# RF Exposure Report

# (Part 0: SAR and PD Char Evaluation)

| | |
|---|---|
| **FCC ID** | **: IHDT56ZC1** |
| **Equipment** | **: Mobile Cellular Phone** |
| **Brand Name** | **: Motorola** |
| **Model Name** | **: XT2075-1** |
| **Applicant** | **: Motorola Mobility LLC<br>222 W,Merchandise Mart Plaza, Chicago IL<br>60654 USA** |
| **Standard** | **: FCC 47 CFR Part 2 (2.1093)** |

**We, SPORTON INTERNATIONAL INC., would like to declare that the tested sample provide by manufacturer and the test data has been evaluated in accordance with the test procedures given in 47 CFR Part 2.1093 and has been meet FCC requirement.**

**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.**

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**Approved by: Cona Huang / Deputy Manager**

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# History of this test report

| Report No. | Version | Description | Issued Date |
|---|---|---|---|
| FA050822-01D | 01 | Initial issue of report | Aug. 11, 2020 |
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# 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 operat 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 | Mobile Cellular Phone |
| FCC ID | IHDT56ZC1 |
| Wireless Technology and Frequency Range | GSM850: 824.2 MHz ~ 848.8 MHz<br>GSM1900: 1850.2 MHz ~ 1909.8 MHz<br>WCDMA Band II: 1850 MHz ~ 1910 MHz<br>WCDMA Band V: 824 MHz ~ 849 MHz<br>LTE Band 2: 1850 MHz ~ 1910 MHz<br>LTE Band 4: 1710 MHz ~ 1755 MHz<br>LTE Band 5: 824 MHz ~ 849 MHz<br>LTE Band 7: 2500 MHz ~ 2570 MHz<br>LTE Band 12: 699 MHz ~ 716 MHz<br>LTE Band 13: 777 MHz ~ 787 MHz<br>LTE Band 17: 704 MHz ~ 716 MHz<br>LTE Band 66: 1710 MHz ~ 1780 MHz<br>5G NR n2 : 1850 MHz ~ 1910 MHz<br>5G NR n5 : 824 MHz ~ 849 MHz<br>5G NR n66 : 1710 MHz ~ 1780 MHz<br>WLAN 2.4GHz Band: 2400 MHz ~ 2483.5 MHz<br>WLAN 5.2GHz Band: 5150 MHz ~ 5250 MHz<br>WLAN 5.3GHz Band: 5250 MHz ~ 5350 MHz<br>WLAN 5.6GHz Band: 5470 MHz ~ 5725 MHz<br>WLAN 5.8GHz Band: 5725 MHz ~ 5825 MHz<br>Bluetooth: 2400 MHz ~ 2483.5 MHz<br>NFC : 13.56 MHz |
| Mode | GSM/GPRS/EGPRS<br>RMC/AMR 12.2Kbps<br>HSDPA<br>HSUPA<br>DC-HSDPA<br>LTE: QPSK, 16QAM, 64QAM<br>5G NR: DFT-s-OFDM/CP-OFDM, Pi/2 BPSK/QPSK/16QAM/64QAM/256QAM<br>WLAN: 802.11a/b/g/n/ac HT20/HT40/VHT20/VHT40/VHT80<br>Bluetooth BR/EDR/LE<br>NFC:ASK |
| EUT Stage | Identical Prototype |

# 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

| Exposure conditions | Trigger Conditions | DSI | SAR design target | W/kg | Remark |
|---|---|---|---|---|---|
| Head | Earpiece on | 2 | 1g SAR design target | 0.79 | For GSM |
| Head | Earpiece on | 2 | 1g SAR design target | 0.67 | For WCDMA & LTE |
| Head | Earpiece on | 2 | 1g SAR design target | 0.85 | FR1 Bottom Antenna |
| Head | Earpiece on | 2 | 1g SAR design target | 0.79 | FR1 Top Antenna |
| Body Worn & Hotspot | Sensor On or Hotspot On | 3 | 1g SAR design target | 0.79 | For GSM |
| Body Worn & Hotspot | Sensor On or Hotspot On | 3 | 1g SAR design target | 0.67 | For WCDMA & LTE |
| Body Worn & Hotspot | Sensor On or Hotspot On | 3 | 1g SAR design target | 0.85 | FR1 Bottom Antenna |
| Body Worn & Hotspot | Sensor On or Hotspot On | 3 | 1g SAR design target | 0.70 | FR1 Top Antenna |
| Body Worn | Sensor Off | 4 | 1g SAR design target | 0.79 | For GSM |
| Body Worn | Sensor Off | 4 | 1g SAR design target | 0.67 | For WCDMA & LTE |
| Body Worn | Sensor Off | 4 | 1g SAR design target | 0.85 | FR1 Bottom Antenna |
| Body Worn | Sensor Off | 4 | 1g SAR design target | 0.70 | FR1 Top Antenna |
| Extremity | Sensor On | 6 | 10g SAR design target | 2.00 | For GSM |
| Extremity | Sensor On | 6 | 10g SAR design target | 1.59 | For WCDMA & LTE |
| Extremity | Sensor On | 6 | 10g SAR design target | 2.26 | FR1 Bottom Antenna |
| Extremity | Sensor On | 6 | 10g SAR design target | 1.98 | FR1 Top Antenna |
| Extremity | Sensor Off | 4 | 1g SAR design target | 2.00 | For GSM |
| Extremity | Sensor Off | 4 | 1g SAR design target | 1.59 | For WCDMA & LTE |
| Extremity | Sensor Off | 4 | 1g SAR design target | 2.26 | FR1 Bottom Antenna |
| Extremity | Sensor Off | 4 | 1g SAR design target | 1.98 | FR1 Top Antenna |

| | Uncertainty dB (k=2) |
|---|---|
| Sub6 radio TxAGC | 1.0 |
| Device to device variation | 1.2 |
| Total uncertainty | 1.5 |

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

| Band | Antenna | Head | Body Worn/ Hotspot | Extremity | Sensor Off | Pmax* |
|---|---|---|---|---|---|---|
| | | DSI 2 | DSI 3 | DSI 6 | DSI 4 | |
| GSM850** | 1 | 25.50 | 23.30 | 27.50 | 32.50 | 24.00 |
| GSM1900 ** | 1 | 35.90 | 17.10 | 21.40 | 28.30 | 21.24 |
| WCDMA II | 1 | 32.20 | 15.30 | 19.20 | 25.50 | 23.00 |
| WCDMA V | 1 | 26.90 | 23.30 | 23.60 | 43.00 | 23.00 |
| LTE Band 2 | 1 | 31.50 | 14.90 | 19.30 | 25.20 | 23.00 |
| LTE Band 2 | 2 | 13.3 | 14.80 | 19.50 | 23.80 | 22.00 |
| LTE Band 66/4 | 1 | 30.90 | 15.10 | 19.50 | 25.80 | 23.00 |
| LTE Band 66/4 | 2 | 13.9 | 15.50 | 19.00 | 26.10 | 22.00 |
| LTE Band 5 | 1 | 28.30 | 22.70 | 23.20 | 31.60 | 23.00 |
| LTE Band 5 | 2 | 23.0 | 25.20 | 26.30 | 42.50 | 22.50 |
| LTE Band 7 | 1 | 31.90 | 13.20 | 18.50 | 25.30 | 23.00 |
| LTE Band 12/17 | 1 | 28.20 | 24.00 | 24.70 | 43.00 | 23.00 |
| LTE Band 13 | 1 | 27.70 | 23.40 | 24.60 | 43.00 | 23.00 |
| 5G FR1 n2 | 1 | 35.10 | 16.80 | 21.30 | 27.30 | 23.00 |
| 5G FR1 n2 | 2 | 14.50 | 15.00 | 20.00 | 25.50 | 23.00 |
| 5G FR1 n5 | 1 | 30.90 | 24.60 | 27.40 | 43.00 | 23.00 |
| 5G FR1 n5 | 2 | 24.00 | 25.60 | 28.20 | 43.00 | 23.00 |
| 5G FR1 n66 | 1 | 35.40 | 18.00 | 21.80 | 28.50 | 23.00 |
| 5G FR1 n66 | 2 | 15.50 | 16.00 | 20.00 | 24.70 | 23.00 |

*Pmax is used for RF tune up procedure. The maximum allowed output power is equal to Pmax + device uncertainty.

