottom)	S1(Front)	S2(Back)
R	2	0.004	0.617	0.068	0.022	0.354	0.155
R	3	0.003	0.591	0.080	0.018	0.330	0.209
R	7	0.003	0.617	0.038	0.012	0.322	0.146
R	8	0.007	0.617	0.133	0.029	0.447	0.177
R	9	0.002	0.617	0.103	0.008	0.342	0.171
R	12	0.004	0.610	0.113	0.013	0.334	0.190
R	13	0.004	0.617	0.067	0.014	0.365	0.151
R	19	0.003	0.604	0.115	0.024	0.398	0.130
R	20	0.006	0.582	0.134	0.008	0.377	0.175
R	21	0.007	0.575	0.178	0.053	0.383	0.253
R	22	0.005	0.617	0.104	0.025	0.411	0.171
R	23	0.005	0.547	0.134	0.007	0.360	0.151
R	28	0.004	0.551	0.127	0.013	0.352	0.116
R	29	0.007	0.579	0.180	0.039	0.369	0.261
R	30	0.009	0.617	0.097	0.018	0.412	0.250
R	31	0.002	0.560	0.119	0.021	0.350	0.118
R	130	0.002	0.583	0.034	0.007	0.170	0.293
R	131	0.003	0.587	0.022	0.007	0.170	0.313
R	135	0.002	0.617	0.106	0.004	0.134	0.273
R	136	0.001	0.590	0.058	0.007	0.163	0.402
R	137	0.002	0.617	0.099	0.005	0.127	0.280
R	140	0.002	0.580	0.099	0.003	0.148	0.281
R	141	0.002	0.617	0.069	0.007	0.152	0.320
R	147	0.004	0.617	0.100	0.017	0.166	0.330
R	148	0.002	0.551	0.103	0.003	0.188	0.372
R	149	0.002	0.583	0.031	0.015	0.201	0.392
R	150	0.005	0.617	0.094	0.023	0.194	0.352
R	151	0.003	0.567	0.123	0.003	0.206	0.271
R	156	0.004	0.584	0.113	0.010	0.177	0.278
R	157	0.002	0.576	0.043	0.005	0.179	0.423
R	158	0.006	0.617	0.039	0.020	0.205	0.376
R	159	0.005	0.610	0.107	0.013	0.154	0.288

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 L simulated 4cm² PD at PD_Design_Target
(if simulation performed with correct housing material properties) (Δ_{min})

Antenna	Beam ID_1	Simulated 4cm² PD(mW/cm²) Corresponding to PD_design_target if the simulation was performed with correct No. Module Type housing material properties					
		S4(Right)	S3(Left)	S5(Top)	S6(Bottom)	S1(Front)	S2(Back)
L	0	0.521	0.006	0.039	0.022	0.301	0.217
L	1	0.617	0.011	0.033	0.012	0.433	0.163
L	4	0.617	0.019	0.061	0.018	0.448	0.155
L	5	0.539	0.008	0.044	0.012	0.408	0.242
L	6	0.617	0.008	0.062	0.014	0.324	0.193
L	10	0.617	0.008	0.056	0.012	0.408	0.167
L	11	0.519	0.010	0.049	0.024	0.318	0.199
L	14	0.573	0.012	0.068	0.029	0.434	0.187
L	15	0.617	0.010	0.081	0.004	0.472	0.176
L	16	0.499	0.026	0.041	0.028	0.386	0.197
L	17	0.552	0.013	0.063	0.032	0.422	0.183
L	18	0.610	0.012	0.115	0.007	0.401	0.176
L	24	0.606	0.014	0.134	0.020	0.395	0.171
L	25	0.617	0.010	0.054	0.004	0.498	0.205
L	26	0.534	0.021	0.029	0.030	0.410	0.234
L	27	0.612	0.014	0.140	0.028	0.422	0.172
L	128	0.617	0.006	0.014	0.025	0.255	0.253
L	129	0.601	0.005	0.036	0.004	0.181	0.365
L	132	0.595	0.007	0.037	0.036	0.248	0.208
L	133	0.617	0.008	0.034	0.006	0.284	0.353
L	134	0.591	0.005	0.036	0.027	0.240	0.196
L	138	0.604	0.005	0.035	0.019	0.269	0.210
L	139	0.617	0.004	0.063	0.007	0.175	0.414
L	142	0.606	0.007	0.085	0.042	0.288	0.333
L	143	0.547	0.009	0.129	0.010	0.285	0.233
L	144	0.617	0.008	0.019	0.006	0.274	0.395
L	145	0.555	0.009	0.048	0.030	0.259	0.299
L	146	0.560	0.008	0.127	0.015	0.264	0.217
L	152	0.617	0.005	0.085	0.029	0.231	0.274
L	153	0.587	0.009	0.057	0.007	0.281	0.283
L	154	0.617	0.008	0.015	0.007	0.270	0.421
L	155	0.617	0.008	0.073	0.036	0.280	0.307

