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# PART 2 RF EXPOSURE EVALUATION REPORT

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**Date of Testing:**
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**Test Site/Location:**
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| | |
|---|---|
| **FCC ID:** | **A3LSMS928U** |
| **APPLICANT:** | **SAMSUNG ELECTRONICS CO., LTD.** |

| | |
|---|---|
| **DUT Type:** | Portable Handset |
| **Application Type:** | Certification |
| **FCC Rule Part(s):** | CFR §2.1093 |
| **Model(s):** | SM-S928U, SM-S928U1 |
| **Device Serial Numbers:** | Pre-Production Samples [0402M, 1410M, 1413M, 0410M] |

Note: This revised test report supersedes and replaces the previously issued test report on the same subject device for the same type of testing as indicated. Please discard or destroy the previously issued test report(s) and dispose of it accordingly.

I attest to the accuracy of data. All measurements reported herein were performed by me or were made under my supervision and are correct to the best of my knowledge and belief. I assume full responsibility for the completeness of these measurements and vouch for the qualifications of all persons taking them. Test results reported herein relate only to the item(s) tested.

RJ Ortanez
Executive Vice President

ACCREDITED
CERT #2041.01

# T A B L E   O F   C O N T E N T S

# 1 DEVICE UNDER TEST

## 1.1 Device Overview

| Band & Mode | Operating Modes | Tx Frequency |
|---|---|---|
| GSM/GPRS/EDGE 850 | Voice/Data | 824.20 - 848.80 MHz |
| GSM/GPRS/EDGE1900 | Voice/Data | 1850.20 - 1909.80 MHz |
| UMTS 850 | Voice/Data | 826.40 - 846.60 MHz |
| UMTS 1750 | Voice/Data | 1712.4 - 1752.6 MHz |
| UMTS 1900 | Voice/Data | 1852.4 - 1907.6 MHz |
| LTE Band 71 | Voice/Data | 665.5 - 695.5 MHz |
| LTE Band 12 | Voice/Data | 699.7 - 715.3 MHz |
| LTE Band 13 | Voice/Data | 779.5 - 784.5 MHz |
| LTE Band 14 | Voice/Data | 790.5 - 795.5 MHz |
| LTE Band 26 | Voice/Data | 814.7 - 848.3 MHz |
| LTE Band 5 | Voice/Data | 824.7 - 848.3 MHz |
| LTE Band 66 | Voice/Data | 1710.7 - 1779.3 MHz |
| LTE Band 4 | Voice/Data | 1710.7 - 1754.3 MHz |
| LTE Band 25 | Voice/Data | 1850.7 - 1914.3 MHz |
| LTE Band 2 | Voice/Data | 1850.7 - 1909.3 MHz |
| LTE Band 30 | Voice/Data | 2307.5 - 2312.5 MHz |
| LTE Band 7 | Voice/Data | 2502.5 - 2567.5 MHz |
| LTE Band 41 | Voice/Data | 2498.5 - 2687.5 MHz |
| LTE Band 38 | Voice/Data | 2572.5 - 2617.5 MHz |
| LTE Band 48 | Voice/Data | 3552.5 - 3697.5 MHz |
| NR Band n71 | Voice/Data | 665.5 - 695.5 MHz |
| NR Band n12 | Voice/Data | 701.5 - 713.5 MHz |
| NR Band n26 | Voice/Data | 816.5 - 846.5 MHz |
| NR Band n5 | Voice/Data | 826.5 - 846.5 MHz |
| NR Band n70 | Voice/Data | 1697.5 - 1707.5 MHz |
| NR Band n66 | Voice/Data | 1712.5 - 1777.5 MHz |
| NR Band n25 | Voice/Data | 1852.5 - 1912.5 MHz |
| NR Band n2 | Voice/Data | 1852.5 - 1907.5 MHz |
| NR Band n30 | Voice/Data | 2307.5 - 2312.5 MHz |
| NR Band n7 | Voice/Data | 2502.5 - 2567.5 MHz |
| NR Band n41 | Voice/Data | 2501.01 - 2685 MHz |
| NR Band n38 | Voice/Data | 2575 - 2615 MHz |
| NR Band n48 | Voice/Data | 3555 - 3694.98 MHz |
| NR Band n77 | Voice/Data | 3455.01 - 3544.98 MHz;<br>3705 - 3975 MHz |
| NR Band n258 | Data | 24250 - 24450 MHz;<br>24750 - 25250 MHz |
| NR Band n260 | Data | 37000 - 40000 MHz |
| NR Band n261 | Data | 27500 - 28350 MHz |
| 2.4 GHz WIFI | Voice/Data | 2412 - 2462 MHz |
| U-NII-1 | Voice/Data | 5180 - 5240 MHz |
| U-NII-2A | Voice/Data | 5260 - 5320 MHz |
| U-NII-2C | Voice/Data | 5500 - 5720 MHz |
| U-NII-3 | Voice/Data | 5745 - 5825 MHz |
| U-NII-4 | Voice/Data | 5845 - 5885 MHz |
| U-NII-5 | Voice/Data | 5935 - 6415 MHz |
| U-NII-6 | Voice/Data | 6435 - 6515 MHz |
| U-NII-7 | Voice/Data | 6535 - 6875 MHz |
| U-NII-8 | Voice/Data | 6895 - 7115 MHz |
| 2.4 GHz Bluetooth | Data | 2402 - 2480 MHz |
| NFC | Data | 13.56 MHz |
| UWB | Data | 6489.6 - 7987.2 MHz |

## 1.2 Time-Averaging Algorithm for RF Exposure Compliance

This device is enabled with Qualcomm® Smart Transmit feature. This feature performs time averaging algorithm in real time to control and manage transmitting power and ensure the time-averaged RF exposure is in compliance with FCC requirements all the time. DUT contains embedded file system (EFS) version 21 configured for the second generation (GEN2) for Sub6, mmWave, and WLAN/BT.

The Smart Transmit algorithm maintains the time-averaged transmit power, in turn, time-averaged RF exposure of SAR_design_target or PD_design_target, below the predefined time-averaged power limit (i.e., Plimit for sub-6 radio, and input.power.limit for 5G mmW NR), for each characterized technology and band.

Smart Transmit allows the device to transmit at higher power instantaneously, as high as $P_{max}$, when needed, but enforces power limiting to maintain time-averaged transmit power to $P_{limit}$ for frequencies < 6 GHz and *input.power.limit* for frequencies > 6 GHz.

Note that the device uncertainty for sub-6GHz WWAN is 1.0 dB for this DUT, the device uncertainty for WLAN is 1.0 dB, the device uncertainty for mmW is 2.0 dB.

The following input parameters are key parameters that are required for functionality of the Smart Transmit feature. These parameters cannot be accessed by the end user, because at the factory they are entered through the embedded file system (EFS) entries by the OEM.

- *WLAN_BT_control: ON/OFF switch. ONLY applicable for Smart Transmit EFS version 19 (or higher)*

  The EFS version 19 (or higher) provides the entry to manage Qualcomm WLAN/BT chipsets under Smart Transmit control. When selected 'ON', Smart Transmit will manage time-averaged RF exposure from all WWAN/WLAN/BT radios. If selected "OFF", then WLAN and BT are the radios outside of Smart Transmit control.

- *Tx_power_at_SAR_design_target (Plimit in dBm) for Tx transmitting frequency < 6 GHz*

  The maximum time-average transmit power, in dBm, at which this radio configuration (i.e., band and technology) reaches the *SAR_design_target*. This *SAR_design_target* is pre-determined for the specific device and it shall be less than regulatory SAR limit after accounting for all design related tolerances. The time-averaged SAR is assessed against this *SAR_design_target* in real time to determine the compliance. The Plimit could vary with technology, band, antenna and DSI (device state index), therefore it has the unique value for each technology, band, antenna and DSI.

The reserve margin for WWAN radios can be configured for each sub6 antenna group, and each exposure category as shown below:

For a given exposure category (head vs. non-head) and antenna group, OEM can configure:

- *TOTAL_MIN_RES_RATIO*

  This entry corresponds to the minimum reserve margin for WWAN radio or WLAN radio when operating in standalone mode per antenna group. Here, *TOTAL_MIN_RES_RATIO* is in linear units ranging between [0 1].

- *WWAN_PRI_SPLIT_RATIO*, *WWAN_SEC_SPLIT_RATIO*

In multi-Tx scenarios in the same antenna group, minimum reserve for each active radio (i.e., WWAN primary radio, WWAN secondary radio, WLAN radio) is a product of the corresponding fraction out of sum of active radio split ratios and *TOTAL_MIN_RES_RATIO*.

In case of WWAN primary, WWAN secondary, and WLAN simultaneous transmission in the same antenna group, the minimum reserve for each radio, respectively, are:

- *TOTAL_MIN_RES_RATIO* * {*WWAN_PRI_SPLIT_RATIO* / (*WWAN_PRI_SPLIT_RATIO+WWAN_SEC_SPLIT_RATIO+WLAN_SPLIT_RATIO*)}
- *TOTAL_MIN_RES_RATIO* * {*WWAN_SEC_SPLIT_RATIO* / (*WWAN_PRI_SPLIT_RATIO+WWAN_SEC_SPLIT_RATIO+ WLAN_SPLIT_RATIO*)}
- *TOTAL_MIN_RES_RATIO* * {*WLAN_SPLIT_RATIO* / (*WWAN_PRI_SPLIT_RATIO+WWAN_SEC_SPLIT_RATIO+ WLAN_SPLIT_RATIO*)}

In case of WWAN primary and WLAN secondary simultaneous transmission in the same antenna group, the minimum reserve for each radio, respectively, are:

- *TOTAL_MIN_RES_RATIO* * {*WWAN_PRI_SPLIT_RATIO* / (*WWAN_PRI_SPLIT_RATIO+WLAN_SEC_SPLIT_RATIO*)}
- *TOTAL_MIN_RES_RATIO* * {*WLAN_SEC_SPLIT_RATIO* / (*WWAN_PRI_SPLIT_RATIO+WLAN_SEC_SPLIT_RATIO*)}

In case of WWAN primary, and WWAN secondary simultaneous transmission in the same antenna group, the minimum reserve for each radio, respectively, are:

- *TOTAL_MIN_RES_RATIO * {WWAN_PRI_SPLIT_RATIO / (WWAN_PRI_SPLIT_RATIO+WWAN_SEC_SPLIT_RATIO)}*
- *TOTAL_MIN_RES_RATIO * {WWAN_SEC_SPLIT_RATIO / (WWAN_PRI_SPLIT_RATIO+WWAN_SEC_SPLIT_RATIO)}*

Here, *WWAN_PRI_SPLIT_RATIO*, *WWAN_SEC_SPLIT_RATIO* and *WLAN_SPLIT_RATIO* are in linear units ranging between [0 1].

- *WLAN_MARGIN_IN_MODEM_APM*

  When WWAN modem is turned off (say, in airplane mode – APM), then the RF exposure budget is split between WLAN and BT radios, where WLAN RF exposure budget is WLAN_MARGIN_IN_MODEM_APM and BT exposure budget is (1 - WLAN_MARGIN_IN_MODEM_APM). Here, WLAN_MARGIN_IN_MODEM_APM is in linear units ranging between [0 1].

- *BT (Bluetooth) Config*

  *BT_STANDALONE*: desired BT transmit power = (*BT_STANDALONE* * $P_{limit}$) in BT single radio transmission condition, where $P_{limit}$ is BT *Tx_power_at_SAR_design_target* in mW.

  *BT_AND_1_RADIO_SAME_AG*: reduced BT transmit power = (*BT_AND_1_RADIO_SAME_AG* * $P_{limit}$) in a two-radio transmission condition. Here, two radios (BT+WLAN or BT+WWAN) are in the same AG.

*BT_AND_2+_RADIO_SAME_AG*: further reduced BT transmit power = (*BT_AND_2+_RADIO_SAME_AG* * $P_{limit}$) in a three (or more)-radio transmission condition. Here, all radios, i.e., BT with 2 or more other radios (WWAN primary, WWAN secondary, WLAN), are in the same AG.

*BT_STANDALONE*, *BT_AND_1_RADIO_SAME_AG* and *BT_AND_2+_RADIO_SAME_AG* are in linear units ranging between [0 1].

**NOTE:** For BT, $P_{max}$ allocated by Smart Transmit ≤ $P_{limit}$. In other words, BT allowed maximum power will be at one of the above 3 levels relative to $P_{limit}$ depending on transmission scenarios as described above.

The equivalent reserve of *Reserve_power_margin* for $P_{reserve}$ calculation in v19 (or higher) EFS if WLAN/BT radios are under Smart Transmit control is (*TOTAL_MIN_RES_RATIO* + *BT_AND_2+_RADIO_SAME_AG*).

- *input.power.limit (*dBm) for Tx transmitting frequency ≥ 6 GHz
  The maximum time-average power at the input of antenna element port, in dBm, at which each beam meets the *PD_design_target* that is less than the regulatory power density limit after accounting for all design related tolerances.

- *Multi_Tx_factor*: ONLY applicable for Smart Transmit EFS version 19 (or higher).

The EFS version 19 (or higher) provides the entry to improve performance of sub6 radios in simultaneous transmission scenarios.

With EFS version 19 or higher: In single Tx transmission scenarios, Smart Transmit ensures time-averaged RF exposure is ≤ (*SAR_design_target* * 10(+ sub6 device uncertainty/10)) < regulatory RF exposure limit for sub6 radio managed by Smart Transmit. In simultaneous Tx transmission scenarios, Smart Transmit ensures time-averaged RF exposure is ≤ (*SAR_design_target* * *multi_Tx_factor* * 10(+ sub6 device uncertainty/10)) < regulatory RF exposure limit for sub6 radios managed by Smart Transmit. These simultaneous transmission scenarios are listed below:

• 2-or-more radio scenarios within WWAN like EN-DC, LTE ULCA, etc.

• 2-or-more-radio across technologies such as WWAN+WLAN, WWAN+BT, WLAN+BT and WWAN+WLAN+BT transmission scenarios (if WLAN/BT radios are also managed by Smart Transmit).

The *multi_Tx_factor* can be determined using

$$multi\_Tx\_factor \leq \frac{regulatory\ SAR\ limit\dagger}{SAR\_design\_target \times 10^{+\frac{sub6\ device\ uncertainty\ (dB)}{10}}}$$

$$= \frac{regulatory\ SAR\ limit\dagger}{reported\ SAR}$$

† $regulatory\ SAR\ limit$ may be *reduced* to meet some specific requirement, e.g., antenna grouping.

**NOTE:** If only 2 WLAN radios are transmitting (e.g., 2.4GHz + 5GHz), then *multi_Tx_factor* is not applied by Smart Transmit.

**NOTE:** If WWAN modem is offline (i.e., in airplane mode), then *multi_Tx_factor* is not applied by Smart Transmit for WLAN and BT simultaneous transmission.

- *Hand exposure applicability when device held next to head*: Yes/No switch. ONLY applicable for Smart Transmit EFS version 19 (or higher).

If "Yes" is selected in Smart Transmit EFS version 19 (or higher) for the country/region of interest, then Smart Transmit will ensure time-averaged RF exposure compliance in both hand and head tissue regions when device is held next to head in a voice call. Otherwise, if "No' is selected, then Smart Transmit will ensure time-averaged RF exposure compliance only in head tissue region when device is held next to head.

This purpose of the Part 2 report is to demonstrate the DUT complies with FCC RF exposure requirement under Tx varying transmission scenarios, thereby validity of Qualcomm® Smart Transmit feature implementation in this device. It serves to compliment the Part 0 and Part 1 Test Reports to justify compliance per FCC.

## 1.3 Bibliography

| Report Type | Report Serial Number |
|---|---|
| SAR Characterization and Evaluation Report | 1M2308210092-24.A3L |
| Part 0 Power Density Test Report | |
| Part 1 Power Density Test Report | 1M2308210092-22.A3L |
| RF Exposure Compliance Summary | 1M2308210092-25.A3L |

# 2 RF EXPOSURE LIMITS

## 2.1 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.

## 2.2 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. This 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.

## 2.3 RF Exposure Limits for Frequencies Below 6 GHz

**Table 2-1**
**SAR Human Exposure Specified in ANSI/IEEE C95.1-1992 and Health Canada Safety Code 6**

| HUMAN EXPOSURE LIMITS | | |
|---|---|---|
| | UNCONTROLLED ENVIRONMENT *General Population* (W/kg) or (mW/g) | CONTROLLED ENVIRONMENT *Occupational* (W/kg) or (mW/g) |
| **Peak Spatial Average SAR** Head | 1.6 | 8.0 |
| **Whole Body SAR** | 0.08 | 0.4 |
| **Peak Spatial Average SAR** Hands, Feet, Ankle, Wrists, etc. | 4.0 | 20 |

1. The Spatial Peak value of the SAR averaged over any 1 gram of tissue (defined as a tissue volume in the shape of a cube) and over the appropriate averaging time.
2. The Spatial Average value of the SAR averaged over the whole body.
3. The Spatial Peak value of the SAR averaged over any 10 grams of tissue (defined as a tissue volume in the shape of a cube) and over the appropriate averaging time.

## 2.4 RF Exposure Limits for Frequencies Above 6 GHz

Per §1.1310 (d)(3), the MPE limits are applied for frequencies above 6 GHz. Power Density is expressed in units of $W/m^2$ or $mW/cm^2$.

Peak Spatially Averaged Power Density was evaluated over a circular area of 4 $cm^2$ per interim FCC Guidance for near-field power density evaluations per October 2018 TCB Workshop notes.