**All Plimit 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 Plimit values, corresponding to SAR_design_target.

Maximum target power, $P_{max}$, is configured in NV settings in EUT to limit maximum transmitting power. This power is converted into peak power in NV settings for TDD schemes. The EUT maximum allowed output power is equal to $P_{max}$ + 1.0dB device uncertainty

# 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.

**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

$$\Delta_{min} = \min\{\textit{simulated PD@8dBm} - \textit{measured PD@8dBm}\}$$

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

## 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 | Beam ID 1 | Beam ID 2 | Antenna Module | # of Antenna Feed Used |
|---|---|---|---|---|
| n260 | 1 | | 0 | 1 |
| n260 | 5 | | 0 | 2 |
| n260 | 6 | | 0 | 2 |
| n260 | 7 | | 0 | 2 |
| n260 | 10 | | 0 | 2 |
| n260 | 11 | | 0 | 2 |
| n260 | 17 | | 0 | 4 |
| n260 | 18 | | 0 | 4 |
| n260 | 19 | | 0 | 4 |
| n260 | 20 | | 0 | 4 |
| n260 | 21 | | 0 | 4 |
| n260 | 26 | | 0 | 4 |
| n260 | 27 | | 0 | 4 |
| n260 | 28 | | 0 | 4 |
| n260 | 29 | | 0 | 4 |
| n260 | | 129 | 0 | 1 |
| n260 | | 133 | 0 | 2 |
| n260 | | 134 | 0 | 2 |
| n260 | | 135 | 0 | 2 |
| n260 | | 138 | 0 | 2 |
| n260 | | 139 | 0 | 2 |
| n260 | | 145 | 0 | 4 |
| n260 | | 146 | 0 | 4 |
| n260 | | 147 | 0 | 4 |
| n260 | | 148 | 0 | 4 |
| n260 | | 149 | 0 | 4 |
| n260 | | 154 | 0 | 4 |
| n260 | | 155 | 0 | 4 |
| n260 | | 156 | 0 | 4 |
| n260 | | 157 | 0 | 4 |
| n260 | 1 | 129 | 0 | 2 |
| n260 | 5 | 135 | 0 | 4 |
| n260 | 6 | 134 | 0 | 4 |
| n260 | 7 | 133 | 0 | 4 |
| n260 | 10 | 139 | 0 | 4 |
| n260 | 11 | 138 | 0 | 4 |
| n260 | 17 | 149 | 0 | 8 |
| n260 | 18 | 148 | 0 | 8 |
| n260 | 19 | 147 | 0 | 8 |
| n260 | 20 | 146 | 0 | 8 |
| n260 | 21 | 145 | 0 | 8 |
| n260 | 26 | 157 | 0 | 8 |
| n260 | 27 | 155 | 0 | 8 |
| n260 | 28 | 156 | 0 | 8 |
| n260 | 29 | 154 | 0 | 8 |

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

| Band | Beam ID 1 | Beam ID 2 | Antenna Module | # of Antenna Feed Used |
|---|---|---|---|---|
| n261 | 1 | | 0 | 1 |
| n261 | 5 | | 0 | 2 |
| n261 | 6 | | 0 | 2 |
| n261 | 7 | | 0 | 2 |
| n261 | 10 | | 0 | 2 |
| n261 | 11 | | 0 | 2 |
| n261 | 17 | | 0 | 4 |
| n261 | 18 | | 0 | 4 |
| n261 | 19 | | 0 | 4 |
| n261 | 20 | | 0 | 4 |
| n261 | 21 | | 0 | 4 |
| n261 | 26 | | 0 | 4 |
| n261 | 27 | | 0 | 4 |
| n261 | 28 | | 0 | 4 |
| n261 | 29 | | 0 | 4 |
| n261 | | 129 | 0 | 1 |
| n261 | | 133 | 0 | 2 |
| n261 | | 134 | 0 | 2 |
| n261 | | 135 | 0 | 2 |
| n261 | | 138 | 0 | 2 |
| n261 | | 139 | 0 | 2 |
| n261 | | 145 | 0 | 4 |
| n261 | | 146 | 0 | 4 |
| n261 | | 147 | 0 | 4 |
| n261 | | 148 | 0 | 4 |
| n261 | | 149 | 0 | 4 |
| n261 | | 154 | 0 | 4 |
| n261 | | 155 | 0 | 4 |
| n261 | | 156 | 0 | 4 |
| n261 | | 157 | 0 | 4 |
| n261 | 1 | 129 | 0 | 2 |
| n261 | 5 | 134 | 0 | 4 |
| n261 | 6 | 133 | 0 | 4 |
| n261 | 7 | 135 | 0 | 4 |
| n261 | 10 | 139 | 0 | 4 |
| n261 | 11 | 138 | 0 | 4 |
| n261 | 17 | 146 | 0 | 8 |
| n261 | 18 | 148 | 0 | 8 |
| n261 | 19 | 147 | 0 | 8 |
| n261 | 20 | 149 | 0 | 8 |
| n261 | 21 | 145 | 0 | 8 |
| n261 | 26 | 157 | 0 | 8 |
| n261 | 27 | 156 | 0 | 8 |
| n261 | 28 | 155 | 0 | 8 |
| n261 | 29 | 154 | 0 | 8 |

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

## 4.3 PD_design_target determination

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

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

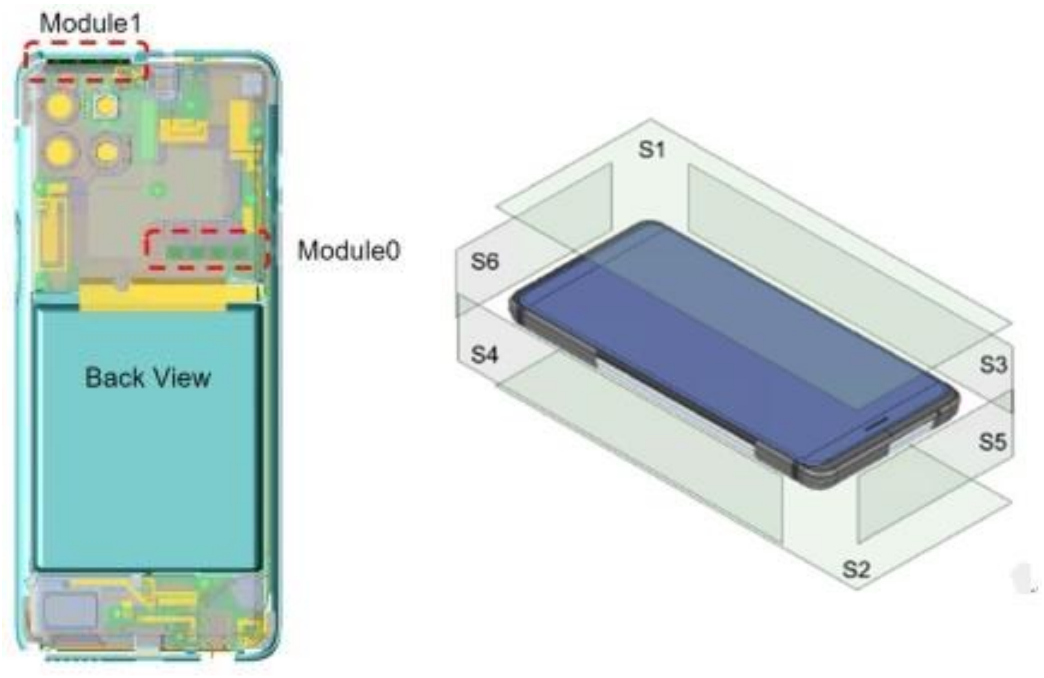
For this EUT, the PD design target and the uncertainty value are listed below

| | | | |
|---|---|---|---|
| N260 | PD design target | Antenna Module | $W/m^2$ |
| | | Antenna Module 0/1 | 3.8 |

| | | | |
|---|---|---|---|
| N261 | PD design target | Antenna Module | $W/m^2$ |
| | | Antenna Module 0/1 | 3.8 |

| Item | Uncertainty dB (k=2) |
|---|---|
| Total uncertainty | 2.1 |

## 4.4 Exposure positions for PD evaluation




Evaluation positions

| Antenna Module | Front | Back | Left From Front View | Right From Front View | Top | Bottom |
|---|---|---|---|---|---|---|
| | S1 | S2 | S3 | S4 | S5 | S6 |
| 0 | O | O | O | O | X | X |
| 1 | O | O | O | O | O | X |

