# Power Density Evaluation Report

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|---|---|
| **FCC ID** | **: IHDT56ZP1** |
| **Equipment** | **: Mobile Cellular Phone** |
| **Model Name** | **: XT2141-1** |
| **Applicant** | **: Motorola Mobility LLC<br>222 W,Merchandise Mart Plaza,<br>Chicago IL 60654 USA** |
| **Standard** | **: FCC 47 CFR Part 2 (2.1093)** |

**We, SPORTON INTERNATIONAL INC have been evaluated in accordance with 47 CFR Part 2.1093 for the device and pass the limit.**

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

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

***Sporton International Inc.***
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# Table of Contents

# History of this test report

| Report No. | Version | Description | Issued Date |
|---|---|---|---|
| FA151724-02B | 01 | Initial issue of report | Aug. 04, 2021 |
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# 1. Summary

The maximum measured average power density found during testing for Motorola Mobility LLC, Mobile Cellular Phone, are as follows.

| Standalone transmission | | | | Simultaneous transmission with other transmitters |
|---|---|---|---|---|
| RF Transmitter | | Measured PD (mW/cm$^2$) | Reported PD (mW/cm$^2$) | Summation of Exposure Ratio |
| 5G FR2 | n260 | 0.421 | 0.616 | 0.976 |
| | n261 | 0.476 | 0.616 | |
| Result | | PASS | | |

**Reviewed by: Jason Wang**
**Report Producer: Wan Liu**

# 2. Guidance Applied

The Power Density testing specification, method, and procedure for this device is in accordance with the following standards:

- FCC 47 CFR Part 2.1091
- FCC 47 CFR Part 2.1093
- FCC KDB 865664 D02 SAR Reporting v01r02
- FCC KDB 447498 D01 General RF Exposure Guidance v06
- FCC KDB 648474 D04 SAR Evaluation Considerations for Wireless Handsets v01r03
- TCBC workshop notes
- IEC Draft TR 63170

# 3. Equipment Under Test (EUT) Information

## 3.1 General Information

| Product Feature & Specification | |
|---|---|
| Equipment Name | Mobile Cellular Phone |
| FCC ID | IHDT56ZP1 |
| 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 48: 3550 MHz ~ 3700 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>5G NR n77 : 3450MHz ~ 3550MHz, 3700 MHz ~ 3980 MHz<br>5G NR n78 : 3450MHz ~ 3550MHz, 3700 MHz ~ 3800 MHz<br>5G NR n260 : 37 GHz~40 GHz<br>5G NR n261 : 27.5 GHz~28.35 GHz<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 5.5GHz Band: 5470 MHz ~ 5725 MHz<br>WLAN 5.8GHz Band: 5725 MHz ~ 5825 MHz<br>WLAN6E UNII 5: 5925 MHz ~ 6425 MHz<br>WLAN6E UNII 6: 6425 MHz ~ 6525 MHz<br>WLAN6E UNII 7: 6525 MHz ~ 6875 MHz<br>WLAN6E UNII 8: 6875 MHz ~ 7125 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/ax<br>HT20/HT40/VHT20/VHT40/VHT80/VHT160/HE20/HE40/HE80/HE160<br>Bluetooth BR/EDR/LE<br>NFC:ASK |

# 4. RF Exposure Limits

## 4.1 Uncontrolled Environment

Uncontrolled Environments are defined as locations where there is the exposure of individuals who have no knowledge or control of their exposure. The general population/uncontrolled exposure limits are applicable to situations in which the general public may be exposed or in which persons who are exposed as a consequence of their employment may not be made fully aware of the potential for exposure or cannot exercise control over their exposure. Members of the general public would come under this category when exposure is not employment-related; for example, in the case of a wireless transmitter that exposes persons in its vicinity.

## 4.2 Controlled Environment

Controlled Environments are defined as locations where there is exposure that may be incurred by persons who are aware of the potential for exposure, (i.e. as a result of employment or occupation). In general, occupational/controlled exposure limits are applicable to situations in which persons are exposed as a consequence of their employment, who have been made fully aware of the potential for exposure and can exercise control over their exposure. The exposure category is also applicable when the exposure is of a transient nature due to incidental passage through a location where the exposure levels may be higher than the general population/uncontrolled limits, but the exposed person is fully aware of the potential for exposure and can exercise control over his or her exposure by leaving the area or by some other appropriate means.

The criteria listed in Table 1 shall be used to evaluate the environmental impact of human exposure above 6GHz to radio frequency (RF) radiation as specified in §1.1310.

General Population Basic restriction for power density for frequencies between 1.5GHz and 100 GHz is 1.0 $mW/cm^2$ = 10 $W/m^2$