**Table 2-2**
**Human Exposure Limits Specified in FCC 47 CFR §1.1310**

| Human Exposure to Radiofrequency (RF) Radiation Limits | | |
|---|---|---|
| **Frequency Range** [MHz] | **Power Density** [$mW/cm^2$] | **Averaging Time** [Minutes] |
| (A) Limits for Occupational / Controlled Environments | | |
| 1,500 – 100,000 | 5.0 | 6 |
| (B) Limits for General Population / Uncontrolled Environments | | |
| 1,500 – 100,000 | 1.0 | 30 |

Note: 1.0 $mW/cm^2$ is 10 $W/m^2$

## 2.5 Time Averaging Windows for FCC Compliance

Per October 2018 TCB Workshop Notes, the below time-averaging windows can be used for assessing time-averaged exposures for devices that are capable of actively monitoring and adjusting power output over time to comply with exposure limits.

| Interim Guidance | Frequency (GHz) | Maximum Averaging Time (sec) |
|---|---|---|
| SAR | < 3 | 100 |
| | 3 – 6 | 60 |
| MPE | 6 - 10 | 30 |
| | 10 - 16 | 14 |
| | 16 – 24 | 8 |
| | 24 – 42 | 4 |
| | 42 – 95 | 2 |

# 3 TIME VARYING TRANSMISSION TEST CASES

To validate the time averaging feature and demonstrate the compliance in Tx varying transmission conditions, the following transmission scenarios are covered in the Part 2 test:

1. During a time-varying Tx power transmission: To prove that the Smart Transmit feature accounts for Tx power variations in time accurately.
2. During a call disconnect and re-establish scenario: To prove that the Smart Transmit feature accounts for history of past Tx power transmissions accurately.
3. During a technology/band handover: To prove that the Smart Transmit feature functions correctly during transitions in technology/band.
4. During a DSI (Device State Index) change: To prove that the Smart Transmit feature functions correctly during transition from one device state (DSI) to another.
5. During an antenna (or beam) switch: To prove that the Smart Transmit feature functions correctly during transitions in antenna (such as AsDiv scenario) or beams (different antenna array configurations) or beams (different antenna array configurations).
6. SAR vs. PD exposure switching during sub-6+mmW transmission: To prove that the Smart Transmit feature functions correctly and ensures total RF exposure compliance during transitions in SAR dominant exposure, SAR+PD exposure, and PD dominant exposure scenarios.
7. During time window switch: To prove that the Smart Transmit feature correctly handles the transition from one time window to another specified by FCC, and maintains the normalized time-averaged RF exposure to be less than normalized FCC limit of 1.0 at all times.
8. SAR exposure switching between two active radios (radio1 and radio2): To prove that the Smart Transmit feature functions correctly and ensures total RF exposure compliance when exposure varies among SAR_radio1 only, SAR_radio1 + SAR_radio2, and SAR_radio2 only scenarios.
9. System level compliance continuity: Within terrestrial networks (WWAN, WLAN, BT, etc.): To demonstrate the time averaged RF exposure compliance continuity during technology transition in both single-radio and multi-radio transmission scenarios and under both modes (i.e., ON and airplane) of WWAN modem.

   NOTE: Technology in this test refers to WWAN, WLAN and/or Bluetooth

   NOTE: For WWAN, theoretically, either sub6 radio or mmW radio can be selected for this system level compliance continuity test as Smart Transmit internal operation is identical. Thus, the test with either WWAN sub6 or mmW radio is sufficient. However, since FCC time average window for WWAN mmW NR is 4 seconds, to be more practical and feasible in actual measurement, sub6 WWAN radio is recommended to be selected for this test.

   NOTE: BT allowed maximum power will be at one of the 3 levels populated in EFS depending on transmission scenarios, and BT's Pmax allocated by Smart Transmit is always ⩽ Plimit. Therefore, for 10.b), either WWAN or WLAN can be selected as a terrestrial network for demonstrating the compliance continuity during bi-directional transitions between non-terrestrial networks and terrestrial network. Test with one pair of terrestrial and non-terrestrial radios is sufficiant as the continuity among all terrestrial technologies is covered and validated.

As described in Part 0 report, the RF exposure is proportional to the Tx power for a SAR- and PD-characterized wireless device. Thus, feature validation in Part 2 can be effectively performed through conducted (for f < 6GHz) and radiated (for f ⩾ 6GHz) power measurement. Therefore, the compliance demonstration under dynamic transmission conditions and feature validation are done in conducted/radiated power measurement setup for transmission scenario 1 through 10.

To add confidence in the feature validation, the time-averaged SAR and PD measurements are also performed but only performed for transmission scenario 1 to avoid the complexity in SAR and PD measurement (such as, for scenario 3 requiring change in SAR probe calibration file to accommodate different bands and/or tissue simulating liquid).

The strategy for testing in Tx varying transmission condition is outlined as follows:

- Demonstrate the total RF exposure averaged over FCC defined time windows does not exceed FCC's SAR and PD limits, through time-averaged power measurements
  - Measure conducted Tx power (for *f* < 6GHz) versus time, and radiated Tx power (EIRP for f > 10GHz) versus time.
  - Convert it into RF exposure and divide by respective FCC limits to get normalized exposure versus time.
  - Perform running time-averaging over FCC defined time windows.
  - Demonstrate that the total normalized time-averaged RF exposure is less than 1 for all transmission scenarios (i.e., transmission scenarios 1, 2, 3, 4, 5, 6, 7, and 8) at all times.

Mathematical expression:

For < 6 GHz transmission only:

$$1g\_or\_10gSAR(t) = \frac{conducted\_Tx\_power(t)}{conducted\_Tx\_power\_P_{limit}} * 1g\_or\_10gSAR\_P_{limit} \quad (1a)$$

$$\frac{\frac{1}{T_{SAR}}\int_{t-T_{SAR}}^{t} 1g\_or\_10gSAR(t)dt}{FCC\ SAR\ limit} \leq 1 \quad (1b)$$

For sub-6+mmW transmission:

$$1g\_or\_10gSAR(t) = \frac{conducted\_Tx\_power(t)}{conducted\_Tx\_power\_P_{limit}} * 1g\_or\_10gSAR\_P_{limit} \quad (2a)$$

$$4cm^2PD(t) = \frac{radiated\_Tx\_power(t)}{radiated\_Tx\_power\_input.power.limit} * 4cm^2PD\_input.power.limit \quad (2b)$$

$$\frac{\frac{1}{T_{SAR}}\int_{t-T_{SAR}}^{t} 1g\_or\_10gSAR(t)dt}{FCC\ SAR\ limit} + \frac{\frac{1}{T_{PD}}\int_{t-T_{PD}}^{t} 4cm^2PD(t)dt}{FCC\ 4cm^2\ PD\ limit} \leq 1 \quad (2c)$$

where, $conducted\_Tx\_power(t)$, $conducted\_Tx\_power\_P_{limit}$, and $1g\_or\_10gSAR\_P_{limit}$ correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at $P_{limit}$, and measured *1gSAR or 10gSAR* values at $P_{limit}$ corresponding to sub-6 transmission. Similarly, $radiated\_Tx\_power(t)$, $radiated\_Tx\_power\_input.power.limit$, and $4cm^2PD\_input.power.limit$ correspond to the measured instantaneous radiated Tx power, radiated Tx power at *input.power.limit* (i.e., radiated power limit), and $4cm^2$PD value at *input.power.limit* corresponding to mmW transmission. Both $P_{limit}$ and *input.power.limit* are the parameters pre-defined in Part 0 and loaded via Embedded File System (EFS) onto the EUT. $T_{SAR}$ is the FCC defined time window for sub-6 radio; $T_{PD}$ is the FCC defined time window for mmW radio.

- Demonstrate the total RF exposure averaged over FCC defined time windows does not exceed FCC's SAR and PD limits, through time-averaged SAR and PD measurements. Note as mentioned earlier, this measurement is performed for transmission scenario 1 only.
    - For sub-6 transmission only, measure instantaneous SAR versus time; for LTE+sub6 NR transmission, request low power (or all-down bits) on LTE so that measured SAR predominantly corresponds to sub6 NR.
    - For LTE + mmW transmission, measure instantaneous E-field versus time for mmW radio and instantaneous conducted power versus time for LTE radio.
    - Convert it into RF exposure and divide by respective FCC limits to obtain normalized exposure versus time.
    - Perform time averaging over FCC defined time window.
    - Demonstrate that the total normalized time-averaged RF exposure is less than 1 for transmission scenario 1 at all times.

Mathematical expression:

- For sub-6 transmission only:

$$1g\_or\_10gSAR(t) = \frac{pointSAR(t)}{pointSAR\_P_{limit}} * 1g\_or\_10gSAR(t)\_P_{limit} \quad (3a)$$

$$\frac{\frac{1}{T_{SAR}}\int_{t-T_{SAR}}^{t} 1g\_or\_10gSAR(t)dt}{FCC\ SAR\ limit} \le 1 \quad (3b)$$

- For sub-6 +*f ≥ 6GHz* transmission:

$$1g\_or\_10gSAR(t) = \frac{conducted\_Tx\_power(t)}{conducted\_Tx\_power\_P_{limit}} * 1g\_or\_10gSAR\_P_{limit} \quad (4a)$$

$$4cm^2PD(t) = \frac{[pointE(t)]^2}{[pointE\_input.power.limit]^2} * 4cm^2PD\_input.power.limit \quad (4b)$$

$$\frac{\frac{1}{T_{SAR}}\int_{t-T_{SAR}}^{t} 1g\_or\_10gSAR(t)dt}{FCC\ SAR\ limit} + \frac{\frac{1}{T_{PD}}\int_{t-T_{PD}}^{t} 4cm^2PD(t)dt}{FCC\ 4cm^2PD\ limit} \le 1 \quad (4c)$$

where, $pointSAR(t)$, $pointSAR\_P_{limit}$, and $1g\_or\_10gSAR\_P_{limit}$ correspond to the measured instantaneous point SAR, measured point SAR at $P_{limit}$, and measured *1gSAR* or 10gSAR values at $P_{limit}$ corresponding to sub-6 transmission. Similarly, $pointE(t)$, $pointE\_input.power.limit$, and $4cm^2PD\_input.power.limit$ correspond to the measured instantaneous E-field, E-field at *input.power.limit*, and 4cm$^2$PD value at *input.power.limit* corresponding to mmW transmission.

Note: cDASY6 measurement system by Schmid & Partner Engineering AG (SPEAG ) of Zurich, Switzerland measures relative E-field, and provides ratio of $\frac{[pointE(t)]^2}{[pointE\_input.power.limit]^2}$ versus time.

# 4 FCC MEASUREMENT PROCEDURES (FREQ < 6 GHZ)

This chapter provides the test plan and test procedure for validating Qualcomm Smart Transmit feature for sub-6 transmission. The 100 seconds time window for operating f < 3GHz is used as an example to detail the test procedures in this chapter. The same test plan and test procedures described in this chapter apply to 60 seconds time window for operating f ≥ 3GHz.

## 4.1 Test sequence determination for validation

Following the FCC recommendation, two test sequences having time-variation in Tx power are predefined for sub-6 (*f* < 6 GHz) validation:

- Test sequence 1: request DUT's Tx power to be at maximum power, measured $P_{max}$†, for 80s, then requesting for half of the maximum power, i.e., measured $P_{max}/2$, for the rest of the time.
- Test sequence 2: request DUT's Tx power to vary with time. This sequence is generated relative to measured $P_{max}$, measured $P_{limit}$ and calculated $P_{reserve}$ (= measured $P_{limit}$ in dBm - *total_min_reserve* in dB) of DUT based on measured $P_{limit}$.

  The details for generating these two test sequences is described and listed in Appendix E.

NOTE: For test sequence generation, "measured $P_{limit}$" and "measured $P_{max}$" are used instead of the "$P_{limit}$" specified in EFS entry and "$P_{max}$" specified for the device, because the Smart Transmit feature operates against the actual power level of the "$P_{limit}$" that was calibrated for the DUT. The "measured $P_{limit}$" accurately reflects what the feature is referencing to, therefore, it should be used during feature validation testing. The RF tune up and device-to-device variation are already considered in Part 0 report prior to determining $P_{limit}$.

## 4.2 Test configuration selection criteria for validating Smart Transmit feature

For validating the Smart Transmit feature, this section provides the general guidance to select test cases.

### 4.2.1 Test configuration selection for time-varying Tx power transmission

The Smart Transmit time averaging feature operation is independent of bands, modes, and channels for a given technology. Hence, validation of Smart Transmit in one band/mode/channel per technology is sufficient. Two bands per technology are proposed and selected for this testing to provide high confidence in this validation.

Note this test is designed for single radio transmission scenario. If UE supports sub6 NR in both non-standalone (NSA) and standalone (SA) modes, then validation in time-varying Tx power transmission scenario described in this section needs to be performed in SA mode. Otherwise, it needs to be performed in NSA mode with LTE anchor set to low power. The choice between SA and NSA mode needs to also take into account the selection criteria described below. In general, one mode out of the two modes (NSA or SA) is sufficient for this test.

The criteria for the selection are based on the $P_{limit}$ values determined in Part 0 report. Select two bands* in each supported technology that correspond to least** and highest*** $P_{limit}$ values that are less than $P_{max}$ for validating Smart Transmit. Note:

1. $P_{max}$ refers to maximum Tx power configured for this device in this technology/band (not rated $P_{max}$). This $P_{max}$ definition applies throughout this Part 2 report.

2. If $P_{limit} > P_{max}$, the validation test with time-varying test sequences is not needed as no power enforcement will be required in this condition.

* If one $P_{limit}$ level applies to all the bands within a technology, then only one band needs to be tested. In this case, within the bands having the same $P_{limit}$, the radio configuration (e.g., # of RBs, channel#) and device position that correspond to the highest *measured* 1gSAR at $P_{limit}$ shown in Part 1 report is selected.

** In case of multiple bands having the same least $P_{limit}$ within the technology, then select the band having the highest *measured* 1gSAR at $P_{limit}$.

*** The band having a higher $P_{limit}$ needs to be properly selected so that the power limiting enforced by Smart Transmit can be validated using the pre-defined test sequences. If the highest $P_{limit}$ in a technology is too high where the power limiting enforcement is not needed when testing with the pre-defined test sequences, then the next highest level is checked. This process is continued within the technology until the second band for validation testing is determined.

### 4.2.2 Test configuration selection for change in call

The criteria to select a test configuration for call-drop measurement is:

- Select technology/band with least $P_{limit}$ among all supported technologies/bands, and select the radio configuration (e.g., # of RBs, channel#) in this technology/band that corresponds to the highest *measured* 1gSAR at $P_{limit}$ listed in Part 1 report.
- In case of multiple bands having same least $P_{limit}$, then select one band/radio configuration for this test.

This test is performed with the DUT's Tx power requested to be at maximum power, the above band selection will result in Tx power enforcement (i.e., DUT forced to have Tx power at $P_{reserve}$) for longest duration in one FCC defined time window. The call change (call drop/reestablish) is performed during the Tx power enforcement duration (i.e., during the time when DUT is forced to have Tx power at $P_{reserve}$). One test is sufficient as the feature operation is independent of technology and band.

### 4.2.3 Test configuration selection for change in technology/band

The selection criteria for this measurement is, for a given antenna, to have DUT switch from a technology/band with lowest $P_{limit}$ within the technology group (in case of multiple bands having the same $P_{limit}$, then select the band with highest *measured* 1gSAR at $P_{limit}$) to a technology/band with highest $P_{limit}$ within the technology group, in case of multiple bands having the same $P_{limit}$, then select the band with lowest *measured* 1gSAR at $P_{limit}$ in Part 1 report, or vice versa.

This test is performed with the DUT's Tx power requested to be at maximum power, the technology/band switch is performed during Tx power enforcement duration (i.e., during the time when DUT is forced to have Tx power at $P_{reserve}$).

### 4.2.4 Test configuration selection for change in antenna

The criteria to select a test configuration for antenna switch measurement is:

- Whenever possible and supported by the DUT, first select antenna switch configuration within the same technology/band (i.e., same technology and band combination).

- Then, select any technology/band that supports multiple Tx antennas, and has the highest difference in $P_{limit}$ among all supported antennas.
- In case of multiple bands having same difference in $P_{limit}$ among supported antennas, then select the band having the highest *measured* 1gSAR at $P_{limit}$ in Part 1 report.

This test is performed with the DUT's Tx power requested to be at maximum power in selected technology/band, and antenna change is conducted during Tx power enforcement duration (i.e., during the time when DUT is forced to have Tx power at $P_{reserve}$).

### 4.2.5 Test configuration selection for change in DSI

The criteria to select a test configuration for DSI change test is

- Select a technology/band having the $P_{limit} < P_{max}$ within any technology and DSI group, and for the same technology/band having a different $P_{limit}$ in any other DSI group. Note that the selected DSI transition need to be supported by the device.

This test is performed with the DUT's Tx power requested to be at maximum power in selected technology/band, and DSI change is conducted during Tx power enforcement duration (i.e., during the time when DUT is forced to have Tx power at $P_{reserve}$).

### 4.2.6 Test configuration selection for change in time window

FCC specifies different time window for time averaging based on operation frequency. The criteria to select a test configuration for validating Smart Transmit feature and demonstrating the compliance during the change in time window is

- Select any technology/band that has operation frequency classified in one time window defined by FCC (such as 100-seconds time window), and its corresponding $P_{limit}$ is less than $P_{max}$ if possible.
- Select the 2$^{nd}$ technology/band that has operation frequency classified in a different time window defined by FCC (such as 60-seconds time window), and its corresponding $P_{limit}$ is less than $P_{max}$ if possible.
- Note it is preferred both $P_{limit}$ values of two selected technology/band less than corresponding $P_{max}$, but if not possible, at least one of technologies/bands has its $P_{limit}$ less than $P_{max}$.

This test is performed with the EUT's Tx power requested to be at maximum power in selected technology/band. Test for one pair of time windows selected is sufficient as the feature operation is the same.

### 4.2.7 Test configuration selection for SAR exposure switching

If supported, the test configuration for SAR exposure switching should cover

1. SAR exposure switch when two active radios are in the same time window
2. SAR exposure switch when two active radios are in different time windows. One test with two active radios in any two different time windows is sufficient as Smart Transmit operation is the same for RF exposure switch in any combination of two different time windows. For device supporting LTE + mmW NR, this test is covered in SAR vs PD exposure switch validation.

The Smart Transmit time averaging operation is independent of the source of SAR exposure (for example, LTE vs. Sub6 NR) and ensures total time-averaged RF exposure compliance. Hence, validation of Smart Transmit in any one simultaneous SAR transmission scenario (i.e., one combination for LTE + Sub6 NR transmission) is sufficient, where the SAR exposure varies among $SAR_{radio1}$ only, $SAR_{radio1}$ + $SAR_{radio2}$, and $SAR_{radio2}$ only scenarios.

The criteria to select a test configuration for validating Smart Transmit feature during SAR exposure switching scenarios is

- Select any two < 6GHz technologies/bands that the EUT supports simultaneous transmission (for example, LTE+Sub6 NR).
- Among all supported simultaneous transmission configurations, the selection order is
  1. select one configuration where both $P_{limit}$ of radio1 and radio2 is less than their corresponding $P_{max}$, preferably, with different $P_{limits}$. If this configuration is not available, then,
  2. select one configuration that has $P_{limit}$ less than its $P_{max}$ for at least one radio. If this can not be found, then,
  3. select one configuration that has $P_{limit}$ of radio1 and radio2 greater than $P_{max}$ but with least ($P_{limit} – P_{max}$) delta.