Remark:

1. Referring to the PD simulation report for the reason of selecting surfaces/edges.
2. The exposure positions selection is based on the all edges and surfaces of the device with a transmitting antenna located within 25 mm from that surface or edge.

## 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 | modulation | Measured results Savg tot 4cm^2 (W/m2) | Simulated Pd (W/m^2), averaged over 4 cm2 | Delta=Sim-Meas(dB) |
|---|---|---|---|---|---|---|---|---|---|---|
| n260 | 0 | 29 | - | 38.5 | S2_Back | 2mm | CW | 7.62 | 13.7262 | 2.56 |
| n260 | 0 | - | 148 | 38.5 | S2_Back | 2mm | CW | 7.42 | 14.5027 | 2.91 |
| n260 | 1 | 24 | - | 38.5 | S2_Back | 2mm | CW | 7.34 | 10.9317 | 1.73 |
| n260 | 1 | - | 153 | 38.5 | S2_Back | 2mm | CW | 6.39 | 9.2674 | 1.61 |
| n260 | 1 | 15 | - | 38.5 | S5_Top Side | 2mm | CW | 8.35 | 15.4098 | 2.66 |
| n260 | 1 | - | 144 | 38.5 | S5_Top Side | 2mm | CW | 7.54 | 13.7039 | 2.59 |
| n261 | 0 | 19 | - | 27.925 | S2_Back | 2mm | CW | 8.49 | 18.9621 | 3.49 |
| n261 | 0 | - | 156 | 27.925 | S2_Back | 2mm | CW | 7.76 | 18.1223 | 3.68 |
| n261 | 1 | 15 | - | 27.925 | S2_Back | 2mm | CW | 3.59 | 11.789 | 5.16 |
| n261 | 1 | - | 152 | 27.925 | S2_Back | 2mm | CW | 3.49 | 11.7827 | 5.28 |
| n261 | 1 | 15 | - | 27.925 | S5_Top Side | 2mm | CW | 4.79 | 15.3997 | 5.07 |
| n261 | 1 | - | 152 | 27.925 | S5_Top Side | 2mm | CW | 4.88 | 14.9759 | 4.87 |

## 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:

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

### 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* $\emptyset$ and for a given channel, determine the worst-case $\emptyset_{worstcase}$ which results in the highest $t$otal $PD$ ($\emptyset$) among all identified surfaces for this beam pair at this channel. When $\emptyset_{worstcase}$ 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 $\emptyset_{worstcase}$ varies with channel and beam pair, the lowest scaling factor among all three channels, $s(i)$, is determined for the beam pair $i$:

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

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

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

### 4.6.3 Worst-case housing influence determination

Referring to the PD simulation report for PD simulation data for all beams . For non-metal material, the material property cannot be accurately characterized at mmW frequencies. The estimated material property for the device housing is used in the simulation model, which could impact 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.

Referring to the PD simulation report for PD simulation data for all beams, and the worst beams are selected to be tested Power density simulation for all

The mmW antenna modules are placed at different locations and only surrounding material/housing has impact on EM field propagation and in turn power density, and depending on the type of 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 procedure to determine worst-case housing influence, denoted as $\Delta_{\text{min}}$:

1. Based on PD simulation, determine one or more worst-surface(s) that contains all the highest 4cm$^2$-averaged PD for each of the 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 $\Delta_{min}$ based on identified worst surface(s) in Step 1, and then follow the procedures described in Section 4.6 to derive *input.power.limit* corresponding to *PD_design_target* for all the beams
    b. Then prove all other surface(s) near-by the mmW module, i.e., surface(s) not selected in Step 1, is not required for housing material loss quantification (in other words, these nonevaluated surfaces have no influence on the determined *input.power.limit*) by:
        i. Scale the simulated 4cm$^2$-averaged PD values for all single beams to correspond to their $sim.power_{limit}$, and identify the worst-PD beam per each non-selected surface.
        ii. Measure 4cm$^2$-averaged PD at *input.power.limit* for the identified worst-PD beam at each non-selected surface
        iii. Demonstrate all measured 4cm$^2$-averaged PD values are below *PD_design_target*.
3. If any of the above surface(s) in Step (2.b.iii) have measured 4cm$^2$-averaged PD ≥ *PD_design_target*, then those surfaces must be included in the $\Delta_{min}$ determination in Step (2.a), and follow the procedures in Section 4.6 to re-evaluate *input.power.limit* with these added surfaces.

Therefore, when comparing a simulated 4cm$^2$-avgeraged PD and measured 4cm$^2$-avgeraged PD for the above identified surfaces, the worst errors introduced when using the estimated material property in the simulation per module and per antenna type (worst out of both polarizations) is highlighted in bolded numbers in section 4.5. Thus, the worst-case housing influence, denoted as $\Delta_{min}$ (= minimum of (sim.PD – meas.PD) for the same antenna type of each module), is determined as:

| Band | Antenna Module | Polarization | Delta Min |
|---|---|---|---|
| N260 | 0 | AG0 | 2.56 |
| | | AG1 | 2.91 |
| | 1 | AG0 | 1.73 |
| | | AG1 | 1.61 |
| N261 | 0 | AG0 | 3.49 |
| | | AG1 | 3.68 |
| | 1 | AG0 | 5.07 |
| | | AG1 | 4.87 |

$\Delta_{min}$ represents the worst case where RF exposure is underestimated the most by simulation upon using the estimated material property for glass/plastics of the housing. For conservative assessment, the $\Delta_{min}$ is used as the worst case correction and applied to each corresponding beam group to determine power limits in PD char for compliance. To ensure that condition described in Step (2.b.iii) is met, apply the correct input.power.limit to derive the PD simulated results for all beams, and select the worst beams (yellow highlighted in the PD table) for each of non-selected applicable surface(s).