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
$4cm^2$ psPD of the selected beams measured on the corresponding surfaces that are not selected for Δ_{min} determination

Band	Antenna	Beam ID	Surface	Tested Power Level (dBm)	input.power.limit (dBm)	Meas. $4cm^2$ PD (mW/cm^2)
n261	R (patch)	30	Front	4.9	4.9	0.219
	L (patch)	15	Front	3.7	2.2	0.258
		17	Top	4.3	2.8	0.132
n260	R (patch)	8	Front	7.2	7.2	0.357
	L (patch)	25	Front	4.6	4.6	0.334
		27	Top	5.1	5.1	0.114

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

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

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*; 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	TxAGC Uncertainty	*input.power.limit*	Notes
		(dB)	(dB)	(dBm)	
n261	R (patch)	2.61	0.5	*input.power.limit(i) = sim.power_limit + 2.11*	Using Eq.8
	L (patch)	2.44	0.5	*input.power.limit(i) = sim.power_limit + 1.94*	Using Eq.8
n260	R (patch)	0.78	0.5	*input.power.limit(i) = sim.power_limit + 0.28*	Using Eq.8
	L (patch)	1.85	0.5	*input.power.limit(i) = sim.power_limit + 1.35*	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
Permanent backoff applied to calculated *input.power.limit*

Band	Antenna	Backoff (dB)
n261	L	1.5

Note: The above backoff values have been permanently applied to the input.power.limits calculated from the equations from Table 3-14. The final input.power.limits implemented in the EFS are in the tables below.

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

Band	Beam ID 1	Beam ID 2	input.power.limit
n261	2	-	9.7
n261	6	-	7.6
n261	7	-	7.8
n261	8	-	7.1
n261	11	-	6.8
n261	12	-	6.5
n261	18	-	6.1
n261	19	-	5.1
n261	20	-	3.9
n261	21	-	4.5
n261	22	-	5.5
n261	27	-	5.9
n261	28	-	4.2
n261	29	-	4.0
n261	30	-	4.9
n261	-	130	8.8
n261	-	134	6.8
n261	-	135	6.6
n261	-	136	6.8
n261	-	139	6.8
n261	-	140	6.6
n261	-	146	4.5
n261	-	147	4.6
n261	-	148	4.2
n261	-	149	4.1
n261	-	150	4.5
n261	-	155	4.3
n261	-	156	4.4
n261	-	157	4.2
n261	-	158	4.0
n261	2	130	5.8
n261	6	134	4.0
n261	7	135	3.5
n261	8	136	4.2
n261	11	139	4.0
n261	12	140	3.6
n261	18	146	1.6
n261	19	147	1.1
n261	20	148	0.7
n261	21	149	0.9
n261	22	150	1.7
n261	27	155	1.4
n261	28	156	0.9
n261	29	157	0.6
n261	30	158	1.2