Test for one simultaneous transmission scenario is sufficient as the feature operation is the same.

### 4.2.8 Test configuration selection for exposure category switch

The criteria to select a test configuration for exposure category switch measurement is:

1. If the device's intended exposure mode is configured for time averaged exposure mode operation, then:

□ If *Plimit* < *Pmax* for at least one radio out of all supported technology/band/antenna/DSI, then:

(a) Out of all head exposure DSIs, select a technology/band/antenna/DSI having the least *Plimit* (< *Pmax*), furthermore, having the largest difference between *Pmax* and *Plimit* (*Plimit* < *Pmax*) should be considered in the selection. Then, select a second DSI in the non- head exposure category DSI that has the least *Plimit* among all the non-head DSIs for the same technology/band/antenna. This technology/band/antenna and selected DSIs are used for head to non-head to head exposure switch test. If the *Plimit* > *Pmax* for all supported technology/band/antenna/DSI in head exposure category, then this test is not required.

(b) Similarly, out of all non-head exposure DSIs, select a technology/band/antenna/DSI having the least *Plimit* (< *Pmax*), furthermore, having the largest difference between *Pmax* and *Plimit* (*Plimit* < *Pmax*) should be considered in the selection. Then, select a second DSI in the head exposure category DSI that has the least Plimit among all the head DSIs for the same technology/band/antenna. This technology/band/antenna and selected DSIs are used for non-head to head to non-head exposure switch test. If the Plimit > Pmax for all supported technology/band/antenna/DSI in non-head exposure category, then this test is not required.

□ If *Plimit* > *Pmax* for all supported technology/band/antenna/DSIs for both head and non-head DSI categories, then:

c) select a supported sub6 simultaneous transmission scenario (like LTE + FR1 NSA, or LTE interband ULCA, or FR1 interband NR-DC, etc.) in head DSI that has Plimit < Pmax +10*log(N) for all radios of selected technology(s)/band(s)/antenna(s), where N is the number of active radios in selected sub6 simultaneous transmission scenario.

Note that the antennas determined for the selected radios of simultaneous transmission scenario should be in the same antenna group if EUT is configured with GEN2_SUB6 or GEN2_SUB6_MMW. Then, select a second DSI in the non-head exposure category that has the lowest Plimit among all the non-head DSIs for all the radios of the selected technology(s)/band(s)/antenna(s) simultaneous transmission scenario. This selected technology(s)/band(s)/antenna(s) and selected DSIs are used for head to non-head to head exposure switch test. If the head DSI has Plimit > Pmax +10*log(N) for all radios supported in sub6 simultaneous transmission scenarios, then this test is not required.

d) select a supported sub6 simultaneous transmission scenario (like LTE + FR1 NSA, or LTE interband ULCA, or FR1 interband NR-DC, etc.) in non-head DSI that has Plimit < Pmax +10*log(N) for all radios of the selected technology(s)/band(s)/antenna(s), where N is the number of active radios in selected sub6 simultaneous transmission scenario. Note that the antennas determined for the selected radios of simultaneous transmission scenario should be in the same antenna group if EUT is configured with GEN2_SUB6 or GEN2_SUB6_MMW. Then, select a second DSI in the head exposure category that has the lowest Plimit among all the head DSIs for all the radios of the selected technology(s)/band(s)/antenna(s) simultaneous transmission scenario. This selected technology(s)/band(s)/antenna(s) and selected DSIs are used for non-head to head to non-head exposure switch test. If the non-head DSI has Plimit > Pmax +10*log(N) for all radios supported in sub6 simultaneous transmission scenarios, then this test is not required.

- Use the highest measured 1g_or_10g SAR at Plimit (Plimit < Pmax) shown in Part 1 report for the selected tech/band/antenna/DSI out of all radio configurations and device positions in Equation (3a), (4a), (5a) and (6a) to calculate time-varying SAR. However, in the case of Plimit > Pmax, the SAR measured in Part 1 report for the corresponding radio configuration selected and tested in Part 2 should be applied in Equation (3a), (4a), (5a) and (6a).

2. If the device's intended exposure mode is configured for peak exposure mode operation, then:

a) Select a supported sub6 simultaneous transmission scenario (like LTE + FR1 NSA, or LTE interband ULCA, or FR1 interband NR-DC, etc.) in head DSI that has Plimit < Pmax +10*log(N) for all radios of selected technology(s)/band(s)/antenna(s), where N is the number of active radios in selected sub6 simultaneous transmission scenario. Note that the antennas determined for the selected radios of simultaneous transmission scenario should be in the same antenna group if EUT is configured with GEN2_SUB6 or GEN2_SUB6_MMW. Then, select a second DSI in the non-head exposure category that has the lowest Plimit among all the non-head DSIs for all the radios of the selected technology(s)/band(s)/antenna(s) simultaneous transmission scenario. This selected technology(s)/band(s)/antenna(s) and selected DSIs are used for head to non-head to head exposure switch test. If the head DSI has Plimit > Pmax +10*log(N) for all radios supported in sub6 simultaneous transmission scenarios, then this test is not required.

b) Select a supported sub6 simultaneous transmission scenario (like LTE + FR1 NSA, or LTE interband ULCA, or FR1 interband NR-DC, etc.) in non-head DSI that has Plimit < Pmax +10*log(N) for all radios of the selected technology(s)/band(s)/antenna(s), where N is the number of active radios in selected sub6 simultaneous transmission scenario. Note that the antennas determined for the selected radios of simultaneous transmission scenario should be in the same antenna group if EUT is configured with GEN2_SUB6 or GEN2_SUB6_MMW. Then, select a second DSI in the head exposure category that has the lowest Plimit among all the head DSIs for all the radios of the selected technology(s)/band(s)/antenna(s) simultaneous transmission scenario. This selected technology(s)/band(s)/antenna(s) and selected DSIs are used for non-head to head to non-head exposure switch test. If the non-head DSI has Plimit >

Pmax +10*log(N) for all radios supported in sub6 simultaneous transmission scenarios, then this test is not required.

- Use the highest measured 1g_or_10g SAR at Plimit (Plimit < Pmax) shown in Part 1 report for the selected tech/band/antenna/DSI out of all radio configurations and device positions in Equation (3a), (4a), (5a) and (6a) to calculate time-varying SAR. However, in the case of Plimit > Pmax, the SAR measured in Part 1 report for the corresponding radio configuration selected and tested in Part 2 should be applied in Equation (3a), (4a), (5a) and (6a).

### 4.2.9 Test configuration selection for system level compliance continuity

The purpose of system level compliance test is to demonstrate the compliance continuity in the following scenarios:

1. Across technology switch
2. During transition from single technology to multi-technology
3. In transition when WWAN went from ON to airplane mode
4. Active WLAN radio and/or Bluetooth (BT) radio with WWAN in airplane mode
5. Time window transition when WWAN in airplane mode

Note: Technology in this section refers to WWAN, WLAN or BT

The selection criteria for radios to be tested is to select a radio which has the largest Pmax/Plimit ratio among all configurations supported (including SISO, MIMO, DBS, SISO+MIMO or DBS+MIMO whichever appropriate) within each technology and within the same antenna group.

If the device supports simultaneous transmission of WWAN, WLAN and BT, then the selection criteria for system level compliance continuity test is:

- For a given DSI and antenna group, select band/antenna configurations for WWAN, WLAN and BT technologies that have the largest (Pmax – Plimit) delta. In case of multiple bands/antennas having the same difference between Pmax and Plimit within a given technology, then select any one band/antenna out of them.

NOTE: The antennas corresponding to the selected technologies/bands for the system level compliance continuity test case should be in the same antenna group if EUT is configured with GEN2_SUB6 or GEN2_SUB6_MMW.

## 4.3 Test procedures for conducted power measurements

This section provides general conducted power measurement procedures to perform compliance test under dynamic transmission scenarios described in Section 3. In practice, an adjustment can be made in these procedures. The justification/clarification may be provided.

### 4.3.1 Time-varying Tx power transmission scenario

This test is performed with the two pre-defined test sequences described in Section 4.1 for all the technologies and bands selected in Section 4.2.1. The purpose of the test is to demonstrate the effectiveness of power limiting enforcement and that the time-averaged SAR (corresponding time-averaged Tx power) does not exceed the FCC limit at all times (see Eq. (1a) and (1b)).

## Test procedure

1. Measure $P_{max}$, measure $P_{limit}$ and calculate $P_{reserve}$ (measured $P_{limit}$ in dBm – *total_min_reserve* in dB) and follow Section 4.1 to generate the test sequences for all the technologies and bands selected in Section 4.2.1. Both test sequence 1 and test sequence 2 are created based on measured $P_{max}$ and measured $P_{limit}$ of the DUT. Test condition to measure $P_{max}$ and $P_{limit}$ is:
    a. Measure $P_{max}$ with Smart Transmit disabled and callbox set to request maximum power.
    b. Measure $P_{limit}$ with Smart Transmit peak exposure mode enabled, and callbox set to request maximum power.
2. Set DUT to the intended Smart Transmit exposure mode, establish radio link in desired radio configuration, with callbox requesting the DUT's Tx power to be at pre-defined test sequence 1, measure and record Tx power versus time, and then convert the conducted Tx power into 1gSAR or 10gSAR value (see Eq. (1a)) using measured $P_{limit}$ from above Step 1. Perform running time average to determine time-averaged power and 1gSAR or 10gSAR versus time as illustrated in Figure 4-1 where using 100-seconds time window as an example.

    Note: In Eq.(1a), instantaneous Tx power is converted into instantaneous 1gSAR or 10gSAR value by applying the measured worst-case 1gSAR or 10gSAR value at $P_{limit}$ for the corresponding technology/band/antenna/DSI reported in Part 1 report.

    Note: For an easier computation of the running time average, 0 dBm can be added at the beginning of the test sequences the length of the responding time window, for example, add 0dBm for 100-seconds so the running time average can be directly performed starting with the first 100-seconds data using excel spreadsheet. This technique applies to all tests performed in this Part 2 report for easier time-averaged computation using excel spreadsheet.

| Time | Power/SAR |
|---|---|
| $t_1$ | $P_{t1}$ or $SAR_{t1}$ |
| $t_2$ | $P_{t2}$ or $SAR_{t2}$ |
| : | : |
| : | : |
| $t_n$ ($t_1$+100s) | $P_{tn}$ or $SAR_{tn}$ |
| $t_{n+1}$ ($t_2$+100s) | $P_{tn+1}$ or $SAR_{tn+1}$ |
| : | : |

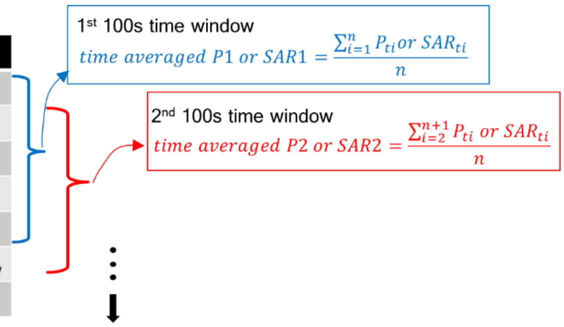



**Figure 4-1**
**Running Average Illustration**

3. Make one plot containing:
   a. Instantaneous Tx power versus time measured in Step 2,
   b. Requested Tx power used in Step 2 (test sequence 1),
   c. Computed time-averaged power versus time determined in Step 2,
   d. Time-averaged power limit (corresponding to FCC SAR limit of 1.6 W/kg for 1gSAR or 4.0W/kg for 10gSAR) given by

$$Time\ averaged\ power\ limit = meas.P_{limit} + 10 \times \log\left(\frac{FCC\ SAR\ limit}{meas.SAR\_Plimit}\right) \qquad (5a)$$

where $meas.P_{limit}$ and $meas.SAR\_Plimit$ correspond to measured power at $P_{limit}$ and measured SAR at $P_{limit}$.

4. Make another plot containing:
   a. Computed time-averaged 1gSAR or 10gSAR versus time determined in Step 2
   b. FCC $1gSAR_{limit}$ of 1.6W/kg or FCC $10gSAR_{limit}$ of 4.0W/kg.
5. Repeat Steps 2 ~ 4 for pre-defined test sequence 2 and replace the requested Tx power (test sequence 1) in Step 2 with test sequence 2.
6. Repeat Steps 2 ~ 5 for all the selected technologies and bands.
7. The validation criteria are, at all times, the time-averaged power versus time shown in Step 3 plot shall not exceed the time-averaged power limit (defined in Eq. (5a)), in turn, the time-averaged 1gSAR or 10gSAR versus time shown in Step 4 plot shall not exceed the FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR (i.e., Eq. (1b)).

### 4.3.2 Change in call scenario

This test is to demonstrate that Smart Transmit feature accurately accounts for the past Tx powers during time-averaging when a new call is established.

The call disconnect and re-establishment needs to be performed during power limit enforcement, i.e., when the DUT's Tx power is at $P_{reserve}$ level, to demonstrate the continuity of RF exposure management and limiting in call change scenario. In other words, the RF exposure averaged over any FCC defined time window (including the time windows containing the call change) doesn't exceed FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

### Test procedure

1. Measure $P_{limit}$ for the technology/band selected in Section 4.2.2. Measure $P_{limit}$ with Smart Transmit peak exposure mode enabled, and callbox set to request maximum power.
2. Set DUT to the intended Smart Transmit exposure mode.
3. Establish radio link with callbox in the selected technology/band.
4. Request DUT's Tx power at 0 dBm for at least one time window specified for the selected technology/band, followed by requesting DUT's Tx power to be at maximum power for about ~60 seconds, and then drop the call for ~10 seconds. Afterwards, re-establish another call in the same radio configuration (i.e., same technology/band/channel) and continue callbox requesting DUT's Tx power to be at maximum power for the remaining time of at least another full duration of the specified time window. Measure and record Tx power versus time. Once the measurement is done, extract instantaneous Tx power versus time, convert the measured conducted Tx power into 1gSAR or 10gSAR value using Eq. (1a), and then perform the running time average to determine time-averaged power and 1gSAR or 10gSAR versus time.

   NOTE: In Eq.(1a), instantaneous Tx power is converted into instantaneous 1gSAR or 10gSAR value by applying the measured worst-case 1gSAR or 10gSAR value at $P_{limit}$ for the corresponding technology/band/antenna/DSI reported in Part 1 report.

5. Make one plot containing: (a) instantaneous Tx power versus time, (b) requested power, (c) computed time-averaged power, (d) time-averaged power limit calculated using Eq.(5a).
6. Make another plot containing: (a) computed time-averaged 1gSAR or 10gSAR versus time, and (b) FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

The validation criteria are, at all times, the time-averaged power versus time shall not exceed the time-averaged power limit (defined in Eq.(5a)), in turn, the time-averaged 1gSAR or 10gSAR versus time shall not exceed the FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR (i.e., Eq. (1b)).

### 4.3.3 Change in technology and band

This test is to demonstrate the correct power control by Smart Transmit during technology switches and/or band handovers.

Similar to the change in call test in Section 4.3.2, to validate the continuity of RF exposure limiting during the transition, the technology and band handover needs to be performed when DUT's Tx power is at $P_{reserve}$ level (i.e., during Tx power enforcement) to make sure that the DUT's Tx power from previous $P_{reserve}$ level to the new $P_{reserve}$ level (corresponding to new technology/band). Since the $P_{limit}$ could vary with technology and band, Eq. (1a) can be written as follows to convert the instantaneous Tx power in 1gSAR or 10gSAR exposure for the two given radios, respectively:

$$1g\_or\_10gSAR_1(t) = \frac{conducted\_Tx\_power\_1(t)}{conducted\_Tx\_power\_P_{limit\_1}} * 1g\_or\_10gSAR\_P_{limit\_1} \quad (6a)$$

$$1g\_or\_10gSAR_2(t) = \frac{conducted\_Tx\_power\_2(t)}{conducted\_Tx\_power\_P_{limit\_2}} * 1g\_or\_10gSAR\_P_{limit\_2} \quad (6b)$$

$$\frac{1}{T_{SAR}}\left[\int_{t-T_{SAR}}^{t_1}\frac{1g\_or\_10gSAR_1(t)}{FCC\ SAR\ limit}dt+\int_{t-T_{SAR}}^{t}\frac{1g\_or\_10gSAR_2(t)}{FCC\ SAR\ limit}dt\right]\leq 1 \qquad (6c)$$

where, *conducted_Tx_power_1(t)*, *conducted_Tx_power_*$P_{limit\_1}$, and *1g_or_10gSAR_*$P_{limit\_1}$ correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at $P_{limit}$, and measured *1gSAR* or *10gSAR* value at $P_{limit}$ of technology1/band1; *conducted_Tx_power_2(t)*, *conducted_Tx_power_*$P_{limit\_2}$*(t)*, and *1g_or_10gSAR_*$P_{limit\_2}$ correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at $P_{limit}$, and measured *1gSAR* or *10gSAR* value at $P_{limit}$ of technology2/band2. Transition from technology1/band1 to the technology2/band2 happens at time-instant '$t_1$'.

## Test procedure

1. Measure $P_{limit}$ for both the technologies and bands selected in Section 4.2.3. Measure $P_{limit}$ with Smart Transmit peak exposure mode enabled, and callbox set to request maximum power.
2. Set DUT to the intended Smart Transmit exposure mode. Establish radio link with callbox in first technology/band selected. Establish radio link with callbox in first technology/band selected.
3. Request DUT's Tx power at 0 dBm for at least one time window specified for the selected technology/band, followed by requesting DUT's Tx power to be at maximum power for about ~60 seconds, and then switch to second technology/band selected. Continue with callbox requesting DUT's Tx power to be at maximum power for the remaining time of at least another full duration of the specified time window. Measure and record Tx power versus time for the full duration of the test.
4. Once the measurement is done, extract instantaneous Tx power versus time, and convert the conducted Tx power into 1gSAR or 10gSAR value using Eq. (6a) and (6b) and corresponding measured $P_{limit}$ values from Step 1 of this section. Perform the running time average to determine time-averaged power and 1gSAR or 10gSAR versus time.