The PD test results for non-selected surfaces are less than PD_design_target, and meets condition in Step (2.b.iii), thus performing Step (3) is not needed

**Simulated 4cm$^2$-averaged PD at input.power.limit**

Determine the worst beam for each of non-selected surface(s)

| Band | Beam ID 1 | Beam ID 2 | Antenna Module | # of Antenna Feed Used | S1 | S2 | S3 | S4 | S5 | S6 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | front | back | left | right | top | bottom |
| n260 | 1 | | 0 | 1 | 0.02 | 3.80 | 0.26 | 0.29 | - | - |
| n260 | 5 | | 0 | 2 | 0.07 | 3.78 | 0.78 | 0.05 | - | - |
| n260 | 6 | | 0 | 2 | 0.11 | 3.80 | 1.07 | 0.09 | - | - |
| n260 | 7 | | 0 | 2 | 0.02 | 3.78 | 0.45 | 0.14 | - | - |
| n260 | 10 | | 0 | 2 | 0.05 | 3.65 | 0.57 | 0.07 | - | - |
| n260 | 11 | | 0 | 2 | 0.05 | 3.80 | 0.48 | 0.19 | - | - |
| n260 | 17 | | 0 | 4 | 0.04 | 3.63 | 0.76 | 0.16 | - | - |
| n260 | 18 | | 0 | 4 | 0.06 | 3.80 | 0.74 | 0.08 | - | - |
| n260 | 19 | | 0 | 4 | 0.08 | 3.80 | 0.76 | 0.29 | - | - |
| n260 | 20 | | 0 | 4 | 0.03 | 3.80 | 0.25 | 0.36 | - | - |
| n260 | 21 | | 0 | 4 | 0.02 | 3.62 | 1.10 | 0.10 | - | - |
| n260 | 26 | | 0 | 4 | 0.04 | 3.80 | 0.76 | 0.15 | - | - |
| n260 | 27 | | 0 | 4 | 0.12 | 3.80 | 1.04 | 0.10 | - | - |
| n260 | 28 | | 0 | 4 | 0.05 | 3.80 | 0.40 | 0.33 | - | - |
| n260 | 29 | | 0 | 4 | 0.03 | 3.78 | 0.61 | 0.15 | - | - |
| n260 | | 129 | 0 | 1 | 0.01 | 3.80 | 0.15 | 0.46 | - | - |
| n260 | | 133 | 0 | 2 | 0.07 | 3.80 | 0.40 | 0.12 | - | - |
| n260 | | 134 | 0 | 2 | 0.16 | 3.80 | 1.15 | 0.06 | - | - |
| n260 | | 135 | 0 | 2 | 0.02 | 3.45 | 0.46 | 0.11 | - | - |
| n260 | | 138 | 0 | 2 | 0.09 | 3.80 | 0.74 | 0.11 | - | - |
| n260 | | 139 | 0 | 2 | 0.08 | 3.65 | 0.68 | 0.07 | - | - |
| n260 | | 145 | 0 | 4 | 0.09 | 3.80 | 0.60 | 0.08 | - | - |
| n260 | | 146 | 0 | 4 | 0.06 | 3.80 | 0.46 | 0.70 | - | - |
| n260 | | 147 | 0 | 4 | 0.10 | 3.80 | 0.91 | 0.14 | - | - |
| n260 | | 148 | 0 | 4 | 0.08 | 3.80 | 0.65 | 0.08 | - | - |
| n260 | | 149 | 0 | 4 | 0.02 | 3.73 | 0.39 | 0.43 | - | - |
| n260 | | 154 | 0 | 4 | 0.05 | 3.80 | 0.31 | 0.29 | - | - |
| n260 | | 155 | 0 | 4 | 0.09 | 3.80 | 0.80 | 0.14 | - | - |
| n260 | | 156 | 0 | 4 | 0.07 | 3.80 | 0.54 | 0.07 | - | - |
| n260 | | 157 | 0 | 4 | 0.07 | 3.80 | 0.66 | 0.18 | - | - |

| Band | Beam ID 1 | Beam ID 2 | Antenna Module | # of Antenna Feed Used | S1 | S2 | S3 | S4 | S5 | S6 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | front | back | left | right | top | bottom |
| n260 | 0 | | 1 | 1 | 0.50 | 2.49 | 0.09 | 0.48 | 3.80 | - |
| n260 | 2 | | 1 | 2 | 0.94 | 1.85 | 0.10 | 0.77 | 3.80 | - |
| n260 | 3 | | 1 | 2 | 0.62 | 2.77 | 0.13 | 0.19 | 3.80 | - |
| n260 | 4 | | 1 | 2 | 0.57 | 2.42 | 0.04 | 0.54 | 3.80 | - |
| n260 | 8 | | 1 | 2 | 0.57 | 2.50 | 0.05 | 0.54 | 3.80 | - |
| n260 | 9 | | 1 | 2 | 0.71 | 2.27 | 0.10 | 0.70 | 3.80 | - |
| n260 | 12 | | 1 | 4 | 0.86 | 2.36 | 0.08 | 1.04 | 3.80 | - |
| n260 | 13 | | 1 | 4 | 0.75 | 2.96 | 0.10 | 0.70 | 3.80 | - |
| n260 | 14 | | 1 | 4 | 0.77 | 2.99 | 0.18 | 0.23 | 3.80 | - |
| n260 | 15 | | 1 | 4 | 0.63 | 2.66 | 0.06 | 1.06 | 3.80 | - |
| n260 | 16 | | 1 | 4 | 0.93 | 2.38 | 0.08 | 1.12 | 3.80 | - |
| n260 | 22 | | 1 | 4 | 0.79 | 2.12 | 0.06 | 1.00 | 3.80 | - |
| n260 | 23 | | 1 | 4 | 0.83 | 2.92 | 0.08 | 0.47 | 3.80 | - |
| n260 | 24 | | 1 | 4 | 0.65 | 2.87 | 0.14 | 0.51 | 3.80 | - |
| n260 | 25 | | 1 | 4 | 0.77 | 2.28 | 0.04 | 1.19 | 3.80 | - |
| n260 | | 128 | 1 | 1 | 0.66 | 2.61 | 0.08 | 0.81 | 3.45 | - |
| n260 | | 130 | 1 | 2 | 0.61 | 2.73 | 0.06 | 1.08 | 3.76 | - |
| n260 | | 131 | 1 | 2 | 0.99 | 2.73 | 0.10 | 0.41 | 3.71 | - |
| n260 | | 132 | 1 | 2 | 0.78 | 2.09 | 0.11 | 0.24 | 3.72 | - |
| n260 | | 136 | 1 | 2 | 0.82 | 2.06 | 0.13 | 0.46 | 3.74 | - |
| n260 | | 137 | 1 | 2 | 0.82 | 1.96 | 0.04 | 0.40 | 3.48 | - |
| n260 | | 140 | 1 | 4 | 1.01 | 2.28 | 0.05 | 1.14 | 3.41 | - |
| n260 | | 141 | 1 | 4 | 0.83 | 2.54 | 0.24 | 0.74 | 3.80 | - |
| n260 | | 142 | 1 | 4 | 0.80 | 2.80 | 0.16 | 0.34 | 3.68 | - |
| n260 | | 143 | 1 | 4 | 0.78 | 2.53 | 0.05 | 0.73 | 3.54 | - |
| n260 | | 144 | 1 | 4 | 0.79 | 2.39 | 0.25 | 0.67 | 3.80 | - |
| n260 | | 150 | 1 | 4 | 0.89 | 2.45 | 0.15 | 1.24 | 3.62 | - |
| n260 | | 151 | 1 | 4 | 0.85 | 2.52 | 0.21 | 0.31 | 3.80 | - |
| n260 | | 152 | 1 | 4 | 0.87 | 2.75 | 0.13 | 0.68 | 3.62 | - |
| n260 | | 153 | 1 | 4 | 0.61 | 2.76 | 0.15 | 0.91 | 3.80 | - |

