RF Exposure Report

(Part 0: SAR and PD Char Evaluation)

FCC ID	**: PU5-TP00139AM**
Equipment	**: Notebook Computer**
Brand Name	**: Lenovo**
Model Name	**: TP00139A**
Applicant	**: Wistron Corporation 21F, No. 88, Sec. 1, Hsin Tai Wu Rd., Hsichih Dist, New Taipei City 221,Taiwan**
Manufacturer	**: Lenovo PC HK Limited. 23/F, Lincoln House, Taikoo Place, 979 King's Road, Quarry Bay, Hong Kong, China**
Standard	**: FCC 47 CFR Part 2 (2.1093)**

We, SPORTON INTERNATIONAL INC., would like to declare that the tested sample has been evaluated in accordance with the test procedures and has been in compliance with the applicable technical standards.

The test results in this report apply exclusively to the tested model / sample. Without written approval of SPORTON INTERNATIONAL INC., the test report shall not be reproduced except in full.

Approved by: Cona Huang / Deputy Manager

Sporton International Inc. EMC & Wireless Communications Laboratory

Table of Contents

History of this test report

Report No.	Version	Description	Issued Date
FA1D1645	01	Initial issue of report	Mar. 13, 2022

1. Introduction

The FCC RF exposure limit is defined based on time-averaged RF exposure. The product implements Qualcomm Smart Transmit feature which controls the instantaneous transmitting power for WWAN transmitter sto ensure the product in compliance with FCC RF exposure limit over a defined time window, for SAR (transmit frequency ≤ 6GHz) and power density (transmit frequency > 6GHz). to control and manage transmitting power in real time and to ensure at all times the time-averaged RF exposure is compliant to the regulation requirement. Cannot operate without SAR and PD characterization at the device level, beforehand.

This report describes the procedures for the SAR char and PD char generation, and the parameters obtained from SAR and PD characterization (reffered to as SAR char and PD char, respectively) will be used as input for Smart Transmit. Both SAR char and PD char will be entered via the Embedded File System (EFS) to enable the Smart Transmit Feature.

Terminologies in this report

P_{limit}	The time-averaged RF power which corresponds to SAR_design_target.
P_{max}	Maximum target power level
SAR_design_target:	The design target for SAR compliance. It should be less than regulatory power density limit to account for all device design related uncertainties.
SAR char	P_{limit} for all the technologies/bands for all applicable DSI
PD_design_target:	The design target for PD compliance. It should be less than regulatory power density limit to account for all device design related uncertainties.
input.power.limit	For a PD characterized wireless device, the input power level at antenna port(s) for each beam corresponding to PD_design_target.
PD char	The table that contains input.power.limit fed to antenna port(s) for all supported beams.

2. Product Description

Product Feature & Specification	
Equipment Name	Notebook Computer
FCC ID	PU5-TP00139AM
Wireless Technology and Frequency Range	WCDMA Band II: 1850 MHz ~ 1910 MHz WCDMA Band IV: 1710 MHz ~ 1755 MHz WCDMA Band V: 824 MHz ~ 849 MHz LTE Band 2: 1850 MHz ~ 1910 MHz LTE Band 4: 1710 MHz ~ 1755 MHz LTE Band 5: 824 MHz ~ 849 MHz LTE Band 7: 2500 MHz ~ 2570 MHz LTE Band 12: 699 MHz ~ 716 MHz LTE Band 13: 777 MHz ~ 787 MHz LTE Band 14: 788 MHz ~ 798 MHz LTE Band 17: 704 MHz ~ 716 MHz LTE Band 25: 1850 MHz ~ 1915 MHz LTE Band 26: 814 MHz ~ 849 MHz LTE Band 30: 2305 MHz ~ 2315 MHz LTE Band 38: 2570 MHz ~ 2620 MHz LTE Band 41: 2496 MHz ~ 2690 MHz LTE Band 42: 3550 MHz ~ 3600 MHz LTE Band 48: 3550 MHz ~ 3700 MHz LTE Band 66: 1710 MHz ~ 1780 MHz LTE Band 71: 663 MHz ~ 698 MHz 5G NR n2 : 1850 MHz ~ 1910 MHz 5G NR n5 : 824 MHz ~ 849 MHz 5G NR n7 : 2500 MHz ~ 2570 MHz 5G NR n12 : 699 MHz ~ 716 MHz 5G NR n25 : 1850 MHz ~ 1915 MHz 5G NR n38 : 2570 MHz ~ 2620 MHz 5G NR n41 : 2496 MHz ~ 2690 MHz 5G NR n66 : 1710 MHz ~ 1780 MHz 5G NR n71 : 663 MHz ~ 698 MHz 5G NR n77: 3700 MHz ~ 3980 MHz 5G NR n260 : 37 GHz~40 GHz 5G NR n261 : 27.5 GHz~28.35 GHz WLAN 2.4 GHz Band: 2400 MHz ~ 2483.5 MHz WLAN 5.2 GHz Band: 5150 MHz ~ 5250 MHz WLAN 5.3 GHz Band: 5250 MHz ~ 5350 MHz WLAN 5.6 GHz Band: 5470 MHz ~ 5725 MHz WLAN 5.8 GHz Band: 5725 MHz ~ 5850 MHz WLAN 6E: 5925 MHz ~ 6425 MHz, 6425 MHz ~ 6525 MHz, 6525 MHz ~ 6875 MHz, 6875 MHz ~ 7125 MHz Bluetooth: 2400 MHz ~ 2483.5 MHz
Mode	RMC 12.2Kbps HSDPA HSUPA DC-HSDPA LTE: QPSK, 16QAM, 64QAM, 256QAM 5G NR: DFT-s-OFDM/CP-OFDM, Pi/2 BPSK/QPSK/16QAM/64QAM/256QAM WLAN: 802.11a/b/g/n/ac/ax HT20/HT40/VHT20/VHT40/VHT80/VHT160/HE20/HE40/HE80/HE160 Bluetooth BR/EDR/LE

3. SAR Characterization

SAR char must be generated to cover all radio configurations and usage scenarios that the wireless device supports for operating at 6 GHz or below. It will then be used as input for Smart Transmit to control and manage RF exposure for f < 6 GHz.