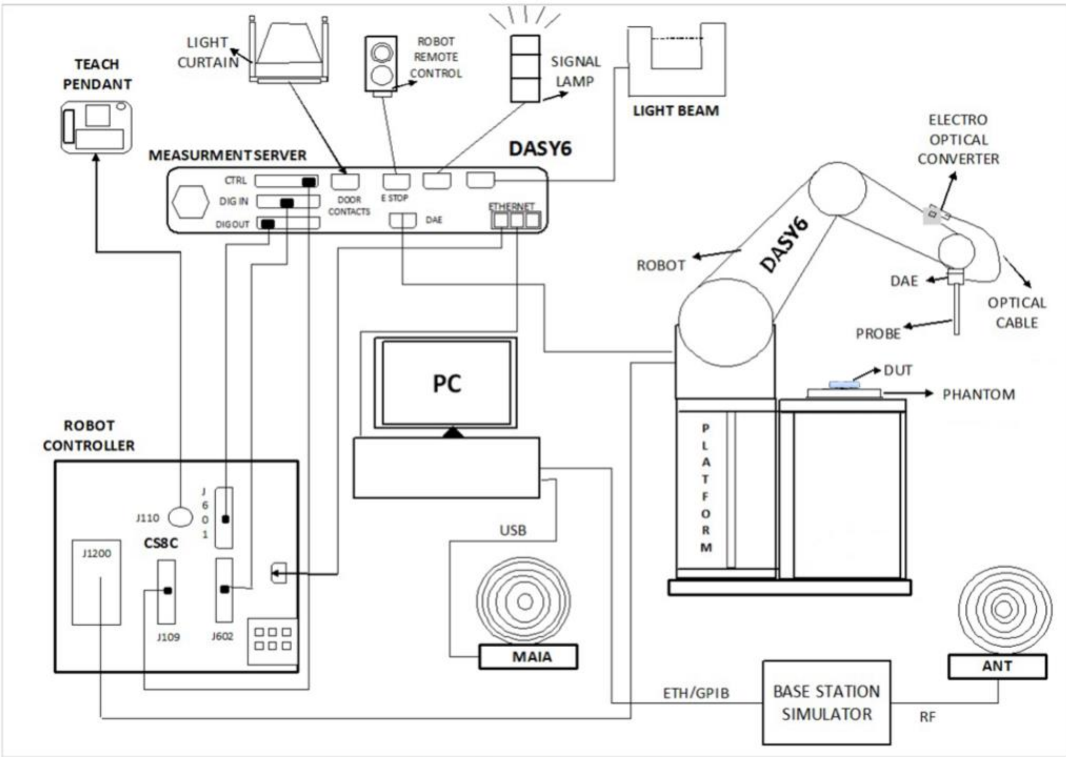
| Frequency range (MHz) | Electric field strength (V/m) | Magnetic field strength (A/m) | Power density ($mW/cm^2$) | Averaging time (minutes) |
|---|---|---|---|---|
| (A) Limits for Occupational/Controlled Exposures | | | | |
| 0.3-3.0 | 614 | 1.63 | *(100) | 6 |
| 3.0-30 | 1842/f | 4.89/f | *(900/f2) | 6 |
| 30-300 | 61.4 | 0.163 | 1.0 | 6 |
| 300-1500 | | | f/300 | 6 |
| 1500-100,000 | | | 5 | 6 |
| (B) Limits for General Population/Uncontrolled Exposure | | | | |
| 0.3-1.34 | 614 | 1.63 | *(100) | 30 |
| 1.34-30 | 824/f | 2.19/f | *(180/f2) | 30 |
| 30-300 | 27.5 | 0.073 | 0.2 | 30 |
| 300-1500 | | | f/1500 | 30 |
| 1500-100,000 | | | 1.0 | 30 |

Table 1

# 5. System Description and Setup

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

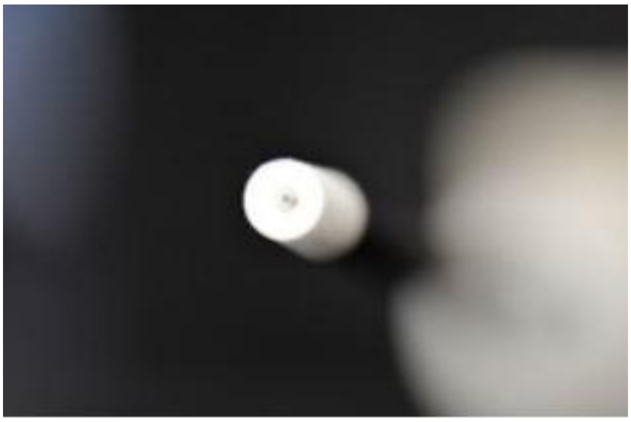
- SPEAG DASY6 system
- SPEAG cDASY6 5G module software
- EUmmWVx probe
- 5G Phantom cover

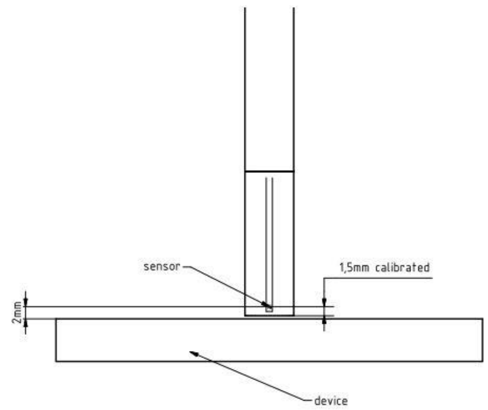


## 5.1 EUmmWave Probe / E-Field 5G Probe

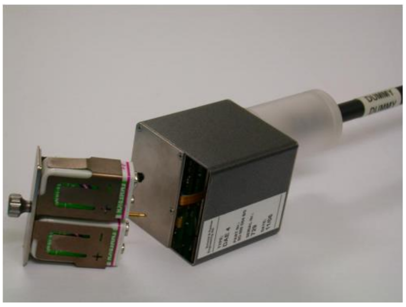
The probe design allows measurements at distances as small as 2 mm from the sensors to the surface of the device under test (DUT). The typical sensor to probe tip distance is 1.5 mm.

| | |
|---|---|
| **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 |





### 5.2 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.

### 5.3 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.

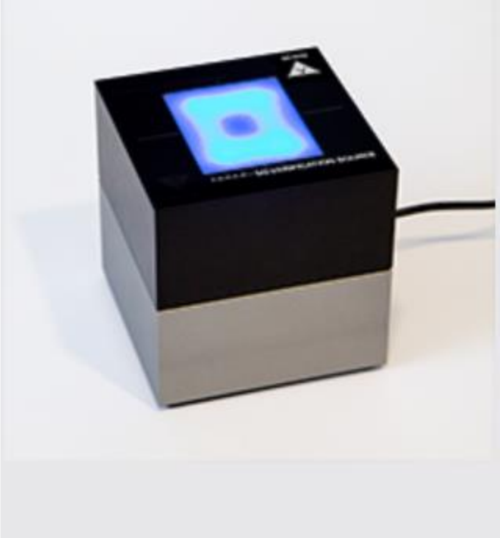
## 6. Test Equipment List

| Manufacturer | Name of Equipment | Type/Model | Serial Number | Calibration | |
|---|---|---|---|---|---|
| | | | | Last Cal. | Due Date |
| SPEAG | 5G Verification Source | 30GHz | 1009 | May. 25, 2021 | May. 24, 2022 |
| SPEAG | EUmmWV Probe Tip Protection | EUmmWV4 | 9441 | Nov. 24, 2020 | Nov. 23, 2021 |
| SPEAG | Data Acquisition Electronics | DAE4 | 656 | Jan. 22, 2021 | Jan. 21, 2022 |
| TESTO | Hygro meter | 608-H1 | 34893240 | Nov. 18, 2020 | Nov. 17, 2021 |
| Aglient | Spectrum Analyzer | E4408B | MY44211028 | Aug. 27, 2020 | Aug. 26, 2021 |
| Custom Microwave | Standard Horn antenna | M15RH | V91113-A | NCR | NCR |