Table 3-17
5G NR n261 Antenna L *input.power.limit*

Band	Beam ID 1	Beam ID 2	input.power.limit
n261	0	-	7.8
n261	1	-	7.5
n261	3	-	6.3
n261	4	-	6.0
n261	5	-	5.0
n261	9	-	5.0
n261	10	-	6.1
n261	13	-	4.3
n261	14	-	2.5
n261	15	-	2.2
n261	16	-	2.9
n261	17	-	2.8
n261	23	-	3.0
n261	24	-	2.4
n261	25	-	2.4
n261	26	-	2.6
n261	-	128	8.5
n261	-	129	9.3
n261	-	131	7.2
n261	-	132	5.6
n261	-	133	6.5
n261	-	137	6.0
n261	-	138	5.7
n261	-	141	3.5
n261	-	142	3.7
n261	-	143	3.3
n261	-	144	3.4
n261	-	145	4.9
n261	-	151	3.4
n261	-	152	3.7
n261	-	153	3.2
n261	-	154	4.0
n261	0	128	4.8
n261	1	129	5.0
n261	3	131	3.7
n261	4	132	2.5
n261	5	133	2.4
n261	9	137	2.2
n261	10	138	2.7
n261	13	141	0.6
n261	14	142	-0.2
n261	15	143	-0.4
n261	16	144	-0.4
n261	17	145	0.2
n261	23	151	0.1
n261	24	152	-0.3
n261	25	153	-0.3
n261	26	154	-0.3

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

Band	Beam ID 1	Beam ID 2	input.power.limit
n260	2	-	8.4
n260	3	-	7.5
n260	7	-	4.5
n260	8	-	7.2
n260	9	-	5.4
n260	12	-	6.2
n260	13	-	4.4
n260	19	-	2.6
n260	20	-	3.2
n260	21	-	4.5
n260	22	-	2.9
n260	23	-	2.9
n260	28	-	2.5
n260	29	-	4.3
n260	30	-	3.9
n260	31	-	2.5
n260	-	130	6.7
n260	-	131	7.9
n260	-	135	3.8
n260	-	136	4.1
n260	-	137	3.7
n260	-	140	3.8
n260	-	141	3.7
n260	-	147	3.0
n260	-	148	2.6
n260	-	149	2.2
n260	-	150	3.0
n260	-	151	2.4
n260	-	156	2.4
n260	-	157	2.2
n260	-	158	3.1
n260	-	159	2.4
n260	2	130	4.2
n260	3	131	4.4
n260	7	135	1.8
n260	8	136	1.9
n260	9	137	1.1
n260	12	140	1.3
n260	13	141	1.0
n260	19	147	-0.7
n260	20	148	-0.4
n260	21	149	0.0
n260	22	150	-0.7
n260	23	151	-1.2
n260	28	156	-1.2
n260	29	157	-0.3
n260	30	158	0.3
n260	31	159	-1.2

Table 3-19
5G NR n260 Antenna L *input.power.limit*

Band	Beam ID 1	Beam ID 2	input.power.limit
n260	0	-	12.0
n260	1	-	9.2
n260	4	-	6.9
n260	5	-	7.2
n260	6	-	8.4
n260	10	-	6.6
n260	11	-	8.3
n260	14	-	5.1
n260	15	-	4.8
n260	16	-	5.4
n260	17	-	5.0
n260	18	-	5.0
n260	24	-	5.0
n260	25	-	4.6
n260	26	-	5.5
n260	27	-	5.1
n260	-	128	8.8
n260	-	129	9.7
n260	-	132	6.0
n260	-	133	6.6
n260	-	134	5.9
n260	-	138	6.0
n260	-	139	7.9
n260	-	142	4.6
n260	-	143	5.1
n260	-	144	4.1
n260	-	145	4.3
n260	-	146	4.8
n260	-	152	4.3
n260	-	153	4.7
n260	-	154	4.1
n260	-	155	4.4
n260	0	128	6.9
n260	1	129	6.1
n260	4	132	3.3
n260	5	133	3.5
n260	6	134	3.6
n260	10	138	3.0
n260	11	139	5.5
n260	14	142	1.1
n260	15	143	1.3
n260	16	144	1.4
n260	17	145	1.3
n260	18	146	1.3
n260	24	152	1.1
n260	25	153	1.1
n260	26	154	1.7
n260	27	155	1.5