   **NOTE:** In Eq.(6a) & (6b), instantaneous Tx power is converted into instantaneous 1gSAR or 10gSAR value by applying the measured worst-case 1gSAR or 10gSAR value at $P_{limit}$ for the corresponding technology/band/antenna/DSI reported in Part 1 report.

5. Make one plot containing: (a) instantaneous Tx power versus time, (b) requested power, (c) computed time-averaged power, (d) time-averaged power limit calculated using Eq.(5a).
6. Make another plot containing: (a) computed time-averaged 1gSAR or 10gSAR versus time, and (b) FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

The validation criteria are, at all times, the time-averaged 1gSAR or 10gSAR versus time shall not exceed the FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR (i.e., Eq. (6c)).

### 4.3.4 Change in antenna

This test is to demonstrate the correct power control by Smart Transmit during antenna switches from one antenna to another. The test procedure is identical to Section 4.3.3, by replacing technology/band switch operation with antenna switch. The validation criteria are, at all times, the time-averaged 1gSAR or 10gSAR versus time shall not exceed FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

**NOTE:** If the DUT does not support antenna switch within the same technology/band, but has multiple antennas to support different frequency bands, then the antenna switch test is included as part of change in technology and band (Section 4.3.3) test.

### 4.3.5 Change in DSI

This test is to demonstrate the correct power control by Smart Transmit during DSI switches from one DSI to another. The test procedure is identical to Section 4.3.3, by replacing technology/band switch operation with DSI switch. The validation criteria are, at all times, the time-averaged 1gSAR or 10gSAR versus time shall not exceed FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

### 4.3.6 Change in time window

This test is to demonstrate the correct power control by Smart Transmit during the change in averaging time window when a specific band handover occurs. FCC specifies time-averaging windows of 100s for Tx frequency < 3GHz, and 60s for Tx frequency between 3GHz and 6GHz.

To validate the continuity of RF exposure limiting during the transition, the band handover test needs to be performed when EUT handovers from operation band less than 3GHz to greater than 3GHz and vice versa. The equations (3a) and (3b) in Section 2 can be written as follows for transmission scenario having change in time window,

$$1gSAR_1(t) = \frac{conducted\_Tx\_power\_1(t)}{conducted\_Tx\_power\_P_{limit\_1}} * 1g\_or\ 10g\_SAR\_P_{limit\_1} \qquad (7a)$$

$$1gSAR_2(t) = \frac{conducted\_Tx\_power\_2(t)}{conducted\_Tx\_power\_P_{limit\_2}} * 1g\_or\ 10g\_SAR\_P_{limit\_2} \qquad (7b)$$

$$\frac{1}{T1_{SAR}}\left[\int_{t-T1_{SAR}}^{t_1} \frac{1g\_or\ 10g\_SAR_1(t)}{FCC\ SAR\ limit} dt\right] + \frac{1}{T2_{SAR}}\left[\int_{t-T2_{SAR}}^{t} \frac{1g_{or}10g\_SAR_2(t)}{FCC\ SAR\ limit} dt\right] \leq 1 \qquad (7c)$$

where, *conducted_Tx_power_1(t)*, *conducted_Tx_power_*$P_{limit\_1}$*(t)*, and *1g_ or 10g_SAR_*$P_{limit\_1}$ correspond to the instantaneous Tx power, conducted Tx power at $P_{limit}$, and compliance *1g_ or 10g_SAR* values at $P_{limit\_1}$ of band1 with time-averaging window '$T1_{SAR}$'; *conducted_Tx_power_2(t)*, *conducted_Tx_power_*$P_{limit\_2}$*(t)*, and *1g_ or 10g_SAR_*$P_{limit\_2}$ correspond to the instantaneous Tx power, conducted Tx power at $P_{limit}$, and compliance *1g_ or 10g_SAR* values at $P_{limit\_2}$ of band2 with time-averaging window '$T2_{SAR}$'. One of the two bands is less than 3GHz, another is greater than 3GHz. Transition from first band with time-averaging window '$T1_{SAR}$' to the second band with time-averaging window '$T2_{SAR}$' happens at time-instant '$t_1$'.

#### Test procedure

1. Measure $P_{limit}$ for both the technologies and bands selected in Section 4.2.6. Measure $P_{limit}$ with Smart Transmit peak exposure mode enabled, and callbox set to request maximum power.
2. Set DUT to the intended Smart Transmit exposure mode.

#### Transition from 100s time window to 60s time window, and vice versa

3. Establish radio link with callbox in the technology/band having 100s time window selected in Section 4.2.6.
4. Request EUT's Tx power to be at 0 dBm for at least 100 seconds, followed by requesting EUT's Tx power to be at maximum power for about ~140 seconds, and then switch to second technology/band (having 60s time window) selected in Section 4.2.6. Continue with callbox requesting EUT's Tx power to be at

maximum power for about ~60s in this second technology/band, and then switch back to the first technology/band. Continue with callbox requesting EUT's Tx power to be at maximum power for at least another 100s. Measure and record Tx power versus time for the entire duration of the test.

5. Once the measurement is done, extract instantaneous Tx power versus time, and convert the conducted Tx power into 1gSAR or 10gSAR value (see Eq. (7a) and (7b)) using corresponding technology/band Step 1 result, and then perform 100s running average to determine time-averaged 1gSAR or 10gSAR versus time. Note that in Eq.(7a) & (7b), instantaneous Tx power is converted into instantaneous 1gSAR or 10gSAR value by applying the worst-case 1gSAR or 10gSAR value tested in Part 1 for the selected technologies/bands at $P_{limit}$.
6. Make one plot containing: (a) instantaneous Tx power versus time measured in Step 4.
7. Make another plot containing: (a) instantaneous 1gSAR versus time determined in Step 5, (b) computed time-averaged 1gSAR versus time determined in Step 5, and (c) corresponding regulatory $1gSAR_{limit}$ of 1.6W/kg or $10gSAR_{limit}$ of 4.0W/kg.

**Transition from 60s time window to 100s time window, and vice versa**

8. Establish radio link with callbox in the technology/band having 60s time window selected in Section 4.2.6.
9. Request EUT's Tx power to be at 0 dBm for at least 60 seconds, followed by requesting EUT's Tx power to be at maximum power for about ~80 seconds, and then switch to second technology/band (having 100s time window) selected in Section 4.2.6. Continue with callbox requesting EUT's Tx power to be at maximum power for about ~100s in this second technology/band, and then switch back to the first technology/band. Continue with callbox requesting EUT's Tx power to be at maximum power for the remaining time for a total test time of 500 seconds. Measure and record Tx power versus time for the entire duration of the test.
10. Repeat above Step 5~7 to generate the plots

The validation criteria is, at all times, the time-averaged 1gSAR or 10gSAR versus time shall not exceed the regulatory $1gSAR_{limit}$ of 1.6W/kg or $10gSAR_{limit}$ of 4.0W/kg.

### 4.3.7 SAR exposure switching

This test is to demonstrate that Smart Transmit feature is accurately accounts for switching in exposures among SAR from radio1 only, SAR from both radio1 and radio2, and SAR from radio2 only scenarios, and ensures total time-averaged RF exposure complies with the FCC limit. Here, radio1 represents primary radio (for example, LTE anchor in a NR non-standalone mode call) and radio2 represents secondary radio (for example, sub6 NR or mmW NR). The detailed test procedure for SAR exposure switching in the case of LTE+Sub6 NR non-standalone mode transmission scenario is provided in APPENDIX F.

**Test procedure:**

1. Measure conducted Tx power corresponding to $P_{limit}$ for radio1 and radio2 in selected band. Test condition to measure conducted $P_{limit}$ is:
   - Establish device in call with the callbox for radio1 technology/band. Measure conducted Tx power corresponding to radio1 $P_{limit}$ with Smart Transmit peak exposure mode <u>enabled,</u> and callbox set to request maximum power.

- Repeat above step to measure conducted Tx power corresponding to radio2 $\underline{P_{limit}}$. If radio2 is dependent on radio1 (for example, non-standalone mode of Sub6 NR requiring radio1 LTE as anchor), then establish radio1 + radio2 call with callbox, and request all down bits for radio1 LTE. In this scenario, with callbox requesting maximum power from radio2 Sub6 NR, measured conducted Tx power corresponds to radio2 $\underline{P_{limit}}$ (as radio1 LTE is at all-down bits)

2. Set DUT to the intended Smart Transmit exposure mode, with EUT setup for radio1 + radio2 call. In this description, it is assumed that radio2 has lower priority than radio1. Establish device in radio1+radio2 call, and request all-down bits or low power on radio1, with callbox requesting EUT's Tx power to be at maximum power in radio2 for at least one time window. After one time window, set callbox to request EUT's Tx power to be at maximum power on radio1, i.e., all-up bits. Continue radio1+radio2 call with both radios at maximum power for at least one time window, and drop (or request all-down bits on) radio2. Continue radio1 at maximum power for at least one time window. Record the conducted Tx power for both radio1 and radio2 for the entire duration of this test.
3. Once the measurement is done, extract instantaneous Tx power versus time for both radio1 and radio2 links. Convert the conducted Tx power for both these radios into 1gSAR or 10gSAR value (see Eq. (6a) and (6b)) using corresponding technology/band $P_{limit}$ measured in Step 1, and then perform the running time average to determine time-averaged 1gSAR or 10gSAR versus time.
4. Make one plot containing: (a) instantaneous Tx power versus time measured in Step 2.
5. Make another plot containing: (a) instantaneous 1gSAR versus time determined in Step 3, (b) computed time-averaged 1gSAR versus time determined in Step 3, and (c) corresponding regulatory $1gSAR_{limit}$ of 1.6W/kg or $10gSAR_{limit}$ of 4.0W/kg.

The validation criteria is, at all times, the time-averaged 1gSAR or 10gSAR versus time shall not exceed the regulatory $1gSAR_{limit}$ of 1.6W/kg or $10gSAR_{limit}$ of 4.0W/kg.

**NOTE:** If *multi_Tx_factor* is set to > 1.0 with EFS version 19 (or higher), then in single Tx transmission scenarios, Smart Transmit ensures time-averaged RF exposure is ≤ (*SAR_design_target* * $10^{(+\text{ sub6 device uncertainty}/10)}$) < regulatory RF exposure limit for sub6 radio managed by Smart Transmit. In simultaneous Tx transmission scenarios, Smart Transmit ensures time-averaged RF exposure is ≤ (*SAR_design_target* * *multi_Tx_factor* * $10^{(+\text{ sub6 device uncertainty}/10)}$) < regulatory RF exposure limit for sub6 radios managed by Smart Transmit. These simultaneous transmission scenarios are listed below:

- 2-or-more radio scenarios within WWAN like EN-DC, LTE ULCA, etc.
- 2-or-more-radio across technologies such as WWAN+WLAN, WWAN+BT, WLAN+BT and WWAN+WLAN+BT transmission scenarios (if WLAN/BT radios are also managed by Smart Transmit).

### 4.3.8 Exposure category switch

This test is performed with the EUT being requested to transmit at maximum power in selected technology/band/antenna/DSI. The change in exposure category is preferrably performed during Tx power enforcement (i.e., EUT forced to transmit at a sustainable level ). One test is sufficient as this feature operation is independent of technology, band and antenna. Test procedure are:

In case of head to non-head to head exposure switch test, 'first DSI' in below test procedure refers to head DSI and 'second DSI' refers to non-head DSI. Similarly, in case of non-head to head to non-head exposure switch test, 'first DSI' in below test procedure refers to non-head DSI and 'second DSI' refers to head DSI.

1. Measure *Plimit* for all the technology(s)/band(s)/antenna(s)/DSI(s) selected following the above selection criteria. Measure *Plimit* with Smart Transmit Peak exposure mode enabled and callbox set to request maximum power.
2. Set EUT to intended Smart Transmit exposure mode.
3. Establish radio link with first DSI and with callbox in the selected technology(s)/band(s)/antenna(s).
4. Request EUT to transmit at 0 dBm for at least 100 seconds, followed by requesting EUT to transmit at maximum Tx power for the active radio(s) for half of the regulatory time window, and then switch to the second DSI for ~10s, and switch back to the first DSI for at least one time window. Throughout this test, when switching between DSIs (i.e., switching between exposure categories), continue with callbox requesting EUT to transmit at maximum Tx power for the active radio(s). Measure and record Tx power versus time for the entire duration of the test.
5. Once the measurement is done, extract instantaneous Tx power versus time, and convert the conducted Tx power into 1g_or_10gSAR value (see Eq. (7a) and (7b)) using the corresponding *Plimit* measured in Step 1 and 1g_or_10gSAR value measured in 80-W2112-4 Part 1 report, and then perform 100s running average to determine time-averaged 1g_or_10gSAR versus time as illustrated in Figure 5-1. Note that in Eq.(7a) & (7b), instantaneous Tx power is converted into instantaneous 1g_or_10gSAR value by applying the worst-case 1gSAR value for the selected technologies/bands at *Plimit* as reported in 80- W2112-4 Part 1 report.
6. Make one plot containing: (a) computed time-averaged normalized 1g_or_10gSAR of the selected technology(s)/band(s)/antenna(s) versus time determined in Step 5 for exposure under first DSI , (b) total time-averaged normalized exposure for exposure under first DSI if simultaneous transmission scenario was tested, and (c) normalized regulatory limit of 1.0.
7. Make another plot containing: (a) computed time-averaged 1g_or_10gSAR of the selected technology(s)/band(s)/antenna(s) versus time determined in Step 5 for exposure under second DSI, (b) total time-averaged normalized exposure for exposure under second DSI if simultaneous transmission scenario was tested, and (c) normalized regulatory limit of 1.0.

The validation criteria is, at all times, the time-averaged normalized exposure versus time shall not exceed the normalized limit of 1.0 for both first & second DSIs (i.e., both head exposure category and non-head exposure category).

### 4.3.9 System level compliance continuity

Below is the test flow outline of the system level compliance test. The test contains 6 sections and 5 transitions: Start with WWAN radio transmission (Section A), transition to WLAN transmission (Section B), transition to simultaneous transmission of WWAN + WLAN + BT (Section C), then drop off WWAN radio and set WWAN to airplane mode, at the same time transition to WLAN+BT transmission simultaneously (Section D), transition to BT only transmission (Section E), and finally transition to WLAN only transmission (Section F).

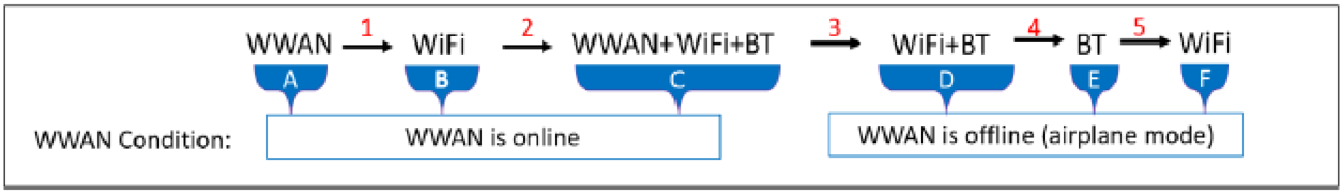



**Figure 4-2**
**Schematic of technology transitions for system level compliance continuity test**

1. Measure conducted Tx power corresponding to *Plimit* for all three (WWAN, WLAN & BT) technologies in the selected radio configurations. Test condition to measure conducted *Plimit* for each technology is:
   - □ Establish device in call with the callbox for the first technology in desired band. Measure conducted Tx power corresponding to the first technology *Plimit* with Smart Transmit Peak exposure mode <u>enabled</u> and callbox set to request maximum power (or maximum duty cycle in case of WLAN/BT).
   - □ Repeat above step to measure conducted Tx power corresponding to the remaining two technologies' *Plimit*. In the case of BT, measured conducted Tx power is compensated by tested duty cycle and *BT_STANDALONE* EFS parameter, i.e., measured *Plimit* = conducted power measured in BT standalone condition / *BT_STANDALONE / BT_duty_cycle*.
2. Set EUT to the intended Smart Transmit exposure mode.
3. As depicted in Figure 4-2, first

i. Section A: Establish WWAN connection with the callbox in selected WWAN radio configuration. Request EUT to transmit at 0 dBm for at least one WWAN time window (100s or 60s), followed by requesting EUT to transmit at maximum Tx power for {one WWAN time window (*TWWAN* = 100s if *f* < 3GHz or 60s if 3GHz < *f* < 6GHz for FCC, 360s for ICNIRP) + the maximum high power duration allowed in one *TWWAN*}, denoted as *TA_WWAN*.

ii. Section B: After *TA_WWAN*, drop WWAN connection and establish WLAN connection with the callbox in selected WLAN radio configuration and request EUT to transmit at maximum duty cycle (and maximum power) for {one WLAN time-window duration (*TWLAN* = 30s for all WLAN frequency bands for FCC, 360s for ICNIRP) + the maximum high power duration allowed in one *TWLAN*}, denoted *TB_WLAN*.

iii. Section C: After *TB_WLAN* , add the selected WWAN and BT radios to have the simultaneous transmission of WWAN + WLAN + BT. Request WWAN radio to transmit at maximum power and request WLAN & BT radios to transmit at maximum duty cycle (and maximum power) for at least one max{*TA_WWAN*, *TB_WLAN*, *TBT*}, where, *TBT* = 100s for FCC, 360s for ICNIRP.

iv. Section D: Drop WWAN connection and set WWAN modem into airplane mode. Continue requesting WLAN & BT radios to transmit at maximum duty cycle (and maximum power) for at least two times the max{ *TWLAN*, *TBT*}.

v. Section E: Drop WLAN connection. Continue requesting BT radio to transmit at maximum duty cycle (and maximum power). Continue the test for at least one *TBT* .

vi. Section F: In the case of FCC time windows, after at least one *TBT*, drop BT connection and establish back WLAN connection in selected radio configuration. Continue requesting WLAN radio to transmit at maximum duty cycle (and maximum power). Continue the test for at least one max { TWLAN, TBT}. In the case of ICNIRP time windows, Section F is not required.