# 7. 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 |



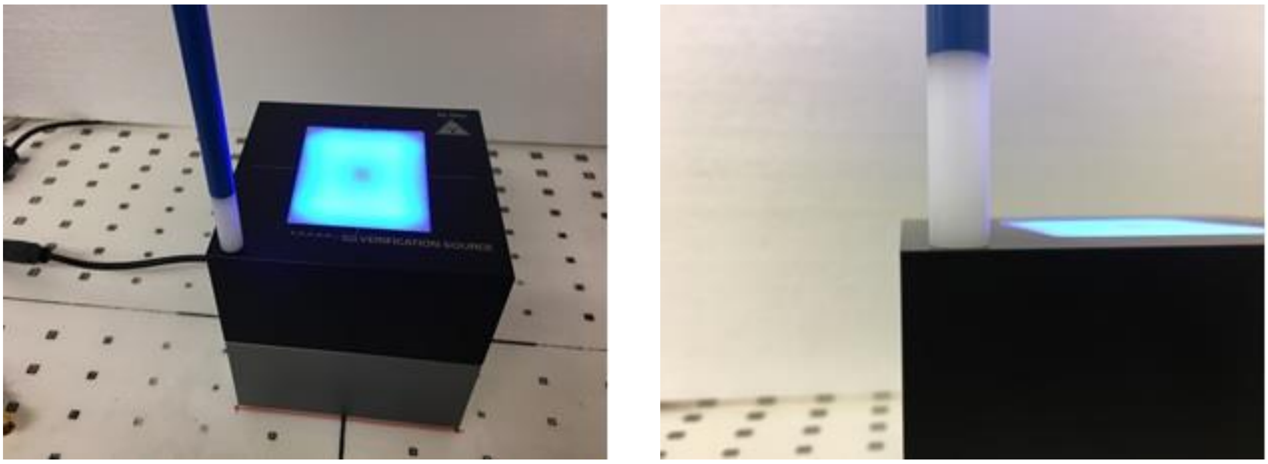
# 8. Power Density System Verification

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 0.66dB 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**

# 9. 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 | Test Site |
|---|---|---|---|---|---|---|---|---|---|
| 30G | 30GHz_1009 | 9441 | 656 | 10 | 26.5 | 29.5 | -0.47 | 2021/6/24 | SAR06-HY |
| 30G | 30GHz_1009 | 9441 | 656 | 10 | 26.7 | 29.5 | -0.43 | 2021/7/2 | SAR06-HY |

## 9.1 Computation of the Electric Field Polarization Ellipse

For the numerical description of an arbitrarily oriented ellipse in three-dimensional space, five parameters are needed: the semi-major axis (a), the semi-minor axis (b), two angles describing the orientation of the normal vector of the ellipse (ø, θ), and one angle describing the tilt of the semi-major axis (ψ). For the two extreme cases, i.e., circular and linear polarizations, three parameters only (a, ø and θ) are sufficient for the description of the incident field.

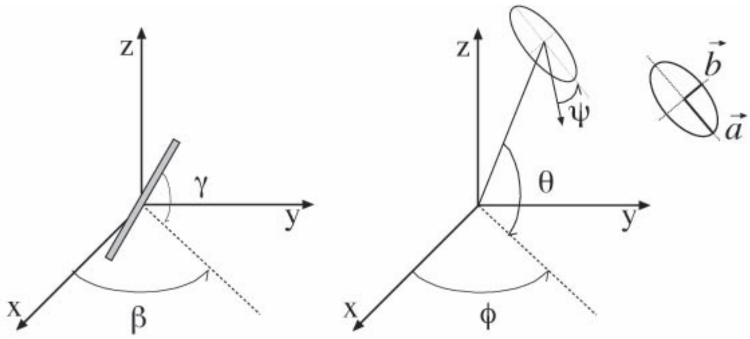



Illustration of the angles used for the numerical description of the sensor and the orientation of an ellipse in 3-D space.

For the reconstruction of the ellipse parameters from measured data, the problem can be reformulated as a nonlinear search problem. The semi-major and semi-minor axes of an elliptical field can be expressed as functions of the three angles (ø, θ and ψ). The parameters can be uniquely determined towards minimizing the error based on least-squares for the given set of angles and the measured data. In this way, the number of free parameters is reduced from five to three, which means that at least three sensor readings are necessary to gain sufficient information for the reconstruction of the ellipse parameters. However, to suppress the noise and increase the reconstruction accuracy, it is desirable that the system of equations be over determined. The solution to use a probe consisting of two sensors angled by $r_1$ and $r_2$ toward the probe axis and to perform measurements at three angular positions of the probe, i.e., at $\beta_1$, $\beta_2$ and $\beta_3$, results in over-determinations by a factor of two. If there is a need for more information or increased accuracy, more rotation angles can be added. The reconstruction of the ellipse parameters can be separated into linear and non-linear parts that are best solved by the Givens algorithm combined with a downhill simplex algorithm. To minimize the mutual coupling, sensor angles are set with a shift of 90 degree ($r_2 = r_1 + 90$ degree), and to simplify, the first rotation angle of the probe ($\beta_1$) can be set to 0 degree.