3.1 SAR design target and uncertainty

SAR design target

The detail SAR design target relate to each exposure conditions pls refer to operation description

1g SAR design target	0.95 W/kg
Uncertainty	1 dB

To account for total uncertainty, SAR_design_target should be determined as:

$$SAR\_design\_target < SAR_{regulatory\_limit} \times 10^{\frac{-total\ uncertainty}{10}}$$

3.2 SAR Char Table

SAR char must be generated to cover all radio configurations and usage scenarios that the wireless device supports for operating at 6 GHz or below. It will then be used as input for Smart Transmit to control and manage RF exposure for f < 6 GHz

<P_{limit} for supported technologies and bands (P_{limit} in EFS file)>

Ant 0

Band	Antenna	Duty cycle	Plimit (dBm) Time-average power	PMax* (dBm) Time-average power
WCDMA II	0	100.00%	17.50	23.50
WCDMA IV	0	100.00%	17.50	23.50
WCDMA V	0	100.00%	20.80	23.50
LTE B7	0	100.00%	14.50	23.00
LTE B12/17	0	100.00%	20.80	23.50
LTE B13	0	100.00%	20.70	23.50
LTE B14	0	100.00%	20.40	23.50
LTE B25/2	0	100.00%	17.50	23.00
LTE B26/5	0	100.00%	18.90	23.50
LTE B30	0	100.00%	16.00	22.00
LTE B38/41**	0	63.30%	15.50	21.00
LTE B41_HPUE**	0	43.30%		22.40
LTE B66/4	0	100.00%	17.40	23.00
LTE B71	0	100.00%	21.60	23.50
FR1 n2	0	100.00%	18.10	23.00
FR1 n5	0	100.00%	19.40	23.00
FR1 n12	0	100.00%	22.00	23.00
FR1 n66	0	100.00%	17.70	23.00
FR1 n71	0	100.00%	20.70	23.00

Ant 2

Band	Antenna	Duty cycle	Plimit (dBm) Time-average power	PMax* (dBm) Time-average power
LTE B2	2	100.00%	16.30	23.00
LTE B7	2	100.00%	17.50	23.00
LTE B42**	2	63.30%	15.40	19.00
LTE B48**	2	63.30%	15.60	19.00
LTE B66	2	100.00%	17.30	23.00
FR1 n7	2	100.00%	16.40	23.00
FR1 n25/2	2	100.00%	15.40	23.00
FR1 n41/38	2	100.00%	16.20	23.00
FR1 n66	2	100.00%	20.20	23.00
FR1 n77	2	100.00%	16.20	23.00
FR1 n77_HPUE**	2	50.00%		23.00

*P_{max} is used for RF tune up procedure. The maximum allowed output power is equal to Pmax + 1dB uncertainty.

**All P_{limit} power levels entered in the Table correspond to average power levels after accounting for duty cycle in the case TDD modulation schemes (for e.g., GSM & LTE TDD & NR TDD).

The max allowed output power is the P_{limit} + device uncertainty, and if P_{limit} is higher than P_{max}, the device output power will be P_{max} instead.