| Band | Beam ID 1 | Beam ID 2 | Antenna Module | # of Antenna Feed Used | S1 | S2 | S3 | S4 | S5 | S6 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | front | back | left | right | - | - |
| n261 | 1 | | 0 | 1 | 0.02 | 3.61 | 0.41 | 0.09 | - | - |
| n261 | 5 | | 0 | 2 | 0.02 | 3.78 | 0.24 | 0.07 | - | - |
| n261 | 6 | | 0 | 2 | 0.00 | 3.74 | 0.25 | 0.01 | - | - |
| n261 | 7 | | 0 | 2 | 0.04 | 3.61 | 0.77 | 0.14 | - | - |
| n261 | 10 | | 0 | 2 | 0.01 | 3.78 | 0.12 | 0.04 | - | - |
| n261 | 11 | | 0 | 2 | 0.03 | 3.62 | 0.73 | 0.09 | - | - |
| n261 | 17 | | 0 | 4 | 0.05 | 3.80 | 0.47 | 0.12 | - | - |
| n261 | 18 | | 0 | 4 | 0.02 | 3.80 | 0.13 | 0.05 | - | - |
| n261 | 19 | | 0 | 4 | 0.01 | 3.80 | 0.12 | 0.02 | - | - |
| n261 | 20 | | 0 | 4 | 0.03 | 3.70 | 0.47 | 0.08 | - | - |
| n261 | 21 | | 0 | 4 | 0.02 | 3.66 | 0.82 | 0.12 | - | - |
| n261 | 26 | | 0 | 4 | 0.02 | 3.80 | 0.24 | 0.06 | - | - |
| n261 | 27 | | 0 | 4 | 0.01 | 3.80 | 0.10 | 0.04 | - | - |
| n261 | 28 | | 0 | 4 | 0.01 | 3.80 | 0.11 | 0.04 | - | - |
| n261 | 29 | | 0 | 4 | 0.02 | 3.68 | 0.67 | 0.10 | - | - |
| n261 | | 129 | 0 | 1 | 0.02 | 3.80 | 0.25 | 0.16 | - | - |
| n261 | | 133 | 0 | 2 | 0.02 | 3.51 | 0.59 | 0.07 | - | - |
| n261 | | 134 | 0 | 2 | 0.02 | 3.64 | 0.17 | 0.02 | - | - |
| n261 | | 135 | 0 | 2 | 0.02 | 3.71 | 0.35 | 0.20 | - | - |
| n261 | | 138 | 0 | 2 | 0.00 | 3.63 | 0.18 | 0.02 | - | - |
| n261 | | 139 | 0 | 2 | 0.03 | 3.61 | 0.25 | 0.02 | - | - |
| n261 | | 145 | 0 | 4 | 0.03 | 3.67 | 0.59 | 0.15 | - | - |
| n261 | | 146 | 0 | 4 | 0.00 | 3.80 | 0.14 | 0.03 | - | - |
| n261 | | 147 | 0 | 4 | 0.01 | 3.80 | 0.08 | 0.04 | - | - |
| n261 | | 148 | 0 | 4 | 0.02 | 3.67 | 0.15 | 0.04 | - | - |
| n261 | | 149 | 0 | 4 | 0.03 | 3.80 | 0.57 | 0.11 | - | - |
| n261 | | 154 | 0 | 4 | 0.01 | 3.80 | 0.28 | 0.03 | - | - |
| n261 | | 155 | 0 | 4 | 0.01 | 3.80 | 0.08 | 0.04 | - | - |
| n261 | | 156 | 0 | 4 | 0.00 | 3.75 | 0.07 | 0.03 | - | - |
| n261 | | 157 | 0 | 4 | 0.03 | 3.80 | 0.43 | 0.10 | - | - |

| Band | Beam ID 1 | Beam ID 2 | Antenna Module | # of Antenna Feed Used | S1 | S2 | S3 | S4 | S5 | S6 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | front | back | left | right | top | bottom |
| n261 | 0 | | 1 | 1 | 0.69 | 2.85 | 0.06 | 0.30 | 3.80 | - |
| n261 | 2 | | 1 | 2 | 0.77 | 2.71 | 0.14 | 0.46 | 3.78 | - |
| n261 | 3 | | 1 | 2 | 0.80 | 3.02 | 0.02 | 0.07 | 3.75 | - |
| n261 | 4 | | 1 | 2 | 0.66 | 2.94 | 0.12 | 0.55 | 3.80 | - |
| n261 | 8 | | 1 | 2 | 0.81 | 3.04 | 0.06 | 0.20 | 3.74 | - |
| n261 | 9 | | 1 | 2 | 0.74 | 3.06 | 0.07 | 0.42 | 3.80 | - |
| n261 | 12 | | 1 | 4 | 1.11 | 2.97 | 0.15 | 1.05 | 3.70 | - |
| n261 | 13 | | 1 | 4 | 1.20 | 2.91 | 0.05 | 0.30 | 3.65 | - |
| n261 | 14 | | 1 | 4 | 0.98 | 2.87 | 0.02 | 0.07 | 3.75 | - |
| n261 | 15 | | 1 | 4 | 1.00 | 2.88 | 0.04 | 0.40 | 3.76 | - |
| n261 | 16 | | 1 | 4 | 0.94 | 2.84 | 0.18 | 1.34 | 3.65 | - |
| n261 | 22 | | 1 | 4 | 1.25 | 3.07 | 0.12 | 0.77 | 3.74 | - |
| n261 | 23 | | 1 | 4 | 1.09 | 2.87 | 0.02 | 0.06 | 3.73 | - |
| n261 | 24 | | 1 | 4 | 0.98 | 2.86 | 0.02 | 0.08 | 3.76 | - |
| n261 | 25 | | 1 | 4 | 0.96 | 2.74 | 0.12 | 0.84 | 3.63 | - |
| n261 | | 128 | 1 | 1 | 0.69 | 2.83 | 0.07 | 0.39 | 3.79 | - |
| n261 | | 130 | 1 | 2 | 1.15 | 2.37 | 0.12 | 0.23 | 3.80 | - |
| n261 | | 131 | 1 | 2 | 0.99 | 2.58 | 0.04 | 0.13 | 3.60 | - |
| n261 | | 132 | 1 | 2 | 0.82 | 2.51 | 0.17 | 0.27 | 3.80 | - |
| n261 | | 136 | 1 | 2 | 1.11 | 2.63 | 0.06 | 0.17 | 3.68 | - |
| n261 | | 137 | 1 | 2 | 0.96 | 2.58 | 0.09 | 0.19 | 3.68 | - |
| n261 | | 140 | 1 | 4 | 1.33 | 3.33 | 0.28 | 1.26 | 3.80 | - |
| n261 | | 141 | 1 | 4 | 1.07 | 2.72 | 0.01 | 0.19 | 3.66 | - |
| n261 | | 142 | 1 | 4 | 0.95 | 2.91 | 0.02 | 0.09 | 3.76 | - |
| n261 | | 143 | 1 | 4 | 1.05 | 2.84 | 0.06 | 0.19 | 3.73 | - |
| n261 | | 144 | 1 | 4 | 0.95 | 2.94 | 0.22 | 0.59 | 3.80 | - |
| n261 | | 150 | 1 | 4 | 1.16 | 2.82 | 0.06 | 0.53 | 3.66 | - |
| n261 | | 151 | 1 | 4 | 1.03 | 2.72 | 0.02 | 0.14 | 3.69 | - |
| n261 | | 152 | 1 | 4 | 0.96 | 2.99 | 0.04 | 0.07 | 3.80 | - |
| n261 | | 153 | 1 | 4 | 1.08 | 2.84 | 0.11 | 0.38 | 3.78 | - |

### 4cm$^2$-averaged PD for the selected beams on non-selected surfaces for $\Delta_{min}$determination

| Band | antenna module | Beam ID 1 | Beam ID 2 | Frequency (GHz) | Exposure Surface | Test separation | modulation | Measured results Savg tot 4cm^2 (W/m2) |
|---|---|---|---|---|---|---|---|---|
| n260 | 0 | - | 134 | 38.5 | S1_Front | 2mm | CW | 0.327 |
| n260 | 0 | - | 146 | 38.5 | S3_Left | 2mm | CW | 0.371 |
| n260 | 0 | - | 134 | 38.5 | S4_Right | 2mm | CW | 0.139 |
| n260 | 1 | - | 140 | 38.5 | S1_Front | 2mm | CW | 0.264 |
| n260 | 1 | - | 144 | 38.5 | S3_Left | 2mm | CW | 0.129 |
| n260 | 1 | - | 150 | 38.5 | S4_Right | 2mm | CW | 1.1 |
| n261 | 0 | 17 | - | 27.925 | S1_Front | 2mm | CW | 0.435 |
| n261 | 0 | - | 135 | 27.925 | S3_Left | 2mm | CW | 0.509 |
| n261 | 0 | 21 | - | 27.925 | S4_Right | 2mm | CW | 0.09 |
| n261 | 1 | - | 140 | 27.925 | S1_Front | 2mm | CW | 0.993 |
| n261 | 1 | - | 140 | 27.925 | S3_Left | 2mm | CW | 0.249 |
| n261 | 1 | 16 | - | 27.925 | S4_Right | 2mm | CW | 1.04 |