4. Once the measurement is done, extract instantaneous Tx power versus time for all WWAN, WLAN and BT radios in selected configurations. Similar to technology/band switch test in Section 4.3.3, convert the conducted Tx power for both these radios into 1g_or_10gSAR value (see Eq. (7a) and (7b)) using corresponding technology/band Plimit measured in Step 1, and then perform running average over corresponding time-windows (i.e., 100s/60s for WWAN radio, 30s for WLAN radio and 100s for BT radio in case of FCC time-windows, and 360s for all of them in case of ICNIRP time-windows) to determine time-averaged 1g_or_10gSAR versus time as illustrated in Figure 4-1.
5. Make one plot containing: (a) computed normalized time-averaged 1g_or_10gSAR for WWAN radio configuration versus time determined in Step 4, (b) computed normalized time- averaged 1g_or_10gSAR for WLAN radio configuration versus time determined in Step 4, (c) computed normalized time-averaged 1g_or_10gSAR for WLAN radio configuration versus time determined in Step 4, (d) computed total normalized time-averaged 1g_or_10gSAR versus time (sum of Steps (5.a), (5.b) and (5.c)) determined in Step 4, and (e) corresponding normalized regulatory 1g_or_10gSARlimit limit of 1.0.

The validation criteria is, at all times, the time-averaged 1g_or_10gSAR versus time shall not exceed the regulatory 1g_or_10gSARlimit limit.

**NOTE:** If *multi_Tx_factor* is set to > 1.0 with EFS version 19 (or higher), then in single Tx transmission scenarios, Smart Transmit ensures time-averaged RF exposure is ≤ (*SAR_design_target* * $10^{(+\text{ sub6 device uncertainty}/10)}$) < regulatory RF exposure limit for sub6 radio managed by Smart Transmit. In simultaneous Tx transmission scenarios, Smart Transmit ensures time-averaged RF exposure is ≤ (*SAR_design_target* * *multi_Tx_factor* * $10^{(+\text{ sub6 device uncertainty}/10)}$) < regulatory RF exposure limit for sub6 radios managed by Smart Transmit. These simultaneous transmission scenarios are listed below:

- 2-or-more radio scenarios within WWAN like EN-DC, LTE ULCA, etc.
- 2-or-more-radio across technologies such as WWAN+WLAN, WWAN+BT, WLAN+BT and WWAN+WLAN+BT transmission scenarios (if WLAN/BT radios are also managed by Smart Transmit).

## 4.4 Test procedure for time-varying SAR measurements

This section provides general time-varying SAR measurement procedures to perform compliance test under dynamic transmission scenarios described in Section 3. In practice, an adjustment can be made in these procedures. The justification/clarification may be provided.

To perform the validation through SAR measurement for transmission scenario 1 described in Section 3, the "path loss" between callbox antenna and DUT needs to be calibrated to ensure that the DUT Tx power reacts to the requested power from callbox in a radiated call. It should be noted that when signaling in closed loop mode, protocol-level power control is in play, resulting in DUT not solely following callbox TPC (Tx power control) commands. In other words, DUT response has many dependencies (RSSI, quality of signal, path loss variation, fading, etc.,) other than just TPC commands. These dependencies have less impact in conducted setup (as it is a controlled environment and the path loss can be very well calibrated) but have significant impact on radiated testing in an uncontrolled environment, such as SAR test setup. Therefore, the deviation in DUT Tx power from callbox requested power is expected, however the time-averaged SAR should not exceed FCC SAR requirement at all times as Smart Transmit controls Tx power at DUT.

The following steps are for time averaging feature validation through SAR measurement:

1. "Path Loss" calibration: Place the DUT against the phantom in the worst-case position determined based on Section 4.2.1. For each band selected, prior to SAR measurement, perform "path loss" calibration between callbox antenna and DUT. Since the SAR test environment is not controlled and well calibrated for OTA (Over the Air) test, extreme care needs to be taken to avoid the influence from reflections. The test setup is described in Section 6.2.

2. Time averaging feature validation:

   i For a given radio configuration (technology/band) selected in Section 4.2.1, enable Smart Transmit peak exposure mode, with callbox to request maximum power, perform area scan, conduct pointSAR measurement at peak location of the area scan. This point SAR value, *pointSAR_*$P_{limit}$, corresponds to point SAR at the measured $P_{limit}$ (i.e., measured $P_{limit}$ from the DUT in Step 1 of Section 4.3.1).

   ii Set DUT to the intended Smart Transmit exposure mode. Note, if *Total_min_reserve* cannot be set wirelessly, care must be taken to re-position the DUT in the exact same position relative to the SAM phantom as in above Step 2.i. Establish radio link in desired radio configuration, with callbox requesting the DUT's Tx power at power levels described by test sequence 1 generated in Step 1 of Section 4.3.1, conduct point SAR measurement versus time at peak location of the area scan determined in Step 2.i of this section. Once the measurement is done, extract instantaneous point SAR vs time data, *pointSAR(t)*, and convert it into instantaneous 1gSAR or 10gSAR vs. time using Eq. (3a), re-written below:

   $$1g\_or\_10gSAR(t) = \frac{pointSAR(t)}{pointSAR\_P_{limit}} * 1g\_or\_10gSAR\_P_{limit}$$

   where, *pointSAR_*$P_{limit}$ is the value determined in Step 2.i, and *pointSAR(t)* is the instantaneous point SAR measured in Step 2.ii, $1g\_or\_10gSAR\_P_{limit}$ is the measured 1gSAR or 10gSAR value listed in Part 1 report.

   iii Perform 100s running average to determine time-averaged 1gSAR or 10gSAR versus time.

   iv Make one plot containing: (a) time-averaged 1gSAR or 10gSAR versus time determined in Step 2.iii of this section, (b) FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

   v Repeat 2.ii ~ 2.iv for test sequence 2 generated in Step 1 of Section 4.3.1.

vi Repeat 2.i ~ 2.v for all the technologies and bands selected in Section 4.2.1.

The time-averaging validation criteria for SAR measurement is that, at all times, the time-averaged 1gSAR or 10gSAR versus time shall not exceed FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR (i.e., Eq. (3b)).

# 5 FCC MEASUREMENT PROCEDURES (FREQ > 6 GHZ)

This section provides the test plan and test procedures for validating Qualcomm Smart Transmit feature for mmW transmission. For this EUT, millimeter wave (mmW) transmission is only in non-standalone mode, i.e., it requires an LTE link as anchor.

## 5.1 Test sequence for validation in mmW NR transmission

In 5G mmW NR transmission, the test sequence for validation is with the callbox requesting EUT's Tx power in 5G mmW NR at maximum power all the time.

## 5.2 Test configuration selection criteria for validating Smart Transmit feature

### 5.2.1 Test configuration selection for time-varying Tx power transmission

The Smart Transmit time averaging operation is independent of bands, modes, channels, and antenna configurations (beams) for a given technology. Hence, validation of Smart Transmit in any one band/mode/channel per technology is sufficient. Two mmW bands are proposed and selected for this testing to provide high confidence in this validation (Note, the EUT used in this report is only supported in one mmW band).

The selection criteria for this measurement is to test EUT transmit in a beam containing highest number of elements (as it has lower *input.power.limit*). Additionally, for EUT enabled with Smart Transmit EFS version 18 (or higher) utilizing DSI applicability feature (see Section 10.1), since this test is performed in non-standalone (NSA) mode with a sub6 anchor, perform this test in a DSI that has *DSI_PD_ratio* < 1 (see equation 9b in Section 12.1) in the EFS for the selected beam.

### 5.2.2 Test configuration selection for change in antenna configuration (beam)

The Smart Transmit time averaging feature operation is independent of bands, modes, channels, and antenna configurations (beams) for a given technology. Hence, validation of Smart Transmit with beam switch between any two beams is sufficient.

**NOTE:** The selected two beams should be in the same module group if EUT is configured with GEN2_MMW or GEN2_SUB6_MMW.

### 5.2.3 Test configuration selection for SAR vs. PD exposure switch during transmission

The Smart Transmit time averaging feature operation is independent of the nature of exposure (SAR vs. PD) and ensures total time-averaged RF exposure compliance. Hence, validation of Smart Transmit in any one band/mode/channel/beam for mmW + sub-6 (LTE) transmission is sufficient, where the exposure varies among SAR dominant scenario, SAR+PD scenario, and PD only scenarios.

The selection criteria for this measurement is to test EUT transmit in a beam containing highest number of elements (as it has lower *input.power.limit*).

## 5.3 Test procedures for mmW radiated power measurements

Perform conducted power measurement (for f < 6GHz) and radiated power measurement (for f > 6GHz) for LTE + mmW transmission to validate Smart Transmit time averaging feature in the various transmission scenarios described in Section 3.

This section provides general conducted power measurement procedures to perform compliance test under dynamic transmission scenarios described in Section 3. In practice, an adjustment can be made in these procedures. The justification/clarification may be provided.

### 5.3.1 Time-varying Tx power scenario

The purpose of the test is to demonstrate the effectiveness of power limiting enforcement and that the time-averaged Tx power when converted into RF exposure values does not exceed the FCC limit at all times (see Eq. (2a), (2b) & (2c) in Section 3).

### Test procedure:

1. Measure conducted Tx power corresponding to $P_{limit}$ for LTE in selected band, and measure radiated Tx power corresponding to *input.power.limit* in desired mmW band/channel/beam by following below steps:
    a. Measure radiated power corresponding to mmW *input.power.limit* by setting up the EUT's Tx power in desired band/channel/beam at *input.power.limit* in Factory Test Mode (FTM). This test is performed in a calibrated anechoic chamber. Rotate the EUT to obtain maximum radiated Tx power, keep the EUT in this position and do not disturb the position of the EUT inside the anechoic chamber for the rest of this test.
    b. Reset EUT to place in online mode and establish radio link in LTE, measure conducted Tx power corresponding to LTE $P_{limit}$ with Smart Transmit peak exposure mode enabled, and callbox set to request maximum power.
2. Set DUT to the intended Smart Transmit exposure mode. With DUT setup for a mmW NR call in the desired/selected LTE band and mmW NR band, perform the following steps:
    a. Establish LTE and mmW NR connection in desired band/channel/beam used in Step 1. As soon as the mmW connection is established, immediately request all-down bits on LTE link. With callbox requesting EUT's Tx power to be at maximum mmW power to test predominantly PD exposure scenario (as SAR exposure is less when LTE's Tx power is at low power).
    b. After 120s, request LTE to go all-up bits for at least 100s. SAR exposure is dominant. There are two scenarios:
        i If $P_{limit} < P_{max}$ for LTE, then the RF exposure margin (provided to mmW NR) gradually runs out (due to high SAR exposure). This results in gradual reduction in the 5G mmW NR transmission power and eventually seized 5G mmW NR transmission when LTE goes to $P_{reserve}$ level.
        ii If $P_{limit} \geq P_{max}$ for LTE, then the 5G mmW NR transmission's averaged power should gradually reduce but the mmW NR connection can sustain all the time (assuming TxAGC uncertainty = 0dB).
    c. Record the conducted Tx power of LTE and radiated Tx power of mmW for the full duration of this test of at least 300s.

3. Once the measurement is done, extract instantaneous Tx power versus time for both LTE and mmW links. Convert the conducted Tx power for LTE into 1gSAR or 10gSAR value using Eq. (2a) and $P_{limit}$ measured in Step 1.b, and then divide by FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR to obtain instantaneous normalized 1gSAR or 10gSAR versus time. Perform 100s running average to determine normalized 100s-averaged 1gSAR or 10gSAR versus time.

   NOTE: In Eq.(2a), instantaneous Tx power is converted into instantaneous 1gSAR or 10gSAR value by applying the measured worst-case 1gSAR or 10gSAR value at $P_{limit}$ for the corresponding technology/band/antenna/DSI reported in Part 1 report.

4. Similarly, convert the radiated Tx power for mmW into 4cm$^2$PD value using Eq. (2b) and the radiated Tx power limit (i.e., radiated Tx power at *input.power.limit*) measured in Step 1.a, then divide by FCC 4cm$^2$PD limit of 10W/m$^2$ to obtain instantaneous normalized 4cm$^2$PD versus time. Perform 4s running average to determine normalized 4s-averaged 4cm$^2$PD versus time.

   NOTE: In Eq.(2b), instantaneous radiated Tx power is converted into instantaneous 4cm$^2$PD by applying the worst-case 4cm$^2$PD value measured at *input.power.limit* for the selected band/beam in Part 1 report.

5. Make one plot containing: (a) instantaneous conducted Tx power for LTE versus time, (b) computed 100s-averaged conducted Tx power for LTE versus time, (c) instantaneous radiated Tx power for mmW versus time, as measured in Step 2, (d) computed 4s-averaged radiated Tx power for mmW versus time, and (e) time-averaged conducted and radiated power limits for LTE and mmW radio using Eq. (5a) & (5b), respectively:

$$Time\ avearged\ LTE\ power\ limit = meas.P_{limit} + 10 \times \log(\frac{FCC\ SAR\ limit}{meas.SAR\_Plimit}) \qquad (5a)$$

$$Time\ avearged\ mmW\ NR\ power\ limit = meas.EIRP_{input.power.limit} + 10 \times \log(\frac{FCC\ PD\ limit}{meas.PD\_input.power.limit}) \qquad (5b)$$

   where $meas.EIRP_{input.power.limit}$ and $meas.PD\_input.power.limit$ correspond to measured EIRP at *input.power.limit* and measured power density at *input.power.limit*.

6. Make another plot containing: (a) computed normalized 100s-averaged 1gSAR or 10gSAR versus time determined in Step 3, (b) computed normalized 4s-averaged 4cm$^2$PD versus time determined in Step 4, and (c) corresponding total normalized time-averaged RF exposure (sum of steps (6.a) and (6.b)) versus time.

The validation criteria are, at all times, the total normalized time-averaged RF exposure versus time determined in Step 6.c shall not exceed the normalized limit of 1.0 of FCC requirement (i.e., Eq. (2c)).

### 5.3.2 Switch in SAR vs. PD exposure during transmission

This test is to demonstrate that Smart Transmit feature is independent of the nature of exposure (SAR vs. PD), accurately accounts for switching in exposures among SAR dominant, SAR+PD, and PD dominant scenarios, and ensures total time-averaged RF exposure compliance.

## Test procedure:

1. Measure conducted Tx power corresponding to $P_{limit}$ for LTE in selected band, and measure radiated Tx power corresponding to *input.power.limit* in desired mmW band/channel/beam by following below steps:

   a. Measure radiated power corresponding to *input.power.limit* by setting up the EUT's Tx power in desired band/channel/beam at *input.power.limit* in FTM. This test is performed in a calibrated anechoic chamber. Rotate the EUT to obtain maximum radiated Tx power, keep the EUT in this position and do not disturb the position of the EUT inside the anechoic chamber for the rest of this test.

   b. Reset EUT to place in online mode and establish radio link in LTE, measure conducted Tx power corresponding to LTE $P_{limit}$ with Smart Transmit peak exposure mode enabled, and callbox set to request maximum power.

2. Set DUT to the intended Smart Transmit exposure mode. With DUT setup for LTE + mmW call, perform the following steps:

   a. Establish LTE (sub-6) and mmW NR connection with callbox.

   b. As soon as the mmW connection is established, immediately request all-down bits on LTE link. Continue LTE (all-down bits) + mmW transmission for more than 100s duration to test predominantly PD exposure scenario (as SAR exposure is negligible from all-down bits in LTE).

   c. After 120s, request LTE to go all-up bits, mmW transmission should gradually run out of RF exposure margin if LTE's $P_{limit} < P_{max}$ and seize mmW transmission (SAR only scenario); or mmW transmission should gradually reduce in Tx power and will sustain the connection if LTE's $P_{limit} > P_{max}$.

   d. After 75s, request LTE to go all-down bits, mmW transmission should start getting back RF exposure margin and resume transmission again.

   e. Record the conducted Tx power of LTE and radiated Tx power of mmW for the entire duration of this test of at least 300s.

3. Once the measurement is done, extract instantaneous Tx power versus time for both LTE and mmW links. Convert the conducted Tx power for LTE into 1gSAR or 10gSAR value using Eq. (2a) and $P_{limit}$ measured in Step 1.b, and then divide by FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR to obtain instantaneous normalized 1gSAR or 10gSAR versus time. Perform 100s running average to determine normalized 100s-averaged 1gSAR or 10gSAR versus time.

   NOTE: In Eq.(2a), instantaneous Tx power is converted into instantaneous 1gSAR or 10gSAR value by applying the measured worst-case 1gSAR or 10gSAR value at $P_{limit}$ for the corresponding technology/band/antenna/DSI reported in Part 1 report.

4. Similarly, convert the radiated Tx power for mmW into $4cm^2$PD value using Eq. (2b) and the radiated Tx power limit (i.e., radiated Tx power at *input.power.limit*) measured in Step 1.a, then divide this by FCC $4cm^2$PD limit of $10W/m^2$ to obtain instantaneous normalized $4cm^2$PD versus time. Perform 4s running average to determine normalized 4s-averaged $4cm^2$PD versus time.

NOTE: In Eq.(2b), instantaneous radiated Tx power is converted into instantaneous $4cm^2$PD by applying the worst-case $4cm^2$PD value measured at *input.power.limit* for the selected band/beam in Part 1 report.

5. Make one plot containing: (a) instantaneous conducted Tx power for LTE versus time, (b) computed 100s-averaged conducted Tx power for LTE versus time, (c) instantaneous radiated Tx power for mmW versus time, as measured in Step 2, (d) computed 4s-averaged radiated Tx power for mmW versus time, and (e) time-averaged conducted and radiated power limits for LTE and mmW radio using Eq. (5a) & (5b), respectively.
6. Make another plot containing: (a) computed normalized 100s-averaged 1gSAR or 10gSAR versus time determined in Step 3, (b) computed normalized 4s-averaged $4cm^2$PD versus time determined in Step 4, and (c) corresponding total normalized time-averaged RF exposure (sum of steps (6.a) and (6.b)) versus time.

The validation criteria are, at all times, the total normalized time-averaged RF exposure versus time determined in Step 6.c shall not exceed the normalized limit of 1.0 of FCC requirement (i.e., Eq. (2c)).