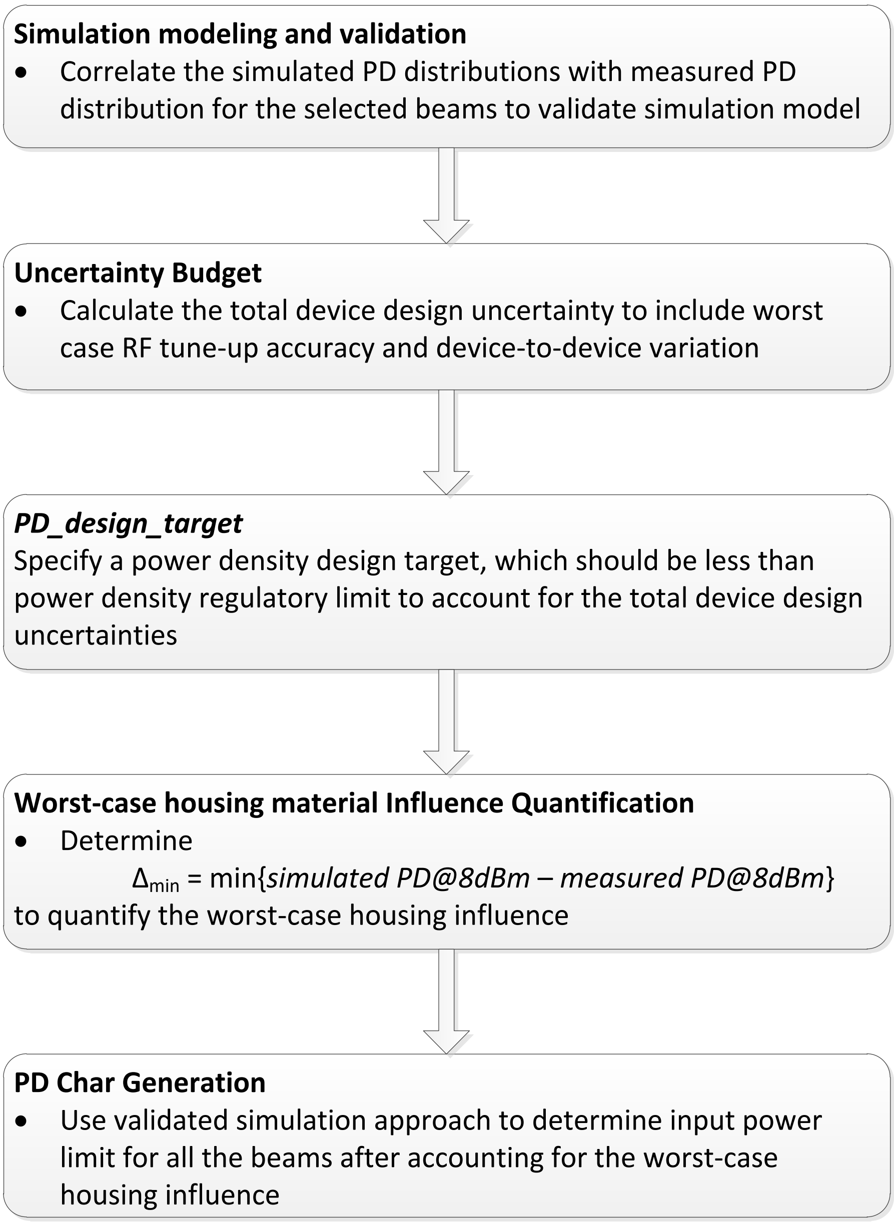
4. Power Density Characterization

The device with 5G mmW NR typically supports many beams and contains multiple mmW antenna arrays installed at different locations to achieve good coverage in the field. The power density (PD) measurement is a time-consuming test, and it is not practical to measure the power density for all the beams on all the surfaces of the device, thus a hybrid approach using electromagnetic (EM) simulation in combination with measurement is recommended for PD char generation

4.1 PD Char Table

The mmW device supports total N beams, where M out of N are single beams and the rest of (N-M) are beam pairs (where 2 single beams are excited at the same time).

The following figure outlines the PD char process.



4.2 Codebook for all beams

All the beams that the device supports are specified in the pre-defined codebook, and the codebook is device design specific and generated after evaluating radiation coverage from this particular device. In the field, a smartphone manages the beam selection and utilization based on this pre-defined codebook that is loaded and stored in the device.

Band	Module	Beam ID 2	Beam ID 1
n260	AiP_0		0
			3
			6
			7
			8
			9
			18
			19
			20
			27
			28
			29
			30
			31
			42
			43
			44
			45
		128	
		131	
		134	
		135	
		136	
		137	
		146	
		147	
		148	
		155	
		156	
		157	
		158	
		159	
		170	
		171	
		172	
		173	
		128	0
		131	3
		134	6
		135	7
		136	8
		137	9
		146	18
		147	19
		148	20
		155	27
		156	28
		157	29
		158	30
		159	31
		170	42

		171	43
		172	44
		173	45
n260	AiP_1		1
			4
			10
			11
			12
			13
			21
			22
			23
			32
			33
			34
			35
			36
			46
			47
			48
			49
		129	
		132	
		138	
		139	
		140	
		141	
		149	
		150	
		151	
		160	
		161	
		162	
		163	
		164	
		174	
		175	
		176	
		177	
		129	1
		132	4
		138	10
		139	11
		140	12
		141	13
		149	21
		150	22
		151	23
		160	32
		161	33
		162	34
		163	35
		164	36
		174	46
		175	47
		176	48
		177	49
n260	AiP_2		2
			5

			14
			15
			16
			17
			24
			25
			26
			37
			38
			39
			40
			41
			50
			51
			52
			53
		130	
		133	
		142	
		143	
		144	
		145	
		152	
		153	
		154	
		165	
		166	
		167	
		168	
		169	
		178	
		179	
		180	
		181	
		130	2
		133	5
		142	14
		143	15
		144	16
		145	17
		152	24
		153	25
		154	26
		165	37
		166	38
		167	39
		168	40
		169	41
		178	50
		179	51
		180	52
		181	53

Band	Module	Beam ID 2	Beam ID 1
n261	AiP_0		0
			3
			6
			7
			8
			9
			18
			19
			20
			27
			28
			29
			30
			31
			42
			43
			44
			45
		128	
		131	
		134	
		135	
		136	
		137	
		146	
		147	
		148	
		155	
		156	
		157	
		158	
		159	
		170	
		171	
		172	
		173	
		128	0
		131	3
		134	6
		135	7
		136	8
		137	9
		146	18
		147	19
		148	20
		155	27
		156	28
		157	29
		158	30
		159	31
		170	42
		171	43
		172	44
		173	45

n261	AiP_1		1
			4
			10
			11
			12
			13
			21
			22
			23
			32
			33
			34
			35
			36
			46
			47
			48
			49
		129	
		132	
		138	
		139	
		140	
		141	
		149	
		150	
		151	
		160	
		161	
		162	
		163	
		164	
		174	
		175	
		176	
		177	
		129	1
		132	4
		138	10
		139	11
		140	12
		141	13
		149	21
		150	22
		151	23
		160	32
		161	33
		162	34
		163	35
		164	36
		174	46
		175	47
		176	48
		177	49
n261	AiP_2		2
			5

			14
			15
			16
			17
			24
			25
			26
			37
			38
			39
			40
			41
			50
			51
			52
			53
		130	
		133	
		142	
		143	
		144	
		145	
		152	
		153	
		154	
		165	
		166	
		167	
		168	
		169	
		178	
		179	
		180	
		181	
		130	2
		133	5
		142	14
		143	15
		144	16
		145	17
		152	24
		153	25
		154	26
		165	37
		166	38
		167	39
		168	40
		169	41
		178	50
		179	51
		180	52
		181	53

4.3 PD_design_target determination

To account for total uncertainty, PD_design_target should meet the criteria:

$$PD\_design\_target < PD_{regulatory\_limit} \times 10^{\frac{-totaluncertainty}{10}}$$

For this EUT, the PD design target and the uncertainty value are listed below

n260/261	PD design target	Antenna Module	W/m^2
		Antenna Module 0	5.55
		Antenna Module 1	3.08
		Antenna Module 2	5.55