## 9.2 Total Field and Power Flux Density Reconstruction

Computation of the power density in general requires knowledge of the electric and magnetic field amplitudes and phases in the plane of incidence. Reconstruction of these quantities from pseudo-vector E-field measurements is feasible, as they are constrained by Maxwell's equations. SPEAG have developed a reconstruction approach based on the Gerchberg-Saxton algorithm, which benefits from the availability of the E-field polarization ellipse information obtained with the EUmmWV2 probe.
The average of the reconstructed power density is evaluated over a circular area in each measurement plane. Two average power density values can be computed, the average total power density and the average incident power density, and the average total power density is used to determine compliance.

- $|Re\{S\}|$ is the total Poynting vector
- $\mathrm{n} \cdot Re\{S\}$ is the normal Poything vector

The software post-processing reports to values, “S avg tot” and “S avg inc”. “S avg tot” represents average total power density (all three xyz components included), and “S avg inc” represents average normal power density. The average total power density “S avg tot” is reported to determine the device compliance.

## 9.3 Test Positions

| Band | Antenna Module | Measurement Plane | | | | | |
|---|---|---|---|---|---|---|---|
| | | Front 2mm | Back 2mm | Left Side 2mm | Right Side 2mm | Top Side 2mm | Bottom Side 2mm |
| 5G NR Band 260 | 0 | No | Yes | No | No | No | No |
| | 1 | No | Yes | No | No | Yes | No |
| 5G NR Band 261 | 0 | No | Yes | No | No | No | No |
| | 1 | No | Yes | No | No | Yes | No |

From the Part 0 and simulation report, beam IDs with highest PD and corresponding input power limit were selected to be tested for each antenna module and for each frequency band.

# 10. RF Exposure Evaluation Results

1. The PD test was performed of a 2mm separation between sensor and EUT surface (the probe tip is 0.5mm to the EUT surface), 2 mm separation distance PD testing is for hotspot and body worn exposure conditions.
2. According to TCBC Workshop in October 2018, 4 cm^2 averaging area are used.
3. This device is enabled with Qualcomm® Smart Transmit feature, smart transmit will manage and ensure LTE and 5G simultaneous transmission is compliant. The validation of the time-averaging algorithm and compliance under the Tx varying transmission scenario for WWAN technologies are reported in Part 2 report.
4. Input power limit parameter for 5G mmW NR radio was calculated in RF Exposure Part 0 test report.
5. The device was configured to transmit CW wave signal for testing, due to Qualcomm® Smart Transmit feature, additional testing was not required for different modulations (CP-OFDM QPSK, CP-OFDM 16QAM, CP-OFDM 64QAM), RB configurations, component carriers, channel configurations (low channel, mid channel, high channel).
6. Power density measurements were performed with DUT transmitting at input.power.limit for one single beam for each polarization (H & V) and one beam-pair, for each antenna type and for each antenna module (0,1) on the worst-surfaces.
7. The Beam ID with one of the highest initial simulated power density for that surface and distance was selected for Part 1 Power Density measurements.
8. Some Power Density Evaluations were performed at a more conservative power level.
9. It's illustrated in Part 0 report that , for 5G mmW NR since there is total design-related uncertainty arising from TxAGC and device-to-device variation, the worst-case RF exposure should be determined by accounting for this device uncertainty of 2.1 dB, as well as PD design target of 3.8W/m2. Therefore, 5G mmW NR RF exposure for this DUT is evaluated by reported PD calculated as:

   Reported PD=PD design target + 2.1 dB =6.16 W/cm2 = 0.616 mW/cm^2

| Test Number | Band | Antenna Module | Beam ID 1 | Beam ID 2 | Frequency (GHz) | Exposure Surface | Test Separation | Input Power limit | Modulation | Epeak [V/m] | Hpeak [A/m] | Measured results Savg inc 4cm^2 (W/m2) | Measured results Savg tot 4cm^2 (W/m2) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n260 | Module 0 | 20 | - | 38.5 | Back (S2) | 2mm | 2.25 | CW | 79.7 | 0.173 | 3.35 | 3.83 |
| | n260 | Module 0 | - | 157 | 37 | Back (S2) | 2mm | 3.54 | CW | 69.5 | 0.223 | 2.83 | 3.65 |
| | n260 | Module 0 | 30 | 158 | 37 | Back (S2) | 2mm | -2.71 | CW | 43.1 | 0.122 | 0.862 | 1.03 |
| | n260 | Module 1 | 27 | - | 40 | Back (S2) | 2mm | 3.1 | CW | 37.2 | 0.121 | 1.23 | 1.4 |
| | n260 | Module 1 | - | 154 | 38.5 | Back (S2) | 2mm | 1.17 | CW | 37.2 | 0.105 | 1.49 | 1.74 |
| | n260 | Module 1 | 17 | 145 | 38.5 | Back (S2) | 2mm | -2.37 | CW | 35.1 | 0.092 | 1.21 | 1.4 |
| 01 | n260 | Module 1 | 15 | - | 38.5 | Top (S5) | 2mm | 2.75 | CW | 93.1 | 0.226 | 3.45 | 4.21 |
| | n260 | Module 1 | - | 145 | 37 | Top (S5) | 2mm | 1.01 | CW | 63.8 | 0.173 | 2.21 | 2.72 |
| | n260 | Module 1 | 27 | 155 | 40 | Top (S5) | 2mm | -2.46 | CW | 67.3 | 0.184 | 1.86 | 2.25 |
| | n260 | Module 0 | 24 | - | 40 | Back (S2) | 2mm | 2.75 | CW | 88.6 | 0.195 | 2.76 | 3.17 |
| | n260 | Module 0 | 3 | - | 38.5 | Back (S2) | 2mm | 8.35 | CW | 76.1 | 0.202 | 2.78 | 3.35 |
| | n261 | Module 0 | 27 | - | 27.5 | Back (S2) | 2mm | 1.69 | CW | 58.9 | 0.177 | 3.08 | 3.68 |
| | n261 | Module 0 | - | 153 | 27.5 | Back (S2) | 2mm | 2.49 | CW | 60.6 | 0.164 | 3.04 | 3.61 |
| | n261 | Module 0 | 19 | 147 | 27.5 | Back (S2) | 2mm | -2.72 | CW | 36.1 | 0.105 | 1.08 | 1.25 |
| | n261 | Module 1 | 23 | - | 27.5 | Back (S2) | 2mm | 3.14 | CW | 45.6 | 0.097 | 1.37 | 1.81 |
| | n261 | Module 1 | - | 142 | 27.5 | Back (S2) | 2mm | 3.59 | CW | 54.1 | 0.138 | 3.12 | 3.2 |
| | n261 | Module 1 | 15 | 153 | 27.5 | Back (S2) | 2mm | -1.6 | CW | 36 | 0.082 | 1.07 | 1.24 |
| | n261 | Module 1 | 23 | - | 27.5 | Top (S5) | 2mm | 3.14 | CW | 69.5 | 0.188 | 3.44 | 4.14 |
| 02 | n261 | Module 1 | - | 142 | 27.5 | Top (S5) | 2mm | 3.59 | CW | 79.1 | 0.19 | 4.18 | 4.76 |
| | n261 | Module 1 | 23 | 151 | 27.5 | Top (S5) | 2mm | -1.66 | CW | 57.4 | 0.148 | 2.06 | 2.54 |
| | n261 | Module 1 | 15 | - | 27.5 | Top (S5) | 2mm | 3.82 | CW | 65.2 | 0.19 | 3.32 | 3.88 |
| | n261 | Module 1 | 0 | - | 27.5 | Top (S5) | 2mm | 9.27 | CW | 78.3 | 0.218 | 2.8 | 3.35 |