### 5.3.3 Change in antenna configuration (beam)

This test is to demonstrate the correct power control by Smart Transmit during changes in antenna configuration (beam). Since the *input.power.limit* varies with beam, the Eq. (2a), (2b) and (2c) in Section 3 are written as below for transmission scenario having change in beam,

$$1g\_or\_10gSAR(t) = \frac{conducted\_Tx\_power(t)}{conducted\_Tx\_power\_P_{limit}} * 1g\_or\_10gSAR\_P_{limit} \quad (8a)$$

$$4cm^2PD_1(t) = \frac{radiated\_Tx\_power\_1(t)}{radiated\_Tx\_power\_input.power.limit\_1} * 4cm^2PD\_input.power.limit\_1 \quad (8b)$$

$$4cm^2PD_2(t) = \frac{radiated\_Tx\_power\_2(t)}{radiated\_Tx\_power\_input.power.limit\_2} * 4cm^2PD\_input.power.limit\_2 \quad (8c)$$

$$\frac{\frac{1}{T_{SAR}}\int_{t-T_{SAR}}^{t} 1g\_or\_10gSAR(t)dt}{FCC\ SAR\ limit} + \frac{\frac{1}{T_{PD}}\left[\int_{t-T_{PD}}^{t_1} 4cm^2\mathrm{PD}_1(t)dt + \int_{t1}^{t} 4cm^2\mathrm{PD}_2(t)dt\right]}{FCC 4cm^2\ PD\ limit} \leq 1 \quad (8d)$$

where, $conducted\_Tx\_power(t)$, $conducted\_Tx\_power\_P_{limit}$, and $1g\_or\_10gSAR\_P_{limit}$ correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at $P_{limit}$, and measured *1gSAR or 10gSAR* values at $P_{limit}$ corresponding to LTE transmission. Similarly, *radiated_Tx_power_1(t)*, *radiated_Tx_power_input.power.limit_1*, and *$4cm^2$PD_input.power.limit_1* correspond to the measured instantaneous radiated Tx power, radiated Tx power at *input.power.limit*, and *$4cm^2$PD* value at *input.power.limit* of beam 1; *radiated_Tx_power_2(t)*, *radiated_Tx_power_input.power.limit_2*, and *$4cm^2$PD_input.power.limit_2* correspond to the measured instantaneous radiated Tx power, radiated Tx power at *input.power.limit*, and *$4cm^2$PD* value at *input.power.limit* of beam 2 corresponding to mmW transmission.

## Test procedure:

1. Measure conducted Tx power corresponding to $P_{limit}$ for LTE in selected band, and measure radiated Tx power corresponding to *input.power.limit* in desired mmW band/channel/beam by following below steps:
   a. Measure radiated power corresponding to mmW *input.power.limit* by setting up the EUT's Tx power in desired band/channel at *input.power.limit* of beam 1 in FTM. Do not disturb the position of the EUT inside the anechoic chamber for the rest of this test. Repeat this Step 1.a for beam 2.
   b. Reset EUT to place in online mode and establish radio link in LTE, measure conducted Tx power corresponding to LTE $P_{limit}$ with Smart Transmit peak exposure mode enabled, and callbox set to request maximum power.
2. Set DUT to the intended Smart Transmit exposure mode. With DUT setup for LTE + mmW connection, perform the following steps:
   a. Establish LTE (sub-6) and mmW NR connection in beam 1. As soon as the mmW connection is established, immediately request all-down bits on LTE link with the callbox requesting EUT's Tx power to be at maximum mmW power.
   b. After beam 1 continues transmission for at least 20s, request the EUT to change from beam 1 to beam 2, and continue transmitting with beam 2 for at least 20s.
   c. Record the conducted Tx power of LTE and radiated Tx power of mmW for the entire duration of this test.
3. Once the measurement is done, extract instantaneous Tx power versus time for both LTE and mmW links. Convert the conducted Tx power for LTE into 1gSAR or 10gSAR value using the similar approach described in Step 3 of Section 5.3.2. Perform 100s running average to determine normalized 100s-averaged 1gSAR versus time.
4. Similarly, convert the radiated Tx power for mmW NR into $4cm^2$PD value using Eq. (8b), (8c) and the radiated Tx power limits (i.e., radiated Tx power at *input.power.limit*) measured in Step 1.a for beam 1 and beam 2, respectively, and then divide the resulted PD values by FCC $4cm^2$PD limit of $10W/m^2$ to obtain instantaneous normalized $4cm^2$PD versus time for beam 1 and beam 2. Perform 4s running average to determine normalized 4s-averaged $4cm^2$PD versus time.

   NOTE: In Eq.(8b) and (8c), instantaneous radiated Tx power of beam 1 and beam 2 is converted into instantaneous $4cm^2$PD by applying the worst-case $4cm^2$PD value measured at the *input.power.limit* of beam 1 and beam 2 in Part 1 report, respectively.

5. Since the measured radiated powers for beam 1 and beam 2 in Step 1.a were performed at an arbitrary rotation of EUT in anechoic chamber, repeat Step 1.a of this procedure by rotating the EUT to determine maximum radiated power at *input.power.limit* in FTM mode for both beams separately. Re-scale the measured instantaneous radiated power in Step 2.c by the delta in radiated power measured in Step 5 and the radiated power measured in Step 1.a for plotting purposes in next Step. In other words, this step essentially converts measured instantaneous radiated power during the measurement in Step 2 into maximum instantaneous radiated power for both beams. Perform 4s running average to compute 4s-averaged radiated Tx power. Additionally, use these EIRP values measured at *input.power.limit* at respective peak locations to determine the EIRP limits (using Eq. (5b)) for both these beams.

6. Make one plot containing: (a) instantaneous conducted Tx power for LTE versus time, (b) computed 100s-averaged conducted Tx power for LTE versus time, (c) instantaneous radiated Tx power for mmW versus time, as obtained in Step 5, (d) computed 4s-averaged radiated Tx power for mmW versus time, as obtained in Step 5, and (e) time-averaged conducted and radiated power limits for LTE and mmW radio, respectively.
7. Make another plot containing: (a) computed normalized 100s-averaged 1gSAR versus time determined in Step 3, (b) computed normalized 4s-averaged 4cm$^2$PD versus time determined in Step 4, and (c) corresponding total normalized time-averaged RF exposure (sum of steps (6.a) and (6.b)) versus time.

The validation criteria are, at all times, the total normalized time-averaged RF exposure versus time determined in Step 6.c shall not exceed the normalized limit of 1.0 of FCC requirement (i.e., (8d)).

## 5.4 Test procedure for time-varying PD measurements

The following steps are used to perform the validation through PD measurement for transmission scenario 1 described in Section 3:

1. Place the EUT on the cDASY6 platform to perform PD measurement in the worst-case position/surface for the selected mmW band/beam. In PD measurement, the callbox is set to request maximum Tx power from EUT all the time. Hence, “path loss” calibration between callbox antenna and EUT is not needed in this test.
2. Time averaging feature validation:
   a. Measure conducted Tx power corresponding to $P_{limit}$ for LTE in selected band, and measure point E-field corresponding to *input.power.limit* in desired mmW band/channel/beam by following the below steps:
      i. Measure conducted Tx power corresponding to LTE $P_{limit}$ with Smart Transmit Peak exposure mode enabled, with callbox set to request maximum power.
      ii. Measure point E-field at peak location of fast area scan corresponding to *input.power.limit* by setting up the EUT’s Tx power in desired mmW band/channel/beam at *input.power.limit* in FTM. Do not disturb the position of EUT and mmW cDASY6 probe.
   b. Set EUT to the intended Smart Transmit exposure mode, place EUT in online mode. With EUT setup for LTE (sub-6) + mmW NR call, as soon as the mmW NR connection is established, request all-down bits on LTE link. Continue LTE (all-down bits) + mmW transmission for more than 100s duration to test predominantly PD exposure scenario. After 120s, request LTE to go all-up bits, mmW transmission should gradually reduce. Simultaneously, record the conducted Tx power of LTE transmission using power meter and point E-field (in terms of ratio of $\frac{[pointE(t)]^2}{[pointE\_input.power.limit]^2}$) of mmW transmission using cDASY6 E-field probe at peak location identified in Step 2.a.ii for the entire duration of this test of at least 300s.
   c. Once the measurement is done, extract instantaneous conducted Tx power versus time for LTE transmission and $\frac{[pointE(t)]^2}{[pointE\_input.power.limit]^2}$ ratio versus time from cDASY6 system for mmW transmission. Convert the conducted Tx power for LTE into 1gSAR or 10gSAR value using Eq. (4a) and $P_{limit}$ measured in Step 2.a.i, and then divide this by FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR to obtain instantaneous normalized 1gSAR or 10gSAR versus time.

Perform 100s running average to determine normalized 100s-averaged 1gSAR or 10gSAR versus time

NOTE: In Eq.(4a), instantaneous Tx power is converted into instantaneous 1gSAR or 10gSAR value by applying the measured worst-case 1gSAR or 10gSAR value at $P_{limit}$ for the corresponding technology/band reported in Part 1 report.

d. Similarly, convert the point E-field for mmW transmission into $4cm^2$PD value using Eq. (4b) and radiated power limit measured in Step 2.a.ii, and then divide this by FCC $4cm^2$PD limit of $10W/m^2$ to obtain instantaneous normalized $4cm^2$PD versus time. Perform 4s running average to determine normalized 4s-averaged $4cm^2$PD versus time.

e. Make one plot containing: (i) computed normalized 100s-averaged 1gSAR or 10gSAR versus time determined in Step 2.c, (ii) computed normalized 4s-averaged $4cm^2$PD versus time determined in Step 2.d, and (iii) corresponding total normalized time-averaged RF exposure (sum of steps (2.e.i) and (2.e.ii)) versus time.

The validation criteria are, at all times, the total normalized time-averaged RF exposure versus time determined in Step 2.e.iii shall not exceed the normalized limit of 1.0 of FCC requirement (i.e., Eq. (4c)).

# 6 MEASUREMENT TEST SETUP (FREQ < 6 GHZ)

## 6.1 Conducted Measurement Test setup

Legacy test setup

The Rohde & Schwarz CMW500 callbox was used in this test. The test setup schematic is shown in Figure 6-1a (Appendix D – Test Setup Photo 1, 2, and 3) for measurements with a single antenna of DUT and antenna switching manually. For the measurement one port (RF1 COM) of the callbox is connected to the RF port of the DUT using a directional coupler.

In the setups, a power meter is used to tap the directional coupler for measuring the conducted output power of the DUT. For all legacy conducted tests, only RF1 COM port of the callbox is used to communicate with the DUT.

All the path losses from RF port of DUT to the callbox RF COM port and to the power meter are calibrated and automatically entered as offsets in the callbox and the power meter via test scripts on the PC used to control callbox and power meter

Sub6 NR test setup:

The Anritsu MT8000A callbox was used in this test. The test setup schematic is the same as the Legacy Test Setup shown in Figure 6-1a (Appendix D – Test Setup Photo 4 and 5). One port of the callbox is connected to the RF port of the DUT using a directional coupler. In the setup, the power meter is used to tap the directional coupler for measuring the conducted output power of the DUT.

All the path losses from RF port of DUT to the callbox RF COM port and to the power meter are calibrated and automatically entered as offsets in the callbox and the power meter via test scripts on the PC used to control callbox and power meter.

LTE+Sub6 NR test setup:

LTE conducted port and Sub6 NR conducted port are different on this EUT, therefore, the LTE and Sub6 NR signals for power meter measurement are performed on separate paths as shown below in Figure 6-1b (Appendix D – Test Setup Photo 8).

All the path losses from RF port of DUT to the callbox RF COM port and to the power meter are calibrated and automatically entered as offsets in the callbox and the power meter via test scripts on the PC used to control callbox and power meter.

WLAN SISO test setup:

The Rohde & Schwarz CMW500 callbox was used in this test. The test setup schematic is shown in Figure 6-1c (Appendix D – Test Setup Photo 6 and 7).

All the path losses from RF port of DUT to the callbox RF COM port and to the power meter are calibrated and automatically entered as offsets in the callbox and the power meter via test scripts on the PC used to control callbox and power meter.

WLAN DBS test setup:

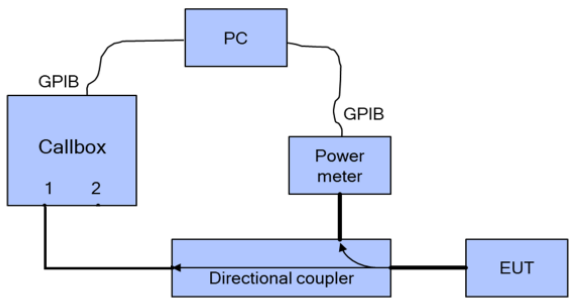
The Rohde & Schwarz CMW500 callbox was used in this test. WLAN 2.4GHz port and WLAN 5GHz conducted port are the same on this EUT, therefore, the WLAN signals for power meter measurement are performed on separate paths as shown below in Figure 6-1d (Appendix D – Test Setup Photo 9).

All the path losses from RF port of DUT to the callbox RF COM port and to the power meter are calibrated and automatically entered as offsets in the callbox and the power meter via test scripts on the PC used to control callbox and power meter.

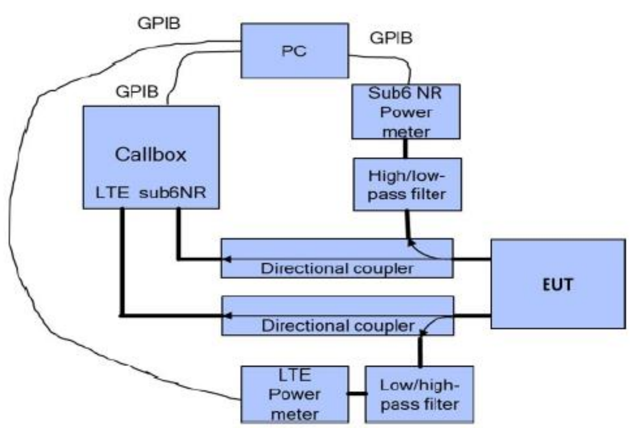
System continuity test setup:

The Rohde & Schwarz CMW500 callbox was used in this test. WWAN conducted port and BT conducted port are the same on this EUT, while the WLAN conducted port is separate. Therefore the WWAN, WLAN, and BT signals for power meter measurement are performed on paths shown below in Figure 6-1f (Appendix D – Test Setup Photo 9).

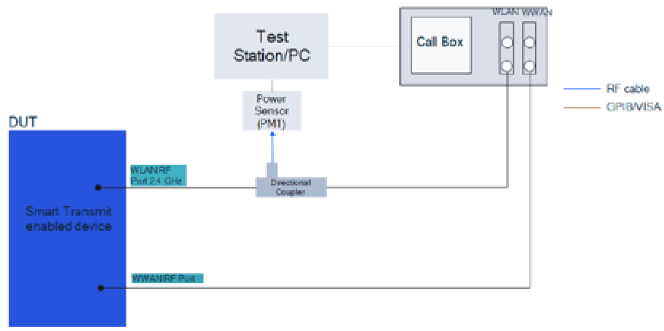
All the path losses from RF port of DUT to the callbox RF COM port and to the power meter are calibrated and automatically entered as offsets in the callbox and the power meter via test scripts on the PC used to control callbox and power meter.



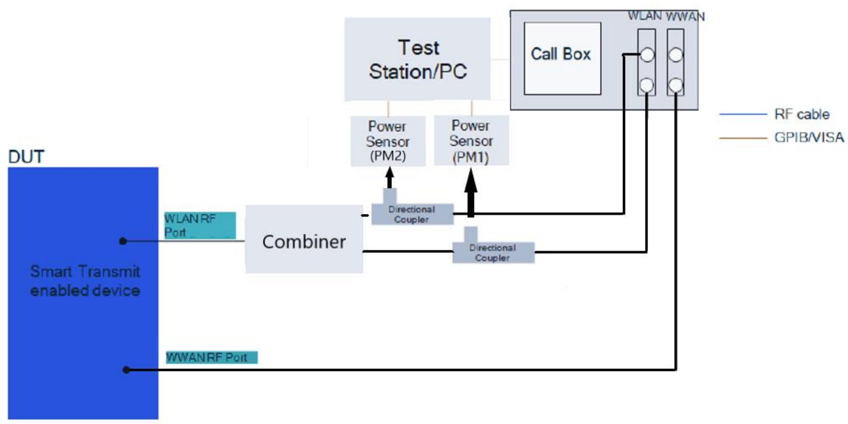

(a) Appendix D – Test Setup Photo 1, 2, 3, 4, 5



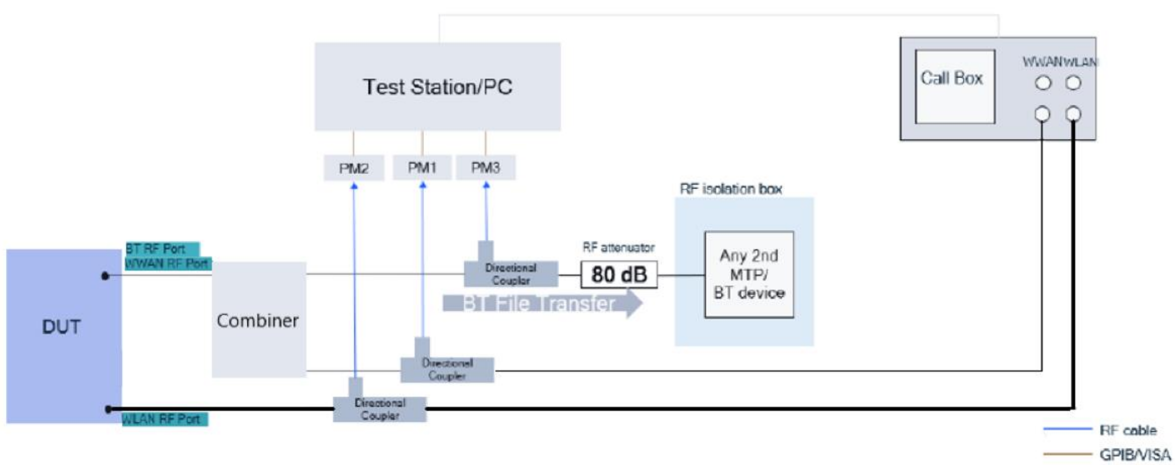

(b) Appendix D – Test Setup Photo 8




(c) Appendix D – Test Setup Photo 6 and 7




(d) Appendix D – Test Setup Photo 9




(e) Appendix D – Test Setup Photo 10

**Figure 6-1**

**Conducted power measurement setup**

Both the callbox and power meter are connected to the PC using GPIB cables. Two test scripts are custom made for automation, and the test duration set in the test scripts is 500 seconds.

For time-varying Tx power measurement, the PC runs the 1st test script to send GPIB commands to control the callbox's requested power versus time, while at the same time to record the conducted power measured at DUT RF port using the power meter. The commands sent to the callbox to request power are:

- 0dBm for 100 seconds
- test sequence 1 or test sequence 2 (defined in Section 4.1 and generated in Section 4.2.1), for 360 seconds.
- stay at the last power level of test sequence 1 or test sequence 2 for the remaining time.