4 EQUIPMENT LIST

Manufacturer	Model	Description	Cal Date	Cal Interval	Cal Due	Serial Number
-	WL25-1	Conducted Cable Set (25GHz)	09/16/20	Annual	09/16/21	WL25-1
-	WL40-1	Conducted Cable Set (40GHz)	09/16/20	Annual	09/16/21	WL40-1
Agilent	N9038A	MXE EMI Receiver	08/11/20	Annual	08/11/21	MY51210133
Agilent	N9030A	PXA Signal Analyzer (44GHz)	08/17/20	Annual	08/17/21	MY52350166
Emco	3116	Horn Antenna (18 - 40GHz)	06/07/18	Triennial	06/07/21	9203-2178
Rohde & Schwarz	ESU40	EMI Test Receiver (40GHz)	9/92020	Annual	09/09/21	100348
Rohde & Schwarz	FSW67	Signal / Spectrum Analyzer	08/10/20	Annual	08/10/21	103200
Sunol	JB5	Bi-Log Antenna (30M - 5GHz)	07/27/20	Biennial	07/27/22	A051107
SPEAG	EUmmWV3	EUmmWV3 Probe	03/17/20	Annual	03/17/21	9414
SPEAG	SM 003 100 AA	30GHz System Verification Ka- Band Source Antenna	12/10/20	Annual	12/10/21	1045
SPEAG	DAE4	Dasy Data Acquisition Electronics	11/17/20	Annual	11/17/21	1639
SPEAG	EUmmWV4	EUmmWV4 Probe	01/11/21	Annual	01/11/22	9523
SPEAG	SM 003 100 AA	30GHz System Verification Ka- Band Source Antenna	02/12/20	Annual	02/12/21	1035
SPEAG	DAE4	Dasy Data Acquisition Electronics	11/17/20	Annual	11/17/21	1638
Agilent	N9030A	PXA Signal Analyzer (44GHz)	08/17/20	Annual	08/17/21	MY52350166
Emco	3115	Horn Antenna (1-18GHz)	06/18/20	Biennial	06/18/22	9704-5182
Keysight Technologies	N9030A	3Hz-44GHz PXA Signal Analyzer	07/17/20	Annual	07/17/21	MY49430494
Rohde & Schwarz	ESU26	EMI Test Receiver (26.5GHz)	07/15/20	Annual	07/15/21	100342
Sunol	JB5	Bi-Log Antenna (30M - 5GHz)	07/27/20	Biennial	07/27/22	A051107

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**	

6 REFERENCES

[1] ANSI/IEEE C95.1-1992, American National Standard safety levels with respect to human exposure to radio frequency electromagnetic fields, 3kHz to 300GHz, New York: IEEE, Sept. 1992.

[2] IEC TR 63170:2018, Measurement Procedure for the Evaluation of Power Density Related to Human Exposure to Radiofrequency Fields from Wireless Communication Devices Operating between 6 GHz and 100 GHz

[3] IEC TR 62630 : 2010, Guidance for Evaluating Exposure from Multiple Electromagnetic Sources

[4] K. Pokovic, T. Schmid, J. Frohlich, and N. Kuster. Novel Probes and Evaluation Procedures to Assess Field Magnitude and Polarization. IEEE Transactions on Electromagnetic Compatibility 42(2): 240 -244, 2000

[5] R. W. Gerchberg and W. O. Saxton. A Practical Algorithm for the Determination of Phase from Image and Diffraction Plane Pictures. Optik 35(2): 237 – 246, 1972

[6] A. P. Anderson and S. Sali. New Possibilities for Phaseless Microwave Diagnostics. Part 1: Error Reduction Techniques. IEE Proceedings H – Microwaves, Antennas and Propagation 132(5): 290 – 298, 1985

[7] FCC KDB 865664 D02 v01r04: SAR Measurement Requirements for 100 MHz to 6 GHz. Federal Communications Commission – Office of Engineering and Technology, Laboratory Division.

[8] FCC KDB 447498 D01 v02r01: RF Exposure Procedures and Equipment Authorization Policies for Mobile and Portable Devices. Federal Communications Commission – Office of Engineering and Technology, Laboratory Division.

[9] November 2017 Telecommunications Certification Body Council (TCBC) Workshop Notes

[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)