# 11. 5G NR + LTE + WLAN + BT Sim-Tx analysis

In 5G NR + LTE + WLAN + BT simultaneous transmission, 5G NR and LTE transmission are managed and controlled by Qualcomm® Smart Transmit, while the RF exposure from WLAN and BT radios is managed using legacy approach, i.e., through a fixed power back-off if needed.

Since WLAN and BT do not employ time-averaging, 1gSAR and 10gSAR measurement for WLAN and BT need to be conducted at their corresponding rated power following current FCC test procedures to determine reported SAR values.

Smart Transmit current implementation assumes hotspots from 5G NR and LTE are collocated. Therefore, for a total of 100% exposure margin, if LTE uses x%, then the exposure margin left for 5G NR is capped to (100-x)%. Thus, the compliance equation for LTE + 5G NR is

$$x\% * A + (100-x)\% * B \leq 1.0,$$

Where, A is normalized reported time-averaged SAR exposure ratio from LTE, and $A \leq 1.0$; B is normalized reported time-averaged exposure ratio from 5G NR (i.e., PD exposure for mmW NR or SAR exposure for sub6 NR), and $B \leq 1.0$.

Let C = normalized reported SAR exposure ratio from WLAN+BT, then for compliance,

$$x\% * A + (100-x)\% * B + C \leq 1.0 \qquad (1)$$

$$x\% * A + (100-x)\% * B \leq x\% * \max(A, B) + (100-x)\% * \max(A, B) \leq \max(A, B)$$

$$x\% * A + (100-x)\% * B + C \leq \max(A, B) + C \leq 1.0 \qquad (2)$$

if $A + C \leq 1.0$ and $B + C \leq 1.0$ can be proven, then "$x\% * A + (100-x)\% * B + C \leq 1.0$". Therefore simultaneous transmission analysis for 5G NR + LTE + WLAN + BT can be performed in two steps

Step 1: Prove total exposure ratio (TER) of LTE + WLAN + BT < 1
Step 2: Prove total exposure ratio (TER) of 5G NR + WLAN + BT < 1

Else, if $A + C > 1.0$ and/or $B + C > 1.0$, then the followings need to hold true for compliance:

i. A and C are decoupled based on the SPLSR criteria , and
ii. $(100-x)\% * B + C \leq 1.0$, and
iii. $x\% * A + (100-x)\% * B \leq 1.0$

Note iii. is covered in Part 2 report; i. and ii. should be addressed in Part 2 report.

Step 1: it's justified in Part 1 SAR report (Sporton report number FA151701-02, rev.01)
Step 2: it's justified in section 12.1

During TER analysis, the ***reported*** **time-averaged PD** (assuming *input.power.limit* for at least one beam < NV setting *Pmax*) applies only to the worst-surface of the device. For other surfaces, worst-case PD needs to be calculated to assess TER for the corresponding surface. To determine worst-case PD for other surfaces, using simulation results

1. Calculate ratio of simulated PD for desired surface to simulated PD of worstsurface for a given beam

2. Repeat 1 to obtain ratios for all supported beams, and determine maximum ratio

3. Repeat 1~2 to obtain the corresponding worst-case PD for rest of surfaces (non worst-case surfaces) needed for TER analysis.

For example, if the back surface of device has highest PD and is determined as worst-surface, then,

- *Back_surface_worst-case_PD* = ***reported*** **time-averaged PD**
  where, ***reported*** **time-averaged PD** = *PD_design_target* + mmW device design related uncertainty

- *For other surfaces*
  - *front_surface_worst-case_PD = PD_ratio_front_to_back* * ***reported*** **timeaveraged PD**
    where, PD_ratio_front_to_back =*max* $\left\{\frac{simulated\ PD_{front(i)}}{simulated\ P\_back(i)}, beam\ i = 1,2 \ldots N\right\}$,N= total N beams (all beams) supported by the mmW module being evaluated being evaluated.