Power meter readings are periodically recorded every 100ms. A running average of this measured Tx power over 100 seconds is performed in the post-data processing to determine the 100s-time averaged power.

For call drop, technology/band/antenna switch, and DSI switch tests, after the call is established, the callbox is set to request the DUT's Tx power at 0dBm for 100 seconds while simultaneously starting the 2nd test script runs at the same time to start recording the Tx power measured at DUT RF port using the power meter. After the initial 100 seconds since starting the Tx power recording, the callbox is set to request maximum power from the DUT for the rest of the test. Note that the call drop/re-establish, or technology/band/antenna switch or DSI switch is manually performed when the Tx power of DUT is at $P_{reserve}$ level. See Section 4.3 for detailed test procedure of call drop test, technology/band/antenna switch test and DSI switch test.

## 6.2 SAR Measurement setup

The measurement setup is similar to normal SAR measurements as described in the Part 1 Test Report. The difference in SAR measurement setup for time averaging feature validation is that the callbox is signaling in close loop power control mode (instead of requesting maximum power in open loop control mode) and callbox is connected to the PC using GPIB so that the test script executed on PC can send GPIB commands to control the callbox's requested power over time (test sequence). The same test script used in conducted setup for time-varying Tx power measurements is also used in this section for running the test sequences during SAR measurements, and the recorded values from the disconnected power meter by the test script were discarded.

As mentioned in Section 4.4, for DUT to follow TPC command sent from the callbox wirelessly, the "path loss" between callbox antenna and the DUT needs to be very well calibrated. Since the SAR chamber is in uncontrolled environment, precautions must be taken to minimize the environmental influences on "path loss". Similarly, in the case of time-varying SAR measurements in Sub6 NR (with LTE as anchor), "path loss" between callbox antenna and the EUT needs to be carefully calibrated for both LTE link as well as for Sub6 NR link.

The DUT is placed in worst-case position according to Table 8-2.

# 7 MEASUREMENT TEST SETUP (FREQ > 6 GHZ)

## 7.1 Radiated Power Measurement Test setup

The Keysight Technologies E7515B UXM callbox is used in this test. The schematic of the setup is shown in Figure 7-1. The UXM callbox has two RF radio heads to up/down convert IF to mmW frequencies, which in turn are connected to two horn antennas for V- and H-polarizations for downlink communication. In the uplink, a directional coupler is used in the path of one of the horn antennas to measure and record radiated power using a Rohde & Schwarz NRP50S power sensor. Note here that the isolation of the directional coupler may not be sufficient to attenuate the downlink signal from the callbox, which will result in high noise floor masking the recording of radiated power from EUT. In that case, either lower the downlink signal strength emanating from the RF radio heads of callbox or add an attenuator between callbox radio heads and directional coupler. Additionally, note that since the measurements performed in this validation are all relative, measurement of EUT's radiated power in one polarization is sufficient. The EUT is placed inside an anechoic chamber with V- and H-pol horn antennas to establish the radio link as shown in Figure 7-1. The callbox's LTE port is directly connected to the EUT's RF port via a directional coupler to measure the EUT's conducted Tx power using a Rohde & Schwarz NRP8S power sensor. Additionally, EUT is connected to the PC via USB connection for sending beam switch command. Care is taken to route the USB cable and RF cable (for LTE connection) away from the EUT's mmW antenna modules.

Setup in Figure 7-1 is used for the test scenario 1, 5 and 6 described in Section 3. The test procedures described in Section 5 are followed. The path losses from the EUT to both the power meters are calibrated and used as offset in the power meter.

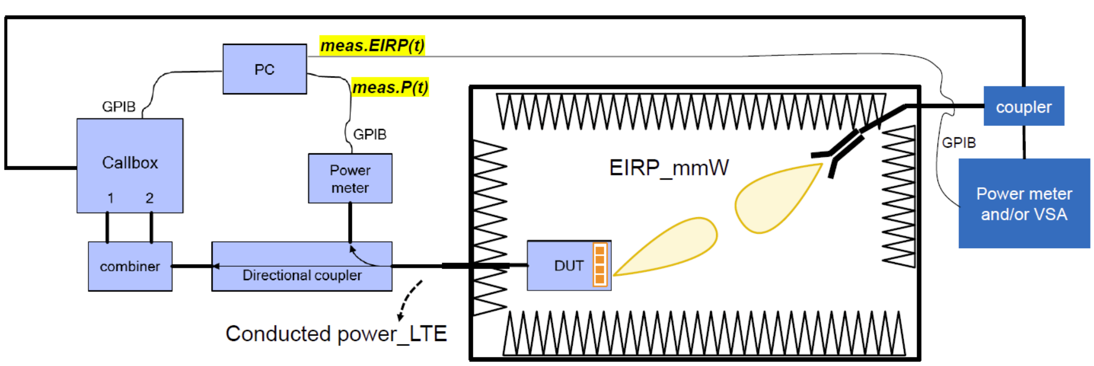



**Figure 7-1**
**mmW NR radiated power measurement setup – Test Setup Photos 11**

Both the callbox and power meters are connected to the PC using USB cables. Test scripts are custom made for automation of establishing LTE + mmW call, LTE + sub6 NR call, and sub6 NR + mmW call conducted Tx powers recording for LTE, sub6 NR and radiated Tx power recording for mmW. These tests are manually stopped after desired time duration. Test script is programmed to set LTE Tx power to all-down bits on the callbox immediately after the mmW link is established and programmed to set toggle between all-up and all-down bits depending on the transmission scenario being evaluated. Similarly, test script is also programmed to send beam switch command manually to the EUT via USB connection. For all the tests, the callbox is set to request maximum Tx power in mmW NR radio from EUT all the time.

Test configurations for this validation are detailed in Section 5.2. Test procedures are listed in Section 5.3.

## 7.2 Power Density Measurement Test setup

The measurement setup is similar to normal PD measurements, the EUT is positioned on cDASY6 platform, and is connected with the callbox (conducted for LTE and wirelessly for mmW). Keysight UXM callbox is set to request maximum mmW Tx power from EUT all the time. Hence, "path loss" calibration between callbox antenna and EUT is not needed in this test. The callbox's LTE port is directly connected to the EUT's RF port via a directional coupler to measure the EUT's conducted Tx power using a Rohde & Schwarz NRP8S power sensor. Additionally, EUT is connected to the PC via USB connection for toggling between FTM and online mode with Smart Transmit enabled following the test procedures described Section 5.4.

Worst-surface of EUT (for the mmW beam being tested) is positioned facing up for PD measurement with cDASY6 mmW probe. Figure 7-2 shows the schematic of this measurement setup.

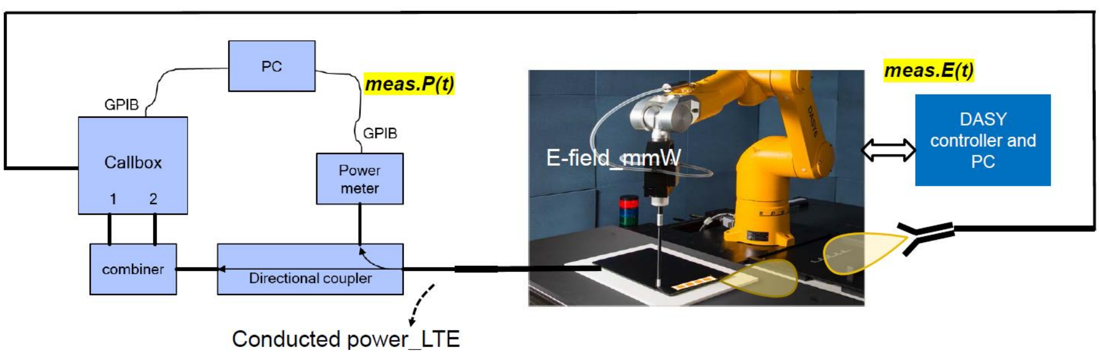



**Figure 7-2**
**Power Density Measurement Setup – Test Setup Photos 12**

Both callbox and power meters are connected to the PC using USB cables. Test scripts are custom made for automation of establishing LTE + mmW call, and for conducted Tx power recording of LTE transmission. These tests are manually stopped after desired time duration. Once the mmW link is established, LTE Tx power is programmed to toggle between all-up and all-down bits on the callbox. For all the tests, the callbox is set to request maximum Tx power in mmW NR radio from EUT all the time. Therefore, the calibration for the pathloss between the EUT and the horn antenna connected to the remote radio head of the callbox is not required.

Power meter readings are periodically recorded every 10ms on NR8S power sensor for LTE conducted Tx power. Time-averaged E-field measurements are performed using EUmmWV4 mmW probe at peak location of fast area scan. The distance between EUmmWV4 mmW probe tip to EUT surface is ~0.5 mm, and the distance between EUmmWV4 mmW probe sensor to probe tip is 1.5 mm. cDASY6 records relative point E-field (i.e., ratio $\frac{[pointE(t)]^2}{[pointE\_input.power.limit]^2}$) versus time for mmW NR transmission.

# 8 TEST CONFIGURATIONS (FREQ < 6 GHZ)

## 8.1 WWAN (sub-6) transmission

The $P_{limit}$ values, corresponding to 1.0 W/kg (1gSAR) and 2.5 W/kg (10gSAR) of *SAR_design_target*, for technologies and bands supported by DUT are derived in Part 0 report and summarized in Table 8-1. Note all $P_{limit}$ power levels entered in Table 8-1 correspond to average power levels after accounting for duty cycle in the case of TDD modulation schemes.

**Table 8-1**
**$P_{limit}$ for supported technologies and bands ($P_{limit}$ in EFS file)**

| Exposure Scenario | | | Maximum Tune-Up Output Power* | Body-Worn, Hotspot, or Phablet | Head |
|---|---|---|---|---|---|
| Averaging Volume | | | | 1g/10g | 1g |
| Spacing | | | | 10mm, 0mm | 0mm |
| Configuration | | | | | |
| DSI | | | | 0 | 1 |
| Technology/Band | Antenna | Antenna Group | Pmax | | |
| GSM 850 | E | AG1 | 24.6 | 27.6 | 21.8 |
| GSM 850 | A | AG0 | 25.1 | 26.4 | 30.0 |
| GSM 1900 | A | AG0 | 21.8 | 18.8 | 29.3 |
| UMTS 850 | E | AG1 | 23.5 | 25.2 | 21.5 |
| UMTS 850 | A | AG0 | 24.0 | 24.9 | 29.4 |
| UMTS 1750 | A | AG0 | 23.0 | 19.0 | 28.7 |
| UMTS 1900 | A | AG0 | 23.0 | 18.0 | 31.1 |
| LTE Band 71 | A | AG0 | 24.0 | 26.9 | 28.3 |
| LTE Band 71 | E | AG1 | 23.5 | 26.2 | 22.8 |
| LTE Band 12 | A | AG0 | 24.3 | 26.1 | 27.2 |
| LTE Band 12 | E | AG1 | 23.8 | 26.6 | 22.0 |
| LTE Band 13 | A | AG0 | 24.0 | 25.2 | 27.6 |
| LTE Band 13 | E | AG1 | 23.5 | 26.1 | 23.0 |
| LTE Band 14 | A | AG0 | 24.3 | 25.2 | 27.2 |
| LTE Band 14 | E | AG1 | 23.8 | 26.1 | 22.0 |
| LTE Band 26/5 | E | AG1 | 23.5 | 26.2 | 21.0 |
| LTE Band 26/5 | A | AG0 | 24.0 | 25.5 | 29.6 |
| LTE Band 66/4 | A | AG0 | 23.5 | 18.5 | 28.1 |
| LTE Band 66/4 | F | AG1 | 23.5 | 20.5 | 18.5 |
| LTE Band 25/2 | A | AG0 | 23.5 | 18.0 | 28.4 |
| LTE Band 25/2 | F | AG1 | 23.5 | 20.0 | 18.5 |
| LTE Band 30 | F | AG1 | 22.5 | 20.0 | 18.0 |
| LTE Band 30 | A | AG0 | 22.5 | 19.5 | 32.4 |
| LTE Band 7 | B | AG0 | 23.0 | 19.5 | 28.0 |
| LTE Band 7 | F | AG1 | 23.0 | 19.5 | 16.0 |
| LTE Band 41/38 PC3 | B | AG0 | 22.0 | 19.5 | 27.1 |
| LTE Band 41/38 PC3 | F | AG1 | 22.0 | 19.5 | 16.5 |
| LTE Band 41 PC2 | B | AG0 | 22.1 | 19.5 | 27.1 |
| LTE Band 41 PC2 | F | AG1 | 22.1 | 19.5 | 16.5 |
| LTE Band 48 | F | AG1 | 20.5 | 20.0 | 16.5 |
| NR Band n71 | A | AG0 | 24.0 | 26.9 | 28.2 |
| NR Band n71 | E | AG1 | 23.5 | 25.3 | 22.0 |
| NR Band n12 | A | AG0 | 24.3 | 26.9 | 28.0 |
| NR Band n12 | E | AG1 | 23.8 | 25.9 | 21.0 |
| NR Band n26/n5 | E | AG1 | 23.5 | 25.9 | 21.0 |
| NR Band n26/n5 | A | AG0 | 24.0 | 25.2 | 29.7 |
| NR Band n70 | A | AG0 | 23.0 | 19.0 | 32.7 |
| NR Band n70 | F | AG1 | 23.0 | 21.5 | 19.0 |
| NR Band n66 | A | AG0 | 23.5 | 18.5 | 28.0 |
| NR Band n66 | F | AG1 | 23.5 | 20.5 | 18.5 |
| NR Band n25/n2 | A | AG0 | 23.5 | 18.0 | 27.3 |
| NR Band n25/n2 | F | AG1 | 23.5 | 20.0 | 18.5 |
| NR Band n30 | F | AG1 | 22.5 | 20.0 | 18.0 |
| NR Band n30 | A | AG0 | 22.5 | 19.5 | 32.3 |
| NR Band n7 | B | AG0 | 23.0 | 19.5 | 27.9 |
| NR Band n7 | F | AG1 | 23.0 | 19.4 | 16.0 |
| NR Band n41 PC2 (Path 1) | F | AG1 | 26.0 | 19.0 | 16.5 |
| NR Band n41 PC2 (Path 1) | B | AG0 | 22.0 | 17.5 | 19.0 |
| NR Band n41 PC2 (Path 1) | E | AG1 | 23.0 | 17.0 | 17.0 |
| NR Band n41 PC2 (Path 1) | D | AG0 | 21.0 | 16.5 | 16.5 |
| NR Band n41 PC2 (Path 2) | B | AG0 | 26.0 | 19.5 | 21.0 |
| NR Band n41 PC2 (Path 2) | F | AG1 | 20.5 | 17.0 | 15.0 |
| NR Band n41 PC2 (Path 2) | D | AG0 | 22.0 | 17.0 | 17.0 |
| NR Band n41 PC2 (Path 2) | E | AG1 | 17.0 | 14.0 | 14.0 |
| NR Band n38 | F | AG1 | 24.0 | 19.0 | 16.5 |
| NR Band n38 | B | AG0 | 24.0 | 19.5 | 21.0 |
| NR Band n48 | F | AG1 | 22.5 | 20.0 | 16.5 |
| NR Band n48 | C | AG0 | 16.5 | 14.5 | 11.5 |
| NR Band n48 | I | AG1 | 21.0 | 19.0 | 16.0 |
| NR Band n48 | D | AG0 | 17.0 | 14.5 | 11.5 |
| NR Band n78 PC2 | F | AG1 | 26.0 | 18.5 | 16.0 |
| NR Band n78 PC2 | C | AG0 | 20.0 | 15.0 | 11.5 |
| NR Band n78 PC2 | I | AG1 | 22.5 | 15.0 | 11.5 |
| NR Band n78 PC2 | D | AG0 | 20.5 | 14.5 | 11.0 |
| NR Band n77 PC2 | F | AG1 | 26.0 | 18.5 | 16.0 |
| NR Band n77 PC2 | C | AG0 | 20.0 | 15.0 | 11.5 |
| NR Band n77 PC2 | I | AG1 | 22.5 | 17.0 | 13.5 |
| NR Band n77 PC2 | D | AG0 | 20.5 | 15.0 | 11.5 |
| 2.4 GHz WIFI | H | AG1 | 19.0 | 18.0 | 16.0 |
| 2.4 GHz WIFI | J | AG1 | 19.0 | 18.0 | 16.0 |
| 2.4 GHz WIFI | MIMO | AG1 | 19.0 | 18.0 | 16.0 |
| 5 GHz WIFI | H | AG1 | 17.0 | 20.0 | 15.5 |
| 5 GHz WIFI | E | AG1 | 17.0 | 20.0 | 15.5 |
| 5 GHz WIFI | MIMO | AG1 | 17.0 | 19.4 | 15.5 |
| 6 GHz WIFI | H | AG1 | 16.0 | 11.5 | 19.8 |
| 6 GHz WIFI | E | AG1 | 16.0 | 11.5 | 21.5 |
| 6 GHz WIFI | MIMO | AG1 | 16.0 | 11.5 | 18.3 |
| 2.4 GHz Bluetooth | H | AG1 | 17.8 | 21.6 | 16.5 |
| 2.4 GHz Bluetooth | J | AG1 | 17.8 | 24.6 | 16.5 |
| 2.4 GHz Bluetooth | MIMO | AG1 | 12.8 | 18.9 | 12.0 |

* Maximum tune up target power, $P_{max}$, is configured in NV settings in DUT to limit maximum transmitting power. This power is converted into peak power in NV settings for TDD schemes. The DUT maximum allowed output power is equal to $P_{max}$ + 1 dB device uncertainty.

Based on selection criteria described in Section 4.2.1, the selected technologies/bands for testing time-varying test sequences are highlighted in yellow in Table 8-1. Per the manufacturer, the *Total_min_reserve* (dB) is set to 3dB in EFS and is used in Part 2 test.

The radio configurations used in Part 2 test for selected technologies, bands, DSIs and antennas are listed in Table 8-2. The corresponding worst-case radio configuration 1gSAR values for selected technology/band/DSI are extracted from Part 1 report and are listed in the last column of Table 8-2.

Based on equations (1a), (2a), (3a) and (4a), it is clear that Part 2 testing outcome is normalized quantity, which implies that it can be applied to any radio configuration within a selected technology/band/DSI. Thus, as long as applying the worst-case SAR obtained from the worst radio configuration in Part 1 testing to calculate time-varying SAR exposure in equations (1a), (2a), (3a) and (4a), the accuracy in compliance demonstration remains the same. Therefore, there may be some differences between the radio configuration selected for Part 2 testing and the radio configuration associated with worst-case SAR obtained in the Part 1 evaluation.