## 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 (***$\Delta_{min}$***), *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 ***$\Delta_{min}$*** (= 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 ***$\Delta_{min}$*** 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 ***$\Delta_{min}$*** 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 Module | Polarization | $\Delta_{min}$ (dB) | TxAGC uncertainty (dB) | Input.power.limit (dBm) |
|---|---|---|---|---|---|
| n260 | 0 | AG0 | 2.56 | 0.5 | 6 +10* log(s(i))+2.06 |
| | | AG1 | 2.91 | 0.5 | 6 +10* log(s(i))+2.41 |
| | 1 | AG0 | 1.73 | 0.5 | 6 +10* log(s(i))+1.23 |
| | | AG1 | 1.61 | 0.5 | 6 +10* log(s(i))+1.11 |
| n261 | 0 | AG0 | 3.49 | 0.5 | 6 +10* log(s(i))+2.99 |
| | | AG1 | 3.68 | 0.5 | 6 +10* log(s(i))+3.18 |
| | 1 | AG0 | 5.07 | 0.5 | 6 +10* log(s(i))+4.57 |
| | | AG1 | 4.87 | 0.5 | 6 +10* log(s(i))+4.37 |

## 4.7.2 PD char Table

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

| Band | Beam ID 1 | Beam ID 2 | Antenna Module | # of Antenna Feed Used | Input power limit |
|---|---|---|---|---|---|
| n260 | 1 | | 0 | 1 | 8.45 |
| n260 | 5 | | 0 | 2 | 4.57 |
| n260 | 6 | | 0 | 2 | 5.51 |
| n260 | 7 | | 0 | 2 | 4.79 |
| n260 | 10 | | 0 | 2 | 4.91 |
| n260 | 11 | | 0 | 2 | 5.34 |
| n260 | 17 | | 0 | 4 | 2.57 |
| n260 | 18 | | 0 | 4 | 2.49 |
| n260 | 19 | | 0 | 4 | 3.41 |
| n260 | 20 | | 0 | 4 | 2.71 |
| n260 | 21 | | 0 | 4 | 2.32 |
| n260 | 26 | | 0 | 4 | 2.59 |
| n260 | 27 | | 0 | 4 | 2.98 |
| n260 | 28 | | 0 | 4 | 3.10 |
| n260 | 29 | | 0 | 4 | 2.46 |
| n260 | | 129 | 0 | 1 | 8.11 |
| n260 | | 133 | 0 | 2 | 4.98 |
| n260 | | 134 | 0 | 2 | 6.20 |
| n260 | | 135 | 0 | 2 | 5.28 |
| n260 | | 138 | 0 | 2 | 6.43 |
| n260 | | 139 | 0 | 2 | 5.44 |
| n260 | | 145 | 0 | 4 | 2.64 |
| n260 | | 146 | 0 | 4 | 4.12 |
| n260 | | 147 | 0 | 4 | 3.44 |
| n260 | | 148 | 0 | 4 | 2.59 |
| n260 | | 149 | 0 | 4 | 3.22 |
| n260 | | 154 | 0 | 4 | 3.19 |
| n260 | | 155 | 0 | 4 | 3.42 |
| n260 | | 156 | 0 | 4 | 2.78 |
| n260 | | 157 | 0 | 4 | 2.77 |
| 1 | 1 | 129 | 0 | 2 | 5.25 |
| 5 | 5 | 135 | 0 | 4 | 1.64 |
| 6 | 6 | 134 | 0 | 4 | 2.40 |
| 7 | 7 | 133 | 0 | 4 | 1.57 |
| 10 | 10 | 139 | 0 | 4 | 2.84 |
| 11 | 11 | 138 | 0 | 4 | 2.60 |
| 17 | 17 | 149 | 0 | 8 | -0.55 |
| 18 | 18 | 148 | 0 | 8 | -0.58 |
| 19 | 19 | 147 | 0 | 8 | -0.19 |
| 20 | 20 | 146 | 0 | 8 | -0.34 |
| 21 | 21 | 145 | 0 | 8 | -0.66 |
| 26 | 26 | 157 | 0 | 8 | -0.54 |
| 27 | 27 | 155 | 0 | 8 | 0.26 |
| 28 | 28 | 156 | 0 | 8 | -0.37 |
| 29 | 29 | 154 | 0 | 8 | -0.15 |

| Band | Beam ID 1 | Beam ID 2 | Antenna Module | # of Antenna Feed Used | Input power limit |
|---|---|---|---|---|---|
| n260 | 0 | | 1 | 1 | 6.21 |
| n260 | 2 | | 1 | 2 | 3.37 |
| n260 | 3 | | 1 | 2 | 4.24 |
| n260 | 4 | | 1 | 2 | 3.72 |
| n260 | 8 | | 1 | 2 | 3.82 |
| n260 | 9 | | 1 | 2 | 3.38 |
| n260 | 12 | | 1 | 4 | 1.15 |
| n260 | 13 | | 1 | 4 | 2.14 |
| n260 | 14 | | 1 | 4 | 1.66 |
| n260 | 15 | | 1 | 4 | 1.15 |
| n260 | 16 | | 1 | 4 | 1.92 |
| n260 | 22 | | 1 | 4 | 1.16 |
| n260 | 23 | | 1 | 4 | 1.80 |
| n260 | 24 | | 1 | 4 | 1.42 |
| n260 | 25 | | 1 | 4 | 1.30 |
| n260 | | 128 | 1 | 1 | 7.08 |
| n260 | | 130 | 1 | 2 | 4.19 |
| n260 | | 131 | 1 | 2 | 5.00 |
| n260 | | 132 | 1 | 2 | 4.01 |
| n260 | | 136 | 1 | 2 | 3.94 |
| n260 | | 137 | 1 | 2 | 4.42 |
| n260 | | 140 | 1 | 4 | 2.31 |
| n260 | | 141 | 1 | 4 | 1.75 |
| n260 | | 142 | 1 | 4 | 2.08 |
| n260 | | 143 | 1 | 4 | 2.08 |
| n260 | | 144 | 1 | 4 | 1.54 |
| n260 | | 150 | 1 | 4 | 2.10 |
| n260 | | 151 | 1 | 4 | 1.72 |
| n260 | | 152 | 1 | 4 | 2.19 |
| n260 | | 153 | 1 | 4 | 1.86 |
| n260 | 0 | 128 | 1 | 2 | 4.59 |
| n260 | 2 | 130 | 1 | 4 | 1.14 |
| n260 | 3 | 132 | 1 | 4 | 1.11 |
| n260 | 4 | 131 | 1 | 4 | 2.12 |
| n260 | 8 | 137 | 1 | 4 | 0.76 |
| n260 | 9 | 136 | 1 | 4 | 0.85 |
| n260 | 12 | 144 | 1 | 8 | -1.41 |
| n260 | 13 | 140 | 1 | 8 | -1.47 |
| n260 | 14 | 142 | 1 | 8 | -1.18 |
| n260 | 15 | 141 | 1 | 8 | -1.42 |
| n260 | 16 | 143 | 1 | 8 | -0.82 |
| n260 | 22 | 153 | 1 | 8 | -1.43 |
| n260 | 23 | 152 | 1 | 8 | -1.20 |
| n260 | 24 | 151 | 1 | 8 | -1.36 |
| n260 | 25 | 150 | 1 | 8 | -1.41 |