  - *Follow similar approach to determine worst-case PD for bottom/top/left/right (if applicable).*

- *For body-worn and hotspot scenario, if SAR was measured at 15mm and 10mm, respectively, then the worst-case PD at 15mm and 10mm separation distance should be determined per surface as*
  - *15mm_worst-case_PD = PD_ratio_15mm_to_0mm* * ***reported*** **timeaveraged PD**
    Here, PD_ratio_15 mm _to_0mm =*max* $\left\{\frac{simulated\ Pd\ at\ 15\ mm\ (i)}{simulated\ PD\ at\ 0\ mm\ (i)}, beam\ i = 1,2 \ldots N\right\}$, , N = total number of beams (**all** beams) supported by the mmW module being evaluated.

  - *10mm_worst-case_PD = PD_ratio_10mm_to_0mm* * ***reported*** **timeaveraged PD**
    Here, PD_ratio_15 mm _to_0mm =*max* $\left\{\frac{simulated\ Pd\ at\ 10\ mm\ (i)}{simulated\ PD\ at\ 0\ mm\ (i)}, beam\ i = 1,2 \ldots N\right\}$, , N = total number of beams (**all** beams) supported by the mmW module being evaluated.

  - Note the validated model/simulation should be used in worst-case PD determination.

# 12. Simultaneous-Tx analysis

| NO. | Simultaneous Transmission Configurations | Exposure Positions | | |
|---|---|---|---|---|
| | | Head | Hotspot | Body-worn |
| 1. | WiFi 5G SISO (Ant 3) + Bluetooth (Ant 4) + n260/n261 | Yes | Yes | Yes |
| 2. | WiFi 5G SISO (Ant 4) + Bluetooth (Ant 4) + n260/n261 | Yes | Yes | Yes |
| 3. | WiFi 5G MIMO (Ant 3+4) + Bluetooth (Ant 4) + n260/n261 | Yes | Yes | Yes |
| 4. | WiFi 5G SISO (Ant 3) + n260/n261 | Yes | Yes | Yes |
| 5. | WiFi 5G SISO (Ant 4) + n260/n261 | Yes | Yes | Yes |
| 6. | WiFi 5G MIMO (Ant 3+4) + n260/n261 | Yes | Yes | Yes |
| 7. | WiFi 2.4G SISO (Ant 3) + n260/n261 | Yes | Yes | Yes |
| 8. | WiFi 2.4G SISO (Ant 4) + n260/n261 | Yes | Yes | Yes |
| 9. | WiFi 2.4G MIMO (Ant 3+4) + n260/n261 | Yes | Yes | Yes |
| 10. | Bluetooth (Ant 4) + n260/n261 | Yes | Yes | Yes |
| 11. | WiFi 2.4G SISO (Ant 4) + WiFi 5G SISO (Ant 3) + n260/n261 | Yes | Yes | Yes |

**General Note:**

1. The WLAN and Bluetooth SAR test results were referring the report of FCC ID: IHDT56ZP1 (Sporton SAR Report No. FA151701-02).
2. Considering n260/n261 transmitter with WLAN and Bluetooth can transmit simultaneously, the basic restrictions are on SAR and power density, and summation of these quantities should follow below formula and the simultaneous transmission analysis was following below step.
   i) Use the standalone SAR according original report to collocate with n260/n261 transmitter power density at each exposure positions, if the result < 1, additional analysis is not necessary.

The [∑ of (the highest measured or estimated SAR for each standalone antenna configuration, adjusted for maximum tune-up tolerance) / 1.6 W/kg] + [∑ of MPE ratios] is ≤ 1.0.

3. This device is enabled with Qualcomm® Smart Transmit feature to control and manage transmitting power in real time and to ensure that the time-averaged RF exposure from WWAN is in compliance with FCC requirements. Since the device enabled with Qualcomm® Smart Transmit feature, 4G LTE and 5G mmW NR simultaneous transmission scenario does not need to be evaluated under Total Exposure Ratio (TER). The validation of the time-averaging algorithm and compliance under the Tx varying transmission scenario for WWAN technologies are reported in Part 2 report.
4. For 5G mmW NR, compute reported time-averaged PD = PD_design_target * 10(mmW device design uncertainty in dB)/10 and use this computed reported time-averaged PD in total exposure ratio (TER) analysis.

## 12.1 Simultaneous transmission analysis for WiFi/BT + 5G NR

## <Head Exposure Condition>

| PD Band | Exposure Position | 5 | 8 | 9 | 10 | 11 | Reported SAR/1.6 + PD/10 Summation | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2.4GHz WLAN Ant 2+4 | 5GHz WLAN Ant 4+12 | Bluetooth Ant 2 | WLAN6GHz Ant 4+12 | PD | 5+11 | 8+11 | 8+9+11 | 10+11 | 9+10+11 |
| | | 1g SAR (W/kg) | 1g SAR (W/kg) | 1g SAR (W/kg) | 1g SAR (W/kg) | 4cm^2(W/m^2) | Summed | Summed | Summed | Summed | Summed |
| n260_Module 0 | Right Cheek | 0.328 | 0.321 | 0.255 | 0.022 | 6.160 | **0.821** | **0.817** | **0.976** | **0.630** | **0.789** |
| | Right Tilted | 0.176 | 0.348 | 0.183 | 0.033 | 6.160 | **0.726** | **0.834** | **0.948** | **0.637** | **0.751** |
| | Left Cheek | 0.130 | 0.197 | 0.139 | 0.015 | 6.160 | **0.697** | **0.739** | **0.826** | **0.625** | **0.712** |
| | Left Tilted | 0.108 | 0.208 | 0.118 | 0.012 | 6.160 | **0.684** | **0.746** | **0.820** | **0.624** | **0.697** |
| n260_Module 1 | Right Cheek | 0.328 | 0.321 | 0.255 | 0.022 | 6.160 | **0.821** | **0.817** | **0.976** | **0.630** | **0.789** |
| | Right Tilted | 0.176 | 0.348 | 0.183 | 0.033 | 6.160 | **0.726** | **0.834** | **0.948** | **0.637** | **0.751** |
| | Left Cheek | 0.130 | 0.197 | 0.139 | 0.015 | 6.160 | **0.697** | **0.739** | **0.826** | **0.625** | **0.712** |
| | Left Tilted | 0.108 | 0.208 | 0.118 | 0.012 | 6.160 | **0.684** | **0.746** | **0.820** | **0.624** | **0.697** |
| n261_Module 0 | Right Cheek | 0.328 | 0.321 | 0.255 | 0.022 | 6.160 | **0.821** | **0.817** | **0.976** | **0.630** | **0.789** |
| | Right Tilted | 0.176 | 0.348 | 0.183 | 0.033 | 6.160 | **0.726** | **0.834** | **0.948** | **0.637** | **0.751** |
| | Left Cheek | 0.130 | 0.197 | 0.139 | 0.015 | 6.160 | **0.697** | **0.739** | **0.826** | **0.625** | **0.712** |
| | Left Tilted | 0.108 | 0.208 | 0.118 | 0.012 | 6.160 | **0.684** | **0.746** | **0.820** | **0.624** | **0.697** |
| n261_Module 1 | Right Cheek | 0.328 | 0.321 | 0.255 | 0.022 | 6.160 | **0.821** | **0.817** | **0.976** | **0.630** | **0.789** |
| | Right Tilted | 0.176 | 0.348 | 0.183 | 0.033 | 6.160 | **0.726** | **0.834** | **0.948** | **0.637** | **0.751** |
| | Left Cheek | 0.130 | 0.197 | 0.139 | 0.015 | 6.160 | **0.697** | **0.739** | **0.826** | **0.625** | **0.712** |
| | Left Tilted | 0.108 | 0.208 | 0.118 | 0.012 | 6.160 | **0.684** | **0.746** | **0.820** | **0.624** | **0.697** |