Item	Uncertainty dB (k=2)
Total uncertainty	2.1

4.4 Exposure positions for PD evaluation

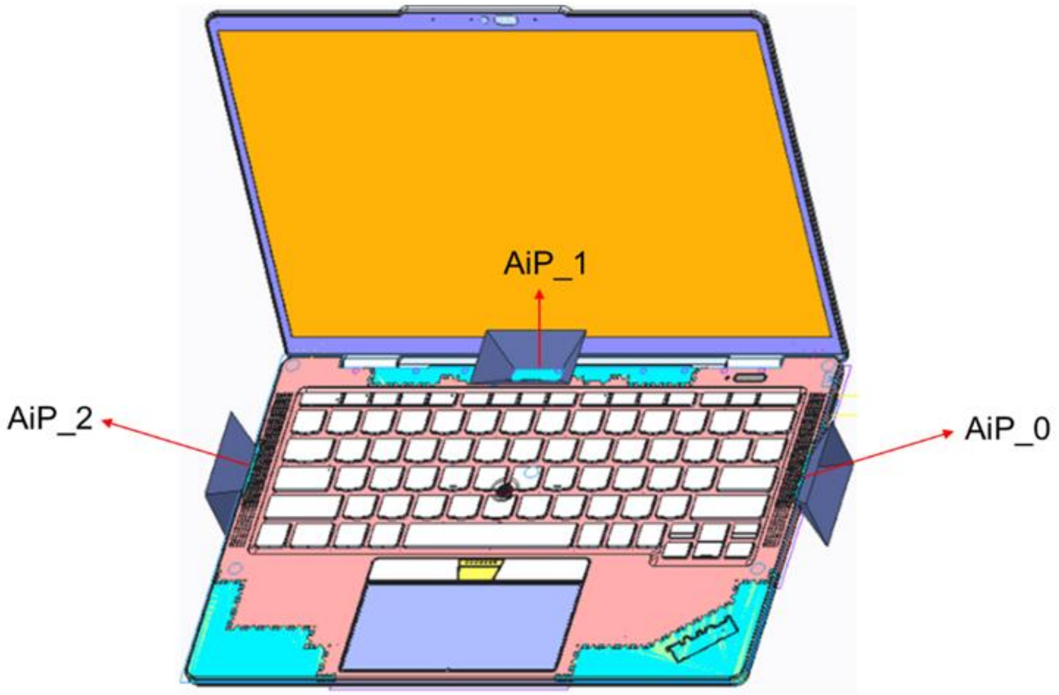


Figure 2 (b) AiP Location (with AiP Sketch)

Evaluation positions

Antenna Module	Bottom of Laptop 2mm
Antenna module 0 / 1 / 2	v

4.5 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. Following Table 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 and n260 band, PD measurements are conducted for at least one single beam per antenna type and per antenna module (0,1) on worst-surface(s) . PD measurements are performed at mid channel of each mmW band and with CW modulation.
PD value will be used to determine worst-case housing influence for conservative assessment

Band	Antenna Module	Beam ID 1	Beam ID 2	Frequency (GHz)	Exposure Surface	Test Separation (mm)	**Measured results Savg tot 4cm^2 (W/m2)**	**Simulated Pd (W/m^2), averaged over 4 cm2**	**Delta= Sim. – Meas. (dB)**
n260	AiP_0	30	-	38.5	Bottom of Laptop	2mm	1.12	6.71	7.775
n260	AiP_0	-	171	38.5	Bottom of Laptop	2mm	1.22	6.28	7.116
n260	AiP_1	33	-	38.5	Bottom of Laptop	2mm	0.81	3.98	6.914
n260	AiP_1	-	164	38.5	Bottom of Laptop	2mm	0.854	2.65	4.918
n260	AiP_2	51	-	38.5	Bottom of Laptop	2mm	1.51	6.41	6.279
n260	AiP_2	-	166	38.5	Bottom of Laptop	2mm	2.28	6.18	4.331
n261	AiP_0	29	-	27.925	Bottom of Laptop	2mm	2.42	5.33	3.429
n261	AiP_0	-	172	27.925	Bottom of Laptop	2mm	2.36	5.32	3.530
n261	AiP_1	49	-	27.925	Bottom of Laptop	2mm	0.924	2.3	3.961
n261	AiP_1	-	160	27.925	Bottom of Laptop	2mm	2.22	1.36	-2.128
n261	AiP_2	39	-	27.925	Bottom of Laptop	2mm	2.51	5.11	3.087
n261	AiP_2	-	168	27.925	Bottom of Laptop	2mm	5.05	5.14	0.077

4.6 PD Char

4.6.1 Simulated input power limit for single beams

Perform simulation at low, mid and high channel for each mmW band supported, with a given input power per active port, *sim.input.power.per.active.port* (6 dBm for this product):

1. Obtain $PD_{surface}$ value (the worst PD among all identified surfaces of the device) at all three channels for all single beams (1~M) specified in *codebook_sim*.
2. Adjust input power to determine a scaling factor at all three channels by:

$$s(i)_{low\_or\_mid\_high} = \frac{PD\ design\ target}{sim.PD_{surface}(i)},\ i = 1,2,\ldots M \qquad (4)$$

3. Determine the worst-case scaling factor among low, mid and high channels:

$$s(i) = min\{s_{low}(i), s_{mid}(i), s_{high}(i)\},\ i = 1,2,\ldots M \qquad (5)$$

   Note: This scaling factor applies to the input power at each antenna port
4. Determine the simulated input power limit, sim.powerlimit, for single beam i by:

$$sim.\ power_{limit}.(i)dBm = 10 * log(s(i)) + sim.input.power.per.active.port,\ i = 1,2,\ldots M \qquad (6)$$

4.6.2 Simulated input power limit for beam pairs

The relative phase between single beams of a beam pair is sweeped to find the worst case PD for beam-pairs operation, and PD simulation data has taken this into considerationfor beam-pair operations take consideration of the variation relative phase was reported

For beam pair, extract the E-fields and H-fields from the corresponding single beams at and high channel for each supported band and for all identified surfaces of the device.