| Band | Beam ID 1 | Beam ID 2 | Antenna Module | # of Antenna Feed Used | Input power limit |
|---|---|---|---|---|---|
| n261 | 1 | | 0 | 1 | 8.14 |
| n261 | 5 | | 0 | 2 | 5.03 |
| n261 | 6 | | 0 | 2 | 4.65 |
| n261 | 7 | | 0 | 2 | 5.24 |
| n261 | 10 | | 0 | 2 | 4.79 |
| n261 | 11 | | 0 | 2 | 4.88 |
| n261 | 17 | | 0 | 4 | 3.05 |
| n261 | 18 | | 0 | 4 | 2.24 |
| n261 | 19 | | 0 | 4 | 2.01 |
| n261 | 20 | | 0 | 4 | 2.24 |
| n261 | 21 | | 0 | 4 | 2.38 |
| n261 | 26 | | 0 | 4 | 2.46 |
| n261 | 27 | | 0 | 4 | 2.11 |
| n261 | 28 | | 0 | 4 | 2.05 |
| n261 | 29 | | 0 | 4 | 2.32 |
| n261 | | 129 | 0 | 1 | 8.45 |
| n261 | | 133 | 0 | 2 | 5.94 |
| n261 | | 134 | 0 | 2 | 5.59 |
| n261 | | 135 | 0 | 2 | 5.55 |
| n261 | | 138 | 0 | 2 | 5.49 |
| n261 | | 139 | 0 | 2 | 5.76 |
| n261 | | 145 | 0 | 4 | 3.19 |
| n261 | | 146 | 0 | 4 | 2.69 |
| n261 | | 147 | 0 | 4 | 2.40 |
| n261 | | 148 | 0 | 4 | 2.33 |
| n261 | | 149 | 0 | 4 | 3.54 |
| n261 | | 154 | 0 | 4 | 2.73 |
| n261 | | 155 | 0 | 4 | 2.56 |
| n261 | | 156 | 0 | 4 | 2.34 |
| n261 | | 157 | 0 | 4 | 2.84 |
| n261 | 1 | 129 | 0 | 2 | 7.22 |
| n261 | 5 | 134 | 0 | 4 | 2.47 |
| n261 | 6 | 133 | 0 | 4 | 2.31 |
| n261 | 7 | 135 | 0 | 4 | 4.01 |
| n261 | 10 | 139 | 0 | 4 | 2.33 |
| n261 | 11 | 138 | 0 | 4 | 2.22 |
| n261 | 17 | 146 | 0 | 8 | -0.09 |
| n261 | 18 | 148 | 0 | 8 | -0.55 |
| n261 | 19 | 147 | 0 | 8 | -0.76 |
| n261 | 20 | 149 | 0 | 8 | 0.02 |
| n261 | 21 | 145 | 0 | 8 | -0.16 |
| n261 | 26 | 157 | 0 | 8 | -0.12 |
| n261 | 27 | 156 | 0 | 8 | -0.57 |
| n261 | 28 | 155 | 0 | 8 | -0.66 |
| n261 | 29 | 154 | 0 | 8 | -0.27 |

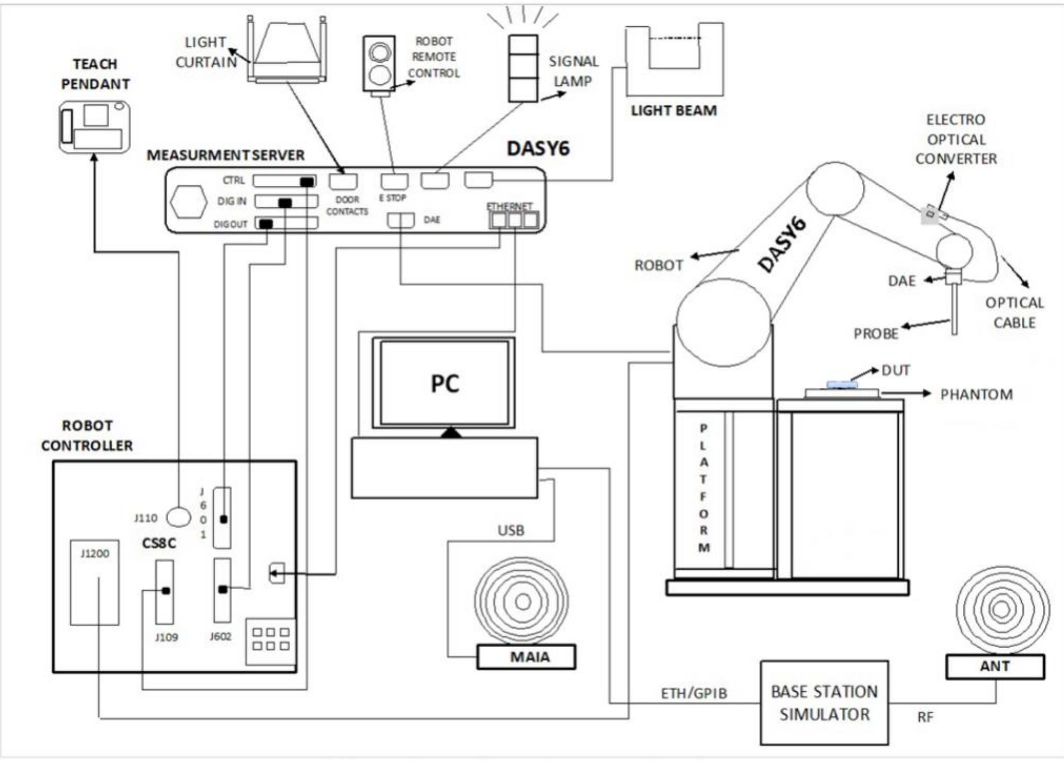
| Band | Beam ID 1 | Beam ID 2 | Antenna Module | # of Antenna Feed Used | Input power limit |
|---|---|---|---|---|---|
| n261 | 0 | | 1 | 1 | 10.20 |
| n261 | 2 | | 1 | 2 | 8.38 |
| n261 | 3 | | 1 | 2 | 7.18 |
| n261 | 4 | | 1 | 2 | 7.90 |
| n261 | 8 | | 1 | 2 | 7.52 |
| n261 | 9 | | 1 | 2 | 7.36 |
| n261 | 12 | | 1 | 4 | 6.79 |
| n261 | 13 | | 1 | 4 | 5.01 |
| n261 | 14 | | 1 | 4 | 4.61 |
| n261 | 15 | | 1 | 4 | 4.44 |
| n261 | 16 | | 1 | 4 | 5.37 |
| n261 | 22 | | 1 | 4 | 6.08 |
| n261 | 23 | | 1 | 4 | 4.65 |
| n261 | 24 | | 1 | 4 | 4.54 |
| n261 | 25 | | 1 | 4 | 4.63 |
| n261 | | 128 | 1 | 1 | 10.08 |
| n261 | | 130 | 1 | 2 | 8.32 |
| n261 | | 131 | 1 | 2 | 7.76 |
| n261 | | 132 | 1 | 2 | 8.50 |
| n261 | | 136 | 1 | 2 | 7.89 |
| n261 | | 137 | 1 | 2 | 8.00 |
| n261 | | 140 | 1 | 4 | 6.51 |
| n261 | | 141 | 1 | 4 | 4.44 |
| n261 | | 142 | 1 | 4 | 4.45 |
| n261 | | 143 | 1 | 4 | 4.44 |
| n261 | | 144 | 1 | 4 | 5.46 |
| n261 | | 150 | 1 | 4 | 4.76 |
| n261 | | 151 | 1 | 4 | 4.53 |
| n261 | | 152 | 1 | 4 | 4.41 |
| n261 | | 153 | 1 | 4 | 4.92 |
| n261 | 0 | 128 | 1 | 2 | 6.77 |
| n261 | 2 | 132 | 1 | 4 | 5.24 |
| n261 | 3 | 131 | 1 | 4 | 3.94 |
| n261 | 4 | 130 | 1 | 4 | 4.94 |
| n261 | 8 | 137 | 1 | 4 | 4.31 |
| n261 | 9 | 136 | 1 | 4 | 4.23 |
| n261 | 12 | 144 | 1 | 8 | 2.69 |
| n261 | 13 | 143 | 1 | 8 | 1.48 |
| n261 | 14 | 142 | 1 | 8 | 1.08 |
| n261 | 15 | 141 | 1 | 8 | 1.27 |
| n261 | 16 | 140 | 1 | 8 | 2.74 |
| n261 | 22 | 153 | 1 | 8 | 2.22 |
| n261 | 23 | 152 | 1 | 8 | 1.09 |
| n261 | 24 | 151 | 1 | 8 | 1.12 |
| n261 | 25 | 150 | 1 | 8 | 1.77 |