## <Hotspot Exposure Condition>

| PD Band | Exposure Position | 5 | 8 | 9 | 10 | 11 | Reported SAR/1.6 + PD/10 Summation | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2.4GHz WLAN Ant 2+4 | 5GHz WLAN Ant 4+12 | Bluetooth Ant 2 | WLAN6GHz Ant 4+12 | PD | 1+2+3+8 Summed | 1+4+5+8 Summed | 1+6+8 Summed | 1+2+7+8 Summed | 1+4+7+8 Summed |
| | | 1g SAR (W/kg) | 1g SAR (W/kg) | 1g SAR (W/kg) | 1g SAR (W/kg) | 4cm^2(W/m^2) | | | | | |
| n260_Module 0 | Front | 0.091 | 0.071 | 0.120 | | 6.160 | **0.673** | **0.660** | **0.735** | **0.616** | **0.691** |
| | Back | 0.397 | 0.342 | 0.133 | | 6.160 | **0.864** | **0.830** | **0.913** | **0.616** | **0.699** |
| | Left side | 0.017 | 0.040 | 0.017 | | 6.160 | **0.627** | **0.641** | **0.652** | **0.616** | **0.627** |
| | Right side | | 0.020 | 0.017 | | 6.160 | **0.616** | **0.629** | **0.639** | **0.616** | **0.627** |
| | Top side | 0.110 | 0.133 | 0.017 | | 6.160 | **0.685** | **0.699** | **0.710** | **0.616** | **0.627** |
| | Bottom side | | | | | | **0.000** | **0.000** | **0.000** | **0.000** | **0.000** |
| n260_Module 1 | Front | 0.091 | 0.071 | 0.120 | | 6.160 | **0.673** | **0.660** | **0.735** | **0.616** | **0.691** |
| | Back | 0.397 | 0.342 | 0.133 | | 6.160 | **0.864** | **0.830** | **0.913** | **0.616** | **0.699** |
| | Left side | 0.017 | 0.040 | 0.017 | | 6.160 | **0.627** | **0.641** | **0.652** | **0.616** | **0.627** |
| | Right side | | 0.020 | 0.017 | | 6.160 | **0.616** | **0.629** | **0.639** | **0.616** | **0.627** |
| | Top side | 0.110 | 0.133 | 0.017 | | 6.160 | **0.685** | **0.699** | **0.710** | **0.616** | **0.627** |
| | Bottom side | | | | | | **0.000** | **0.000** | **0.000** | **0.000** | **0.000** |
| n261_Module 0 | Front | 0.091 | 0.071 | 0.120 | | 6.160 | **0.673** | **0.660** | **0.735** | **0.616** | **0.691** |
| | Back | 0.397 | 0.342 | 0.133 | | 6.160 | **0.864** | **0.830** | **0.913** | **0.616** | **0.699** |
| | Left side | 0.017 | 0.040 | 0.017 | | 6.160 | **0.627** | **0.641** | **0.652** | **0.616** | **0.627** |
| | Right side | | 0.020 | 0.017 | | 6.160 | **0.616** | **0.629** | **0.639** | **0.616** | **0.627** |
| | Top side | 0.110 | 0.133 | 0.017 | | 6.160 | **0.685** | **0.699** | **0.710** | **0.616** | **0.627** |
| | Bottom side | | | | | | **0.000** | **0.000** | **0.000** | **0.000** | **0.000** |
| n261_Module 1 | Front | 0.091 | 0.071 | 0.120 | | 6.160 | **0.673** | **0.660** | **0.735** | **0.616** | **0.691** |
| | Back | 0.397 | 0.342 | 0.133 | | 6.160 | **0.864** | **0.830** | **0.913** | **0.616** | **0.699** |
| | Left side | 0.017 | 0.040 | 0.017 | | 6.160 | **0.627** | **0.641** | **0.652** | **0.616** | **0.627** |
| | Right side | | 0.020 | 0.017 | | 6.160 | **0.616** | **0.629** | **0.639** | **0.616** | **0.627** |
| | Top side | 0.110 | 0.133 | 0.017 | | 6.160 | **0.685** | **0.699** | **0.710** | **0.616** | **0.627** |
| | Bottom side | | | | | | **0.000** | **0.000** | **0.000** | **0.000** | **0.000** |