For a given beam pair containing *beam_a* and *beam_b with relative phase Ø* and for a given channel, determine the worst-case $Ø_{worstcase}$ which results in the highest $\text{total } PD$ (∅) among all identified surfaces for this beam pair at this channel. When $Ø_{worstcase}$ is determined for all three channels, obtain the scaling factor given by the below equation for low, mid and high channels:

$$s(i)_{low\_or\_mid\_high} = \frac{PD\ design\ target}{total.PD(\emptyset(\mathrm{i})_{worstcase})},\ i = M+1,\ M+2, \ldots N \qquad (8)$$

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

$$s(i) = min\{s_{low}(i), s_{mid}(i), s_{high}(i)\},\ i = M+1,\ M+2, \ldots N \qquad (9)$$

The simulated input power limit, $sim.power_{limit}$, for beam pair *i* can be determined by

$$sim.power_{limit}(i)dBm = 10*\log(\mathrm{s(i)}) + sim.input.power.per.active.port, i = M+1,\ M+2,\ \ldots N \qquad (10)$$

4.7 PD Char

This section describes the PD char generation that complies with the *PD_design_target* and is in compliance with the regulatory power density limit.

4.7.1 PD char generation

Ideally, if there is no uncertainty associated with hardware as described in Section 4.4, after accounting for the housing influence (Δ_{min}), *input.power.limit(i)*, for beam *i* can be obtained:

$$input.power.limit(i) = 6\,dBm + 10 * \log(s(i)) + \Delta_{min},\ i \in all\ beams \quad (11)$$

If simulation overestimates the housing influence, then Δ_{min} (= minimum {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 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 in equation (11). In Section 4.7, the TxAGC uncertainty at reference power level (6dBm in report) is embedded in the process of Δ_{min} determination and should be removed to avoid double counting this uncertainty.

If -TxAGC uncertainty at reference power level < *Δmin* < TxAGC uncertainty at reference power level,

$$Input.power.limit(i) = sim.power_{limit}(i), i = 1,2,..,N \quad (12)$$

else if Δmin < -TxAGC uncertainty at reference power level,

$$Input.power.limit(i) = sim.power_{limit}(i) + (\Delta min + TxAGC\ uncertainty), i = 1,2,..,N \quad (13)$$

else if Δmin > TxAGC uncertainty at reference power level,

$$Input.power.limit(i) = sim.power_{limit}(i) + (\Delta min - TxAGC\ uncertainty), i = 1,2,..,N \quad (14)$$

The input power limit is derived and listed in the table below

Band	Antenna	Beam ID	Delta_min (dB)	TxAGC uncertainty (dB)	Input.power.limit (dBm)=
n260	AiP_0	Beam ID 1	7.775	0.5	6 + 10* log(s(i)) +7.275
		Beam ID 2	7.116	0.5	6 + 10* log(s(i)) +6.616
	AiP_1	Beam ID 1	6.914	0.5	6 + 10* log(s(i)) +6.414
		Beam ID 2	4.918	0.5	6 + 10* log(s(i)) +4.418
	AiP_2	Beam ID 1	6.279	0.5	6 + 10* log(s(i)) +5.779
		Beam ID 2	4.331	0.5	6 + 10* log(s(i)) +3.831
n261	AiP_0	Beam ID 1	3.429	0.5	6 + 10* log(s(i)) +2.929
		Beam ID 2	3.53	0.5	6 + 10* log(s(i)) +3.03
	AiP_1	Beam ID 1	3.961	0.5	6 + 10* log(s(i)) +3.461
		Beam ID 2	-2.128	0.5	6 + 10* log(s(i)) +0.287
	AiP_2	Beam ID 1	3.087	0.5	6 + 10* log(s(i)) +2.587
		Beam ID 2	0.077	0.5	6 + 10* log(s(i)) +0.077

4.7.2 PD char Table

Combining the information in previous sections, PD char is derived and listed below

Band	Module	Beam ID 2	Beam ID 1	Input power limit(dBm)
n260	AiP_0		0	17.84
			3	18.44
			6	16.79
			7	15.13
			8	14.48
			9	15.34
			18	16.23
			19	14.99
			20	15.10
			27	13.30
			28	13.26
			29	12.70
			30	12.45
			31	13.56
			42	13.28
			43	13.14
			44	12.56
			45	12.64
		128		18.63
		131		18.45
		134		15.32
		135		15.51
		136		15.01
		137		14.85
		146		16.13
		147		15.10
		148		15.94
		155		12.36
		156		12.50
		157		12.52
		158		12.09
		159		12.54
		170		12.60
		171		12.08
		172		12.62
		173		12.21
		128	0	14.01
		131	3	14.07
		134	6	11.51
		135	7	11.26
		136	8	11.07
		137	9	11.06
		146	18	12.52
		147	19	10.97
		148	20	11.59
		155	27	8.89
		156	28	8.54
		157	29	8.37
		158	30	8.90
		159	31	8.99
		170	42	9.20

		171	43	8.56
		172	44	9.11
		173	45	8.37
n260	AiP_1		1	19.50
			4	16.39
			10	14.63
			11	13.36
			12	15.99
			13	12.41
			21	13.88
			22	14.70
			23	16.25
			32	14.70
			33	10.03
			34	12.55
			35	14.99
			36	13.15
			46	13.27
			47	12.28
			48	11.59
			49	14.16
		129		15.52
		132		18.85
		138		15.77
		139		14.40
		140		14.95
		141		13.78
		149		12.25
		150		12.70
		151		12.33
		160		13.00
		161		10.40
		162		11.27
		163		12.96
		164		9.75
		174		11.53
		175		11.83
		176		11.51
		177		11.11
		129	1	14.70
		132	4	12.81
		138	10	11.23
		139	11	10.14
		140	12	12.36
		141	13	8.28
		149	21	9.70
		150	22	9.38
		151	23	12.36
		160	32	10.75
		161	33	5.85
		162	34	7.43
		163	35	11.47
		164	36	7.55
		174	46	8.58
		175	47	8.80
		176	48	7.42