# 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 Test Side Location

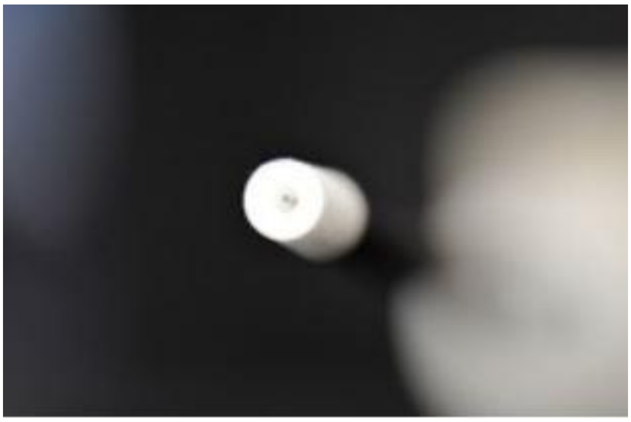
Sporton Lab and below test site location are accredited to ISO 17025 by Taiwan Accreditation Foundation (TAF code: 1190) and the FCC designation No. TW1190 under the FCC 2.948(e) by Mutual Recognition Agreement (MRA) in FCC test.

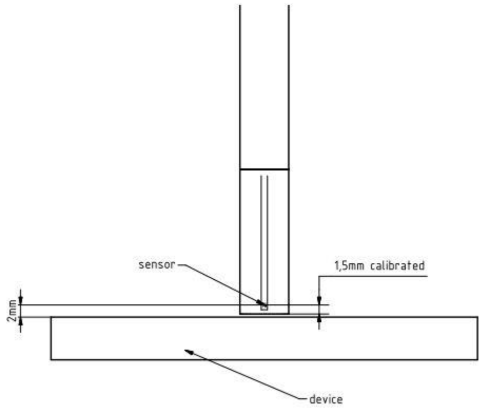
| | |
|---|---|
| Test Site | SPORTON INTERNATIONAL INC. EMC & Wireless Communications Laboratory |
| Test Site Location | TW1190<br>No. 52, Huaya 1st Rd., Guishan Dist.,<br>Taoyuan City 333,<br>CHINESE TAIPEI |
| Test Site No. | SAR06-HY |

## 5.3 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.

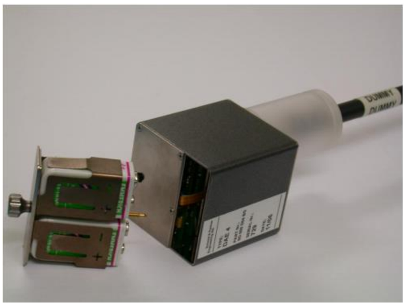
| | |
|---|---|
| **Frequency** | 750 MHz – 110 GHz |
| **Probe Overall Length** | 320 mm |
| **Probe Body Diameter** | 8.0 mm |
| **Tip Length** | 23.0 mm |
| **Tip Diameter** | 8.0 mm |
| **Probe's two dipoles length** | 0.9 mm – Diode loaded |
| **Dynamic Range** | < 20 V/m - 10000 V/m with PRE-10 (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)<br>Power density, H-field and far-field analysis using total field reconstruction. |
| **Compatibility** | cDASY6 + 5G-Module SW1.0 and higher |





### 5.4 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.

### 5.5 Scan configuration

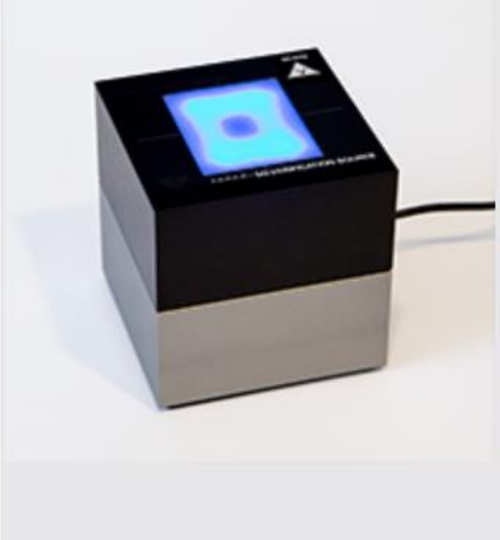
Fine-resolution scans on 2 different planes are performed to reconstruct the E- and H-fields as well as the power density; the z-distance between the 2 planes is set to λ/4.

The (x, y) grid step is also setλ/4, the grid extent is set to sufficiently large to identify the field pattern and the peak.

### 5.6 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 |

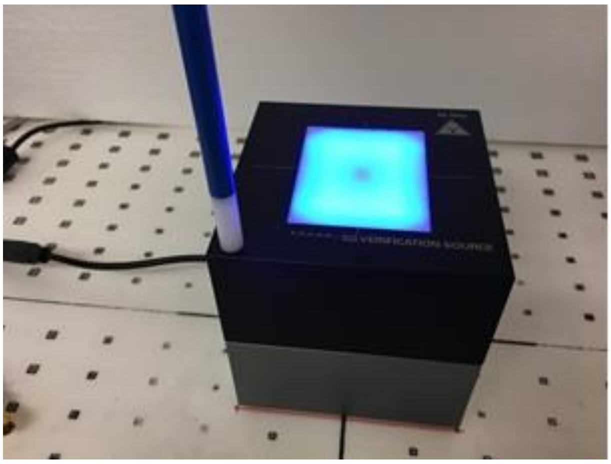


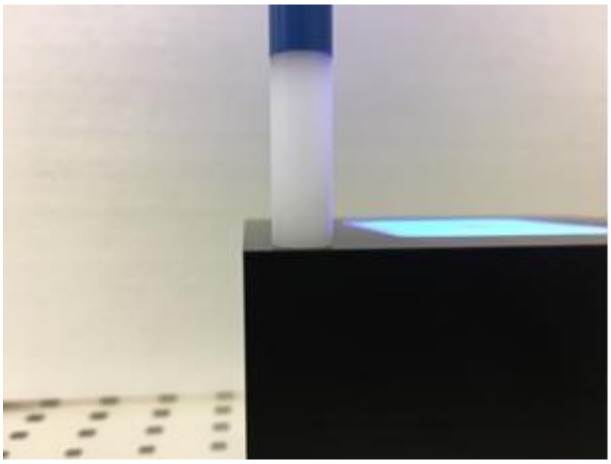
## 5.7 Power Density System Verification

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 | $16 \times 16$ |
| 30 | 0.25 ($\frac{\lambda}{4}$) | 60/60 | $24 \times 24$ |
| 60 | 0.25 ($\frac{\lambda}{4}$) | 32.5/32.5 | $26 \times 26$ |
| 90 | 0.25 ($\frac{\lambda}{4}$) | 30/30 | $36 \times 36$ |

**Settings for measurement of verification sources**





**Verification Setup photo**

## 5.8 System Verification Results

| System Verification | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 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 |
| 30 | 30GHz_1007 | 9461 | 1424 | 10 | 31.2 | 34.1 | -0.354 | 2020/6/4 |
| 30 | 30GHz_1007 | 9461 | 1424 | 10 | 32.1 | 34.1 | -0.248 | 2020/7/2 |
| 30 | 30GHz_1007 | 9461 | 1424 | 10 | 35.1 | 34.1 | 0.129 | 2020/8/3 |

# 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<br>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 | |