## <Body-Worn Exposure Condition>

| PD Band | Exposure Position | 5 | 8 | 9 | 10 | 11 | Reported SAR/1.6 + PD/10 Summation | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2.4GHz WLAN Ant 2+4 | 5GHz WLAN Ant 4+12 | Bluetooth Ant 2 | WLAN6GHz Ant 4+12 | PD | 1+2+3+8 Summed | 1+4+5+8 Summed | 1+6+8 Summed | 1+2+7+8 Summed | 1+4+7+8 Summed |
| | | 1g SAR (W/kg) | 1g SAR (W/kg) | 1g SAR (W/kg) | 1g SAR (W/kg) | 4cm^2(W/m^2) | | | | | |
| n260_Module 0 | Front | 0.091 | 0.093 | 0.120 | 0.011 | 6.160 | **0.673** | **0.674** | **0.749** | **0.623** | **0.698** |
| | Back | 0.397 | 0.397 | 0.133 | 0.388 | 6.160 | **0.864** | **0.864** | **0.947** | **0.859** | **0.942** |
| n260_Module 1 | Front | 0.091 | 0.093 | 0.120 | 0.011 | 6.160 | **0.673** | **0.674** | **0.749** | **0.623** | **0.698** |
| | Back | 0.397 | 0.397 | 0.133 | 0.388 | 6.160 | **0.864** | **0.864** | **0.947** | **0.859** | **0.942** |
| n261_Module 0 | Front | 0.091 | 0.093 | 0.120 | 0.011 | 6.160 | **0.673** | **0.674** | **0.749** | **0.623** | **0.698** |
| | Back | 0.397 | 0.397 | 0.133 | 0.388 | 6.160 | **0.864** | **0.864** | **0.947** | **0.859** | **0.942** |
| n261_Module 1 | Front | 0.091 | 0.093 | 0.120 | 0.011 | 6.160 | **0.673** | **0.674** | **0.749** | **0.623** | **0.698** |
| | Back | 0.397 | 0.397 | 0.133 | 0.388 | 6.160 | **0.864** | **0.864** | **0.947** | **0.859** | **0.942** |

## <Product Specific Exposure Condition>

| PD Band | Exposure Position | 5 | 8 | 10 | 11 | Reported SAR/1.6 + PD/10 Summation | | |
|---|---|---|---|---|---|---|---|---|
| | | 2.4GHz WLAN Ant 2+4 | 5GHz WLAN Ant 4+12 | WLAN6GHz Ant 4+12 | PD | 5+11 | 8+11 | 10+11 |
| | | 1g SAR (W/kg) | 1g SAR (W/kg) | 1g SAR (W/kg) | 4cm^2(W/m^2) | Summed | Summed | Summed |
| n260_Module 0 | Front | | 0.228 | 0.013 | 6.160 | **0.616** | **0.673** | **0.619** |
| | Back | 1.250 | 1.274 | 0.300 | 6.160 | **0.929** | **0.935** | **0.691** |
| | Left side | | 0.183 | 0.081 | 6.160 | **0.616** | **0.662** | **0.636** |
| | Right side | | 0.055 | | 6.160 | **0.616** | **0.630** | **0.616** |
| | Top side | | 0.380 | 0.066 | 6.160 | **0.616** | **0.711** | **0.633** |
| | Bottom side | | | | 6.160 | **0.616** | **0.616** | **0.616** |
| n260_Module 1 | Front | | 0.228 | 0.013 | 6.160 | **0.616** | **0.673** | **0.619** |
| | Back | 1.250 | 1.274 | 0.300 | 6.160 | **0.929** | **0.935** | **0.691** |
| | Left side | | 0.183 | 0.081 | 6.160 | **0.616** | **0.662** | **0.636** |
| | Right side | | 0.055 | | 6.160 | **0.616** | **0.630** | **0.616** |
| | Top side | | 0.380 | 0.066 | 6.160 | **0.616** | **0.711** | **0.633** |
| | Bottom side | | | | 6.160 | **0.616** | **0.616** | **0.616** |
| n261_Module 0 | Front | | 0.228 | 0.013 | 6.160 | **0.616** | **0.673** | **0.619** |
| | Back | 1.250 | 1.274 | 0.300 | 6.160 | **0.929** | **0.935** | **0.691** |
| | Left side | | 0.183 | 0.081 | 6.160 | **0.616** | **0.662** | **0.636** |
| | Right side | | 0.055 | | 6.160 | **0.616** | **0.630** | **0.616** |
| | Top side | | 0.380 | 0.066 | 6.160 | **0.616** | **0.711** | **0.633** |
| | Bottom side | | | | 6.160 | **0.616** | **0.616** | **0.616** |
| n261_Module 1 | Front | | 0.228 | 0.013 | 6.160 | **0.616** | **0.673** | **0.619** |
| | Back | 1.250 | 1.274 | 0.300 | 6.160 | **0.929** | **0.935** | **0.691** |
| | Left side | | 0.183 | 0.081 | 6.160 | **0.616** | **0.662** | **0.636** |
| | Right side | | 0.055 | | 6.160 | **0.616** | **0.630** | **0.616** |
| | Top side | | 0.380 | 0.066 | 6.160 | **0.616** | **0.711** | **0.633** |
| | Bottom side | | | | 6.160 | **0.616** | **0.616** | **0.616** |

**Test Engineer：**Steven Chang

# 13. 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 | |

# 14. References

[1] FCC 47 CFR Part 2 "Frequency Allocations and Radio Treaty Matters; General Rules and Regulations"

[2] FCC KDB 447498 D01 v06, "Mobile and Portable Device RF Exposure Procedures and Equipment Authorization Policies", Oct 2015

[3] FCC KDB 865664 D02 v01r02, "RF Exposure Compliance Reporting and Documentation Considerations" Oct 2015.

[4] FCC KDB 648474 D04 v01r03, "SAR Evaluation Considerations for Wireless Handsets", Oct 2015.