		177	49	9.33
n260	AiP_2		2	18.02
			5	19.05
			14	14.09
			15	13.22
			16	14.06
			17	13.63
			24	13.34
			25	15.02
			26	14.14
			37	12.28
			38	11.35
			39	11.50
			40	11.87
			41	11.67
			50	11.36
			51	11.15
			52	11.55
			53	12.15
		130		15.37
		133		15.84
		142		12.40
		143		11.98
		144		13.33
		145		11.87
		152		11.69
		153		12.17
		154		13.06
		165		9.95
		166		9.36
		167		9.44
		168		9.75
		169		9.68
		178		9.73
		179		9.83
		180		9.51
		181		10.23
		130	2	13.28
		133	5	13.98
		142	14	10.55
		143	15	9.35
		144	16	11.17
		145	17	9.22
		152	24	9.93
		153	25	10.21
		154	26	10.02
		165	37	7.66
		166	38	7.08
		167	39	7.56
		168	40	6.92
		169	41	7.52
		178	50	7.38
		179	51	7.80
		180	52	7.20
		181	53	7.86

Band	Module	Beam ID 2	Beam ID 1	Input power limit(dBm)
n261	AiP_0		0	16.64
			3	15.10
			6	14.41
			7	11.64
			8	13.49
			9	13.30
			18	13.56
			19	11.93
			20	13.77
			27	10.86
			28	10.42
			29	9.10
			30	10.31
			31	10.88
			42	10.09
			43	9.84
			44	9.55
			45	10.96
		128		15.61
		131		15.47
		134		13.59
		135		14.74
		136		11.22
		137		13.15
		146		14.22
		147		12.39
		148		13.48
		155		11.30
		156		11.59
		157		9.82
		158		9.07
		159		10.61
		170		10.80
		171		10.98
		172		9.21
		173		10.40
		128	0	11.41
		131	3	10.91
		134	6	10.06
		135	7	9.93
		136	8	7.61
		137	9	9.40
		146	18	9.95
		147	19	8.30
		148	20	9.58
		155	27	8.06
		156	28	7.01
		157	29	6.13
		158	30	5.51
		159	31	7.31
		170	42	7.25
		171	43	6.64
		172	44	5.86
		173	45	6.45

n261	AiP_1		1	12.36
			4	12.32
			10	9.31
			11	9.40
			12	9.29
			13	9.94
			21	10.13
			22	8.28
			23	10.60
			32	6.92
			33	6.80
			34	5.99
			35	7.69
			36	7.42
			46	6.98
			47	6.33
			48	6.28
			49	8.83
		129		6.56
		132		6.92
		138		4.64
		139		4.33
		140		4.19
		141		4.45
		149		6.35
		150		3.98
		151		2.87
		160		2.35
		161		3.47
		162		1.58
		163		0.88
		164		1.46
		174		2.75
		175		1.79
		176		0.92
		177		0.90
		129	1	7.76
		132	4	7.56
		138	10	5.83
		139	11	5.41
		140	12	5.48
		141	13	7.35
		149	21	6.71
		150	22	3.99
		151	23	4.91
		160	32	3.90
		161	33	3.51
		162	34	3.08
		163	35	3.35
		164	36	3.61
		174	46	3.74
		175	47	2.34
		176	48	2.36
		177	49	3.20
n261	AiP_2		2	15.03
			5	15.03

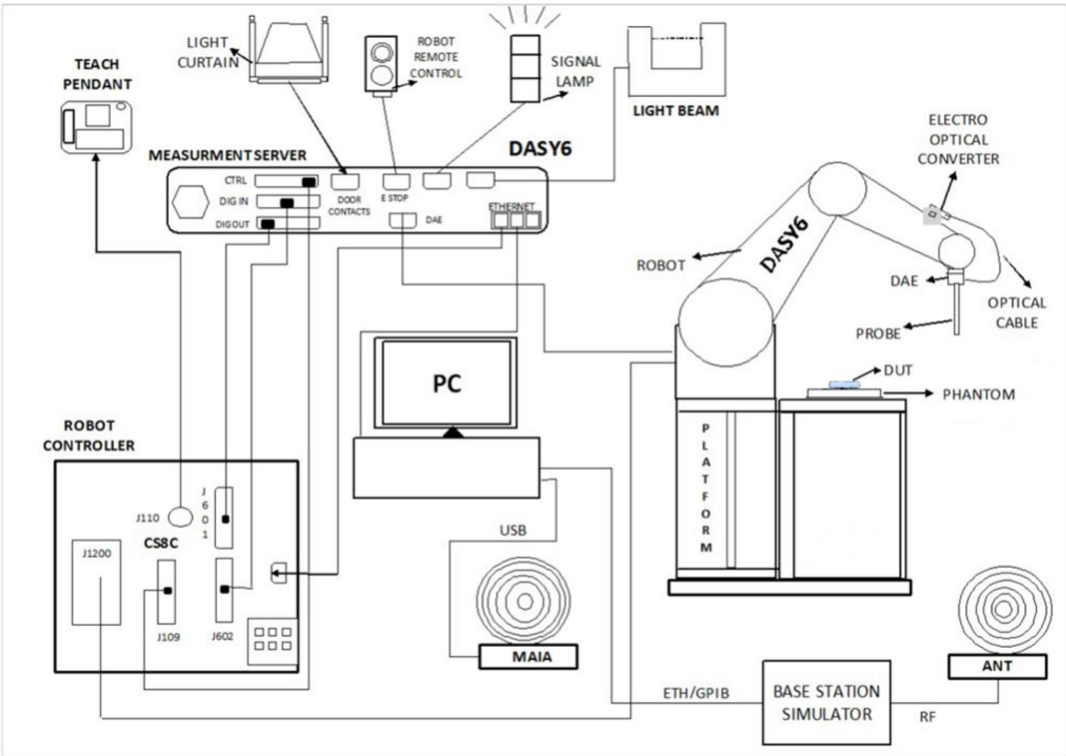
			14	12.21
			15	12.17
			16	11.95
			17	12.81
			24	13.00
			25	11.23
			26	13.50
			37	9.67
			38	9.73
			39	8.84
			40	10.45
			41	10.37
			50	9.73
			51	9.04
			52	9.23
			53	11.30
		130		11.59
		133		11.72
		142		9.68
		143		9.20
		144		9.08
		145		9.37
		152		11.12
		153		8.80
		154		7.90
		165		7.39
		166		8.37
		167		6.61
		168		5.72
		169		6.49
		178		7.77
		179		6.82
		180		5.91
		181		5.93
		130	2	10.56
		133	5	10.44
		142	14	8.71
		143	15	8.19
		144	16	8.36
		145	17	10.10
		152	24	9.59
		153	25	6.95
		154	26	7.86
		165	37	6.82
		166	38	6.07
		167	39	5.86
		168	40	6.05
		169	41	6.49
		178	50	6.22
		179	51	5.22
		180	52	5.25
		181	53	6.07

5. PD Test Setup

5.1 PD Test – System Setup

The system to be used for the near field power density measurement

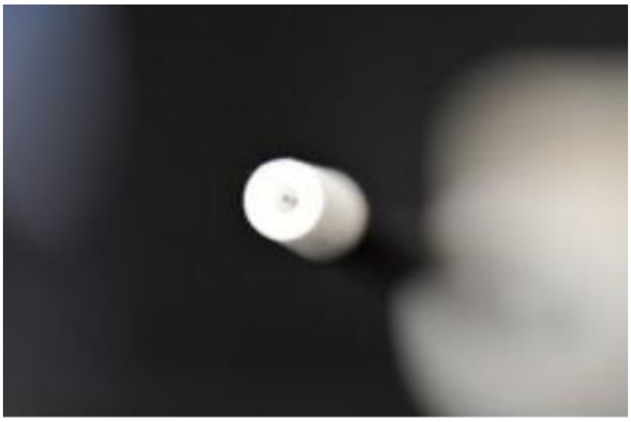
- SPEAG DASY6 system
  - SPEAG cDASY6 5G module software
  - EUmmWVx probe
- 5G Phantom cover

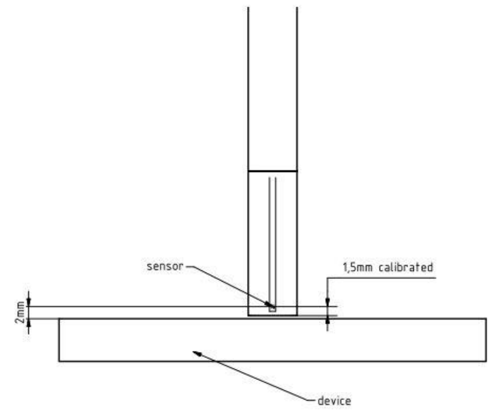


5.2 EUmmWave Probe / E-Field 5G Probe

The probe design allows measurements at distances as small as 2 mm from the sensors to the surface of the device under test (DUT). The typical sensor to probe tip distance is 1.5 mm.

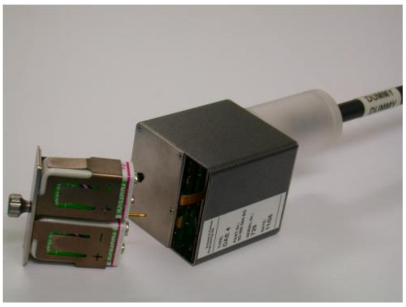
Frequency	750 MHz – 110 GHz
Probe Overall Length	320 mm
Probe Body Diameter	8.0 mm
Tip Length	23.0 mm
Tip Diameter	8.0 mm
Probe's two dipoles length	0.9 mm – Diode loaded
Dynamic Range	< 20 V/m - 10000 V/m with PRE-10 (min < 50 V/m - 3000 V/m)
Position Precision	< 0.2 mm
Distance between diode sensors and probe's tip	1.5 mm
Minimum Mechanical separation between probe tip and a Surface	0.5 mm
Applications	E-field measurements of 5G devices and other mm-wave transmitters operating above 10GHz in < 2 mm distance from device (free-space) Power density, H-field and far-field analysis using total field reconstruction.
Compatibility	cDASY6 + 5G-Module SW1.0 and higher





5.3 Data Acquisition Electronics (DAE)

The data acquisition electronics (DAE) consists of a highly sensitive electrometer-grade preamplifier with auto-zeroing, a channel and gain-switching multiplexer, a fast 16 bit AD-converter and a command decoder and control logic unit. Transmission to the measurement server is accomplished through an optical downlink for data and status information as well as an optical uplink for commands and the clock.
The input impedance of the DAE is 200 MOhm; the inputs are symmetrical and floating. Common mode rejection is above 80 dB.



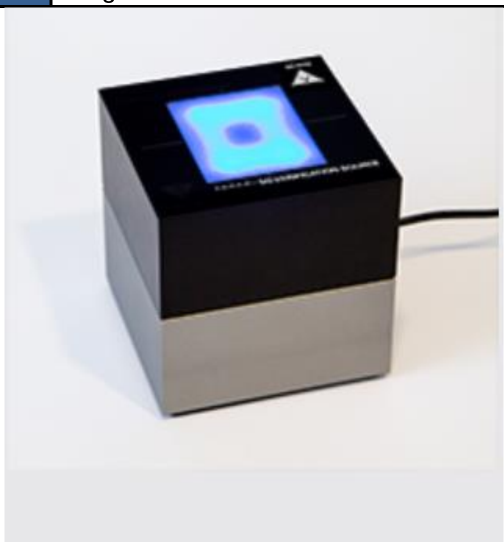
5.4 Scan configuration

Fine-resolution scans on 2 different planes are performed to reconstruct the E- and H-fields as well as the power density; the z-distance between the 2 planes is set to $\lambda/4$.
The (x, y) grid step is also set $\lambda/4$, the grid extent is set to sufficiently large to identify the field pattern and the peak.

5.5 System Verification Source

The System Verification sources at 30 GHz and above comprise horn-antennas and very stable signal generators.

Model	Ka-band horn antenna
Calibrated frequency:	30 GHz at 10mm from the case surface
Frequency accuracy	± 100 MHz
E-field polarization	linear
Harmonics	-20 dBc
Total radiated power	14 dBm
Power stability	0.05 dB
Power consumption	5 W
Size	00 x 100 x 100 mm
Weight	1 kg

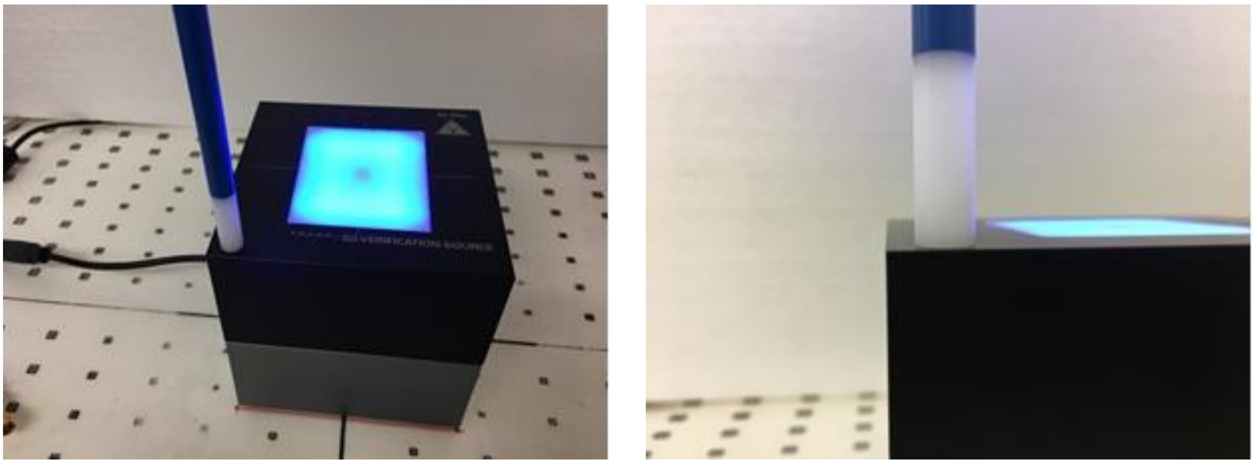


5.6 Power Density System Verification

The system performance check verifies that the system operates within its specifications.
The EUT is replaced by a calibrated source, the same spatial resolution, measurement region and the test separation used in the calibration was applied to system check. Through visual inspection into the measured power density distribution, both spatially (shape) and numerically (level) have no noticeable difference. The measured results should be within 0.66B of the calibrated targets.

Frequency [GHz]	Grid step	Grid extent X/Y [mm]	Measurement points
10	$0.25\ (\frac{\lambda}{4})$	120/120	16×16
30	$0.25\ (\frac{\lambda}{4})$	60/60	24×24
60	$0.25\ (\frac{\lambda}{4})$	32.5/32.5	26×26
90	$0.25\ (\frac{\lambda}{4})$	30/30	36×36

Settings for measurement of verification sources



Verification Setup photo

5.7 System Verification Results

Frequency (GHz)	5G Verification Source	Probe S/N	DAE S/N	Distance (mm)	Measured 4 cm^2 (W/m^2)	Targeted 4 cm^2 (W/m^2)	Deviation (dB)	Date
30G	30GHz_1007	9441	778	10	33.1	35.8	-0.34	2021/12/29
30G	30GHz_1007	9441	778	10	32.6	35.8	-0.41	2022/1/31
30G	30GHz_1007	9441	778	10	32.8	35.8	-0.38	2022/3/10

6. Uncertainty Assessment

The budget is valid for evaluation distances > λ/2π. For specific tests and configurations, the Uncertainty could be considerably smaller.

Preliminary Module mmWave Uncertainty Budget Evaluation Distances to the Antennas > λ / 2π						
Error Description	**Uncertainty Value (± dB)**	**Probability**	**Divisor**	**(Ci)**	**Standard Uncertainty (±dB)**	**(Vi) Veff**
Measurement System						
Probe Calibration	0.49	N	1	1	0.49	∞
Hemispherical Isotropy	0.50	R	1.732	1	0.29	∞
Linearity	0.20	R	1.732	0	0.12	∞
System Detection Limits	0.04	R	1.732	1	0.02	∞
Modulation Response	0.40	R	1.732	1	0.23	∞
Readout Electronics	0.03	N	1	1	0.03	∞
Response Time	0.00	R	1.732	1	0.00	∞
Integration Time	0.00	R	1.732	1	0.00	∞
RF Ambient Noise	0.2	R	1.732	1	0.12	∞
RF Ambient Reflections	0.21	R	1.732	1	0.12	∞
Probe Positioner	0.04	R	1.732	1	0.02	∞
Probe Positioning	0.30	R	1.732	1	0.17	∞
S_{avg} Reconstruction	0.60	R	1.732	1	0.35	∞
Test Sample Related						
Power Drift	0.2	R	1.732	1	0.12	∞
Input Power	0	N	1	0	0.00	∞
Combined Std. Uncertainty					0.76 dB	∞
Coverage Factor for 95 %					K=2	
Expanded STD Uncertainty					1.52 dB	