The measured $P_{limit}$ for all the selected radio configurations are listed in below Table 8-2. $P_{max}$ was also measured for radio configurations selected for testing time-varying Tx power transmission scenarios in order to generate test sequences following the test procedures in Section 4.1.

## Table 8-2
## Radio configurations selected for Part 2 test

| Test Case # | Test Scenario | Tech | Band | Antenna | DSI | Channel | Frequency [MHz] | Test Configurations | SAR Exposure Scenario | Part 1 Worst Case Measured SAR at Plimit (W/kg) | EFS Plimit [dBm] | Tune-up Pmax [dBm] | Measured Plimit [dBm] | Measured Pmax [dBm] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Test Sequence 1<br>Test Sequence 2 | GSM | 850 | E | 1 | 251 | 824.2 | GPRS 4 Tx Slots<br>- | Left, Cheek | 0.692 | 21.8 | 23.8 | 20.45 | 23.69 |
| 2 | Test Sequence 1<br>Test Sequence 2 | | 1900 | A | 0 | 661 | 1880 | GPRS 4 Tx Slots<br>- | Bottom Edge, 10mm | 0.665 | 18.8 | 21.3 | 18.60 | 20.82 |
| 3 | Test Sequence 1<br>Test Sequence 2 | WCDMA | 5 | E | 1 | 4183 | 836.5 | RMC<br>- | Left, Cheek | 0.884 | 21.5 | 23.5 | 21.52 | 23.23 |
| 4 | Test Sequence 1<br>Test Sequence 2 | | 2 | A | 0 | 9400 | 1880 | RMC<br>- | Bottom Edge, 10mm | 0.966 | 18.0 | 23.0 | 17.90 | 22.59 |
| 5 | Test Sequence 1<br>Test Sequence 2 | LTE | 12 | E | 1 | 23095 | 707.5 | QPSK<br>1/25/10 MHz BW | Left, Cheek | 0.604 | 22.0 | 23.8 | 21.16 | 23.82 |
| 6 | Test Sequence 1<br>Test Sequence 2 | | 7 | F | 1 | 21100 | 2535 | QPSK<br>1/50/20 MHz BW | Right, Tilt | 0.873 | 16.0 | 23.0 | 16.11 | 23.26 |
| 7 | Test Sequence 1<br>Test Sequence 2 | NR | n5/SA | E | 1 | 167300 | 836.5 | DFT-S-OFDM, QPSK<br>1/1/20 MHz BW | Left, Cheek | 0.715 | 21.0 | 23.5 | 21.23 | 23.48 |
| 8 | Test Sequence 1<br>Test Sequence 2 | | n7/SA | F | 1 | 507000 | 2535 | DFT-S-OFDM, QPSK<br>1/1/40 MHz BW | Right, Tilt | 0.873 | 16.0 | 23.0 | 16.61 | 23.86 |
| 9 | Test Sequence | WLAN | 2.4 | J | 1 | 1 | 2412 | 802.11b<br>DSSS | Left, Cheek | 0.472 | 16.0 | 19.0 | 16.66 | 18.99 |
| 10 | Test Sequence | | 5 | H | 1 | 58 | 5290 | 802.11ac 80MHz BW<br>DSSS | Right, Cheek | 0.518 | 15.5 | 17.0 | 16.22 | 17.71 |
| 11 | Change in Call | LTE | 7 | F | 1 | 21100 | 2535 | QPSK<br>1/50/20 MHz BW | Right, Tilt | 0.873 | 16.0 | 23.0 | 16.11 | 23.26 |
| 12 | Change in Technology/Band/Antenna | LTE | 7 | B | 0 | 21100 | 2535 | QPSK<br>1/50/20 MHz BW | Bottom Edge, 10mm | 0.523 | 19.5 | 23.0 | 20.23 | 23.33 |
| | | WCDMA | 2 | A | 0 | 9400 | 1880 | RMC<br>- | Bottom Edge, 10mm | 0.966 | 18.0 | 23.0 | 17.90 | 22.59 |
| 13 | Change in Time Window | LTE | 25 | F | 1 | 26365 | 1882.5 | QPSK<br>1/50/20 MHz BW | Right, Tilt | 1.020 | 18.5 | 23.5 | 19.17 | 23.80 |
| | | | 48 | F | 1 | 56207 | 3646.7 | QPSK<br>1/50/20 MHz BW | Right, Tilt | 0.847 | 16.5 | 20.5 | 16.57 | 20.01 |
| 14 | WWAN SAR Exposure Switching (EN-DC) | LTE | 5 | E | 1 | 20525 | 836.5 | QPSK<br>1/25/10 MHz BW | Left, Cheek | 0.692 | 21.0 | 23.5 | 20.25 | 23.44 |
| | | Sub6 NR | n66 | F | 1 | 349000 | 1745 | DFT-S-OFDM, QPSK<br>1/1/40 MHz BW | Right, Tilt | 0.903 | 18.5 | 23.5 | 18.38 | 23.71 |
| 15 | WLAN SAR Exposure | WLAN | 2.4 | J | 1 | 1 | 2412 | 802.11b<br>DSSS | Left, Cheek | 0.472 | 16.0 | 19.0 | 16.66 | 18.99 |
| | | | 5 | E | 1 | 58 | 5690 | 802.11ac 80MHz BW<br>DSSS | Left, Tilt | 0.452 | 15.5 | 17.0 | 15.95 | 17.50 |
| 16 | System Level Compliance Continuity | WWAN (LTE) | 5 | E | 1 | 20525 | 836.5 | QPSK<br>1/25/10 MHz BW | Left, Cheek | 0.692 | 21.0 | 23.5 | 20.25 | 23.44 |
| | | Bluetooth | 2.4 | H | 1 | 1 | 2402 | FHSS | Right, Cheek | 0.241 | 16.5 | 17.8 | 16.05 | 18.05 |
| | | WLAN | 2.4 | J | 1 | 1 | 2412 | 802.11b<br>DSSS | Left, Cheek | 0.472 | 16.0 | 19.0 | 16.66 | 18.99 |
| 17 | Exposure Category Switch (Head-Body-Head) | LTE | 7 | F | 1 | 21100 | 2535 | QPSK<br>1/50/20 MHz BW | Right, Tilt | 0.873 | 16.0 | 23.0 | 16.11 | 23.26 |
| | | | | | 0 | 21100 | 2535 | QPSK<br>1/50/20 MHz BW | Top Edge, 0mm | 0.587 | 19.5 | 23.0 | 19.67 | 23.38 |

Note: The device uncertainty of $P_{max}$ is +/- 1 dB as provided by manufacturer.

Note: Multi-Tx factor is set to 1.0 per the manufacturer.

Note: The above $P_{max}$ value for GPRS850 and GPRS1900 are for 4 Tx Slots.

## Table 8-3
## DSI and Corresponding Exposure Scenarios

| Scenario | Description | SAR Test Cases |
|---|---|---|
| Head<br>(DSI = 1) | ▪ Device positioned next to head<br>▪ Receiver Active | *Head SAR per KDB Publication 648474 D04* |
| Hotspot mode<br>(DSI = 0) | ▪ Device transmits in hotspot mode near body<br>▪ Hotspot Mode Active | *Hotspot SAR per KDB Publication 941225 D06* |
| Phablet<br>(DSI = 0) | ▪ Device is held with hand | *Phablet SAR per KDB Publication 648474 D04 & KDB Publication 616217 D04* |

| Scenario | Description | SAR Test Cases |
| --- | --- | --- |
| Body-worn (DSI = 0) | ▪ Device being used with a body-worn accessory | *Body-worn SAR per KDB Publication 648474 D04* |

Based on the selection criteria described in Section 4.2, the radio configurations for the Tx varying transmission test cases listed in Section 3 are:

1. Technologies and bands for time-varying Tx power transmission: The test case 1~10 listed in Table 8-2 are selected to test with the test sequences defined in Section 4.1 in both time-varying conducted power measurement and time-varying SAR measurement.
2. Technology and band for change in call test: LTE Band 7, having the lowest $P_{limit}$ among all technologies and bands (test case 11 in Table 8-2), is selected for performing the call drop test in conducted power setup.
3. Technologies and bands for change in technology/band/antenna test: Following the guidelines in Section 4.2.3, test case 12 in Table 8-2 is selected for handover test from a technology/band within one technology group (LTE Band 7, DSI=0, antenna B), to a technology/band in the same DSI within another technology group (WCDMA Band 2, DSI=0, antenna A) in conducted power setup.
4. Technologies and bands for change in time-window: Based on selection criteria in Section 4.2.6, for a given DSI=1, test case 13 in Table 8-2 is selected for time window switch between 60s window (LTE Band 48, Antenna F) and 100s window (LTE Band 25, Antenna F) in conducted power setup.
5. Technologies and bands for switch in SAR exposure: Based on selection criteria in Section 4.2.7 Scenario 1, test case 14 in Table 8-2 is selected for SAR exposure switching test in one of the supported simultaneous WWAN transmission scenario, i.e., LTE + Sub6 NR active in the same 100s time window, in conducted power setup. Test case 15 in Table 8-2 is selected for SAR exposure switching test in one of the supported simultaneous DBS WLAN transmission scenario, i.e., WLAN + WLAN active in the same 30s time window, in conducted power setup. Since this device supports LTE+mmW NR, test for Section 4.2.7 Scenario 2 for RF exposure switch is covered in Sections 13.1 and 13.2 between LTE (100s window) and mmW NR (4s window).
6. Technologies and bands for switch in exposure category: Based on selection criteria in Section 4.2.8, test case 17 in Table 8-2 is selected for switch in exposure category test by establishing a call in LTE Band 7 in DSI=1 (head exposure) and then handing over to DSI=0 (non-head exposure) scenario in conducted power setup, and vice versa.
7. Technologies and bands for system level compliance continuity: Based on selection criteria in Section 4.2.10, test case 16 in Table 8-2 is selected for system level compliance continuity test by establishing a call in LTE Band 5 in DSI=1 and then handing over to WLAN and BT in scenario described in section 4.3.10.

   Note: All switching and EN-DC test cases (#12 - #16) were done with modes/bands within the same antenna group.

   Note: System level compliance continuity was performed with USB disconnected from DUT per Qualcomm 80-W2112-51 RevAD guidance.

## 8.2 EFS v21 Verification

Per Qualcomm's 80-w2112-5 document, embedded file system (EFS) version 21 products are required to be verified for Smart Tx generation for relevant MCC settings. It was confirmed that this DUT contains embedded file system (EFS) version 21 configured for Smart Tx second generation (GEN2) for Sub6, WLAN/BT, and mmWave with MCC settings for the US market.

| EFS v21 Generation | MCC |
|---|---|
| GEN2_UNIFIED | 310 |

# 9 CONDUCTED TX CASES (FREQ < 6 GHZ)

## 9.1 Time-varying Tx Power Case

The measurement setup is shown in Figure 6-1.The purpose of the time-varying Tx power measurement is to demonstrate the effectiveness of power limiting enforcement and that the time-averaged Tx power when represented in time-averaged 1gSAR or 10gSAR values does not exceed FCC limit as shown in Eq. (1a) and (1b), rewritten below:

$$1g\_or\_10gSAR(t) = \frac{conducted\_Tx\_power(t)}{conducted\_Tx\_power\_P_{limit}} * 1g\_or\_10gSAR\_P_{limit} \quad (1a)$$

$$\frac{\frac{1}{T_{SAR}}\int_{t-T_{SAR}}^{t} 1g\_or\_10gSAR(t)dt}{FCC\ SAR\ limit} \leq 1 \quad (1b)$$

where, $conducted\_Tx\_power(t)$, $conducted\_Tx\_power\_P_{limit}$, and $1g\_or\_10gSAR\_P_{limit}$ correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at $P_{limit}$, and measured *1gSAR* and *10gSAR* values at $P_{limit}$ reported in Part 1 test (listed in Table 8-2 of this report as well).

Following the test procedure in Section 4.3, the conducted Tx power measurement for all selected configurations are reported in this section. In all the conducted Tx power plots, the green curve represents time-averaged power and red line represents the conducted power limit that corresponds to FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

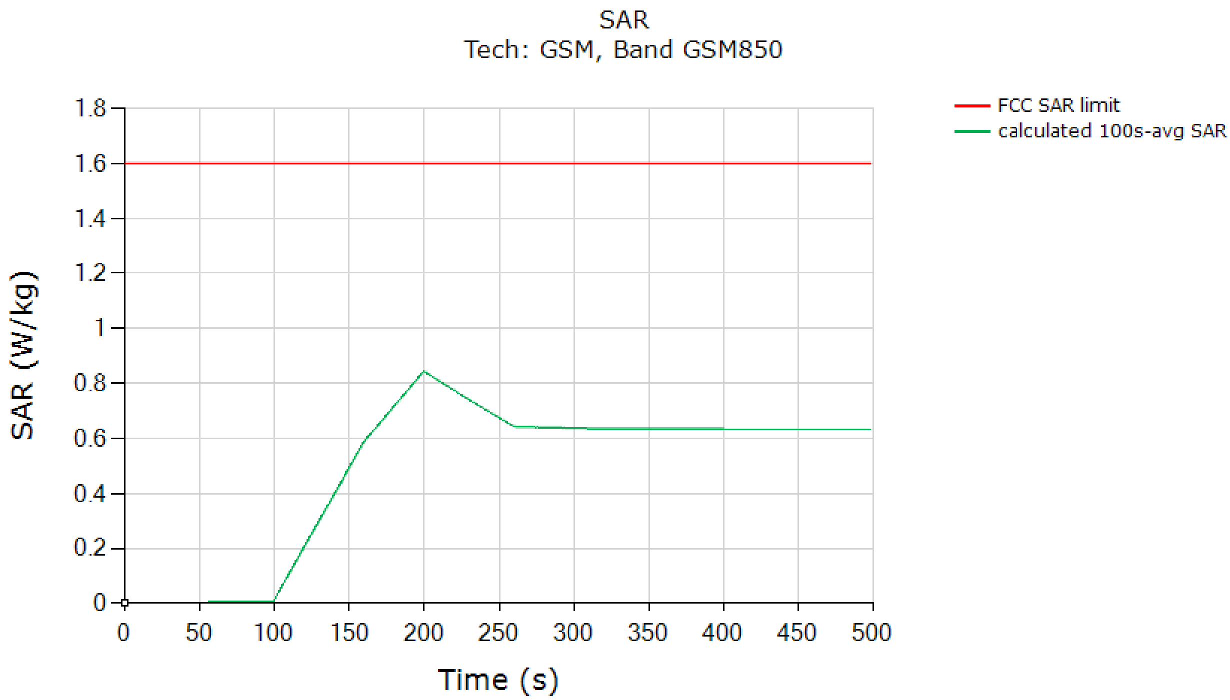
Similarly, in all the 1g or 10gSAR plots (when converted using Eq. (1a)), the green curve represents the 100s/60s-time averaged 1gSAR or 10gSAR value calculated based on instantaneous 1gSAR or 10gSAR; and the red line limit represents the FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

Time-varying Tx power measurements were conducted on test cases #1 ~ #10 in Table 8-2, by generating test sequence 1 and test sequence 2 given in APPENDIX E: using measured $P_{limit}$ and measured $P_{max}$ (last two columns of Table 8-2) for each of these test cases. Measurement results for test cases #1 ~ #10 are given in Sections 9.1.1-9.1.10.

### 9.1.1 GSM/GPRS/EDGE 850

<u>Test result for test sequence 1:</u>

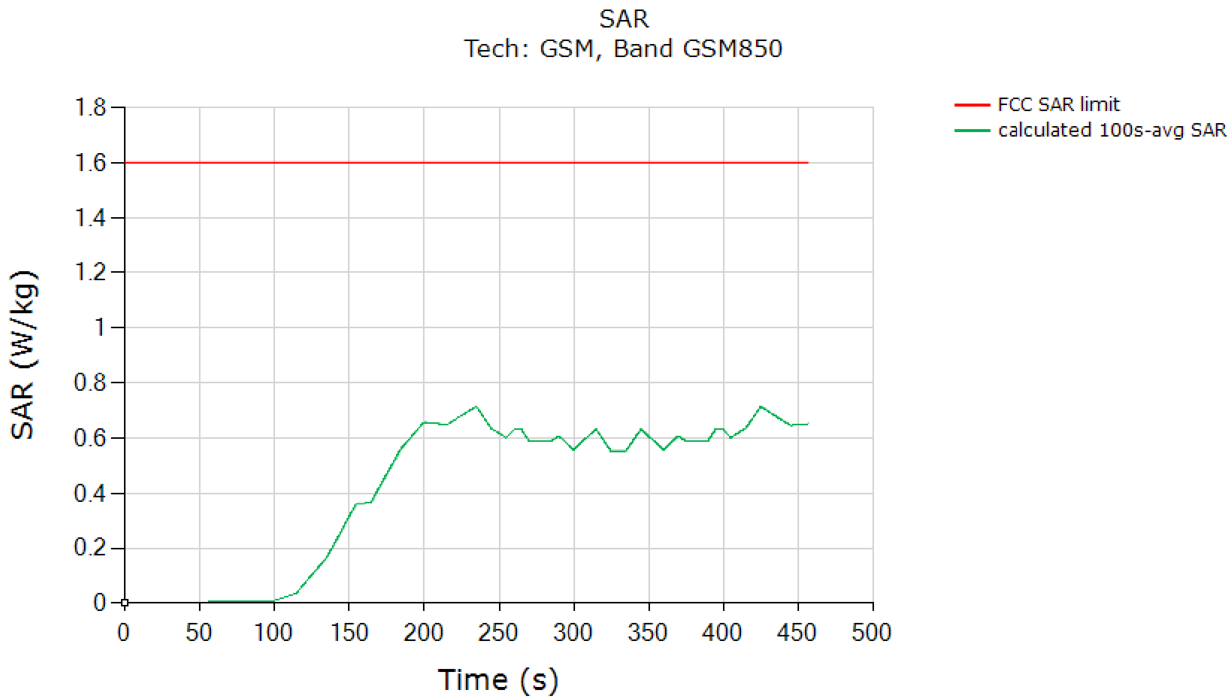
Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged 1gSAR (green curve) | 0.843 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

Test result for test sequence 2:

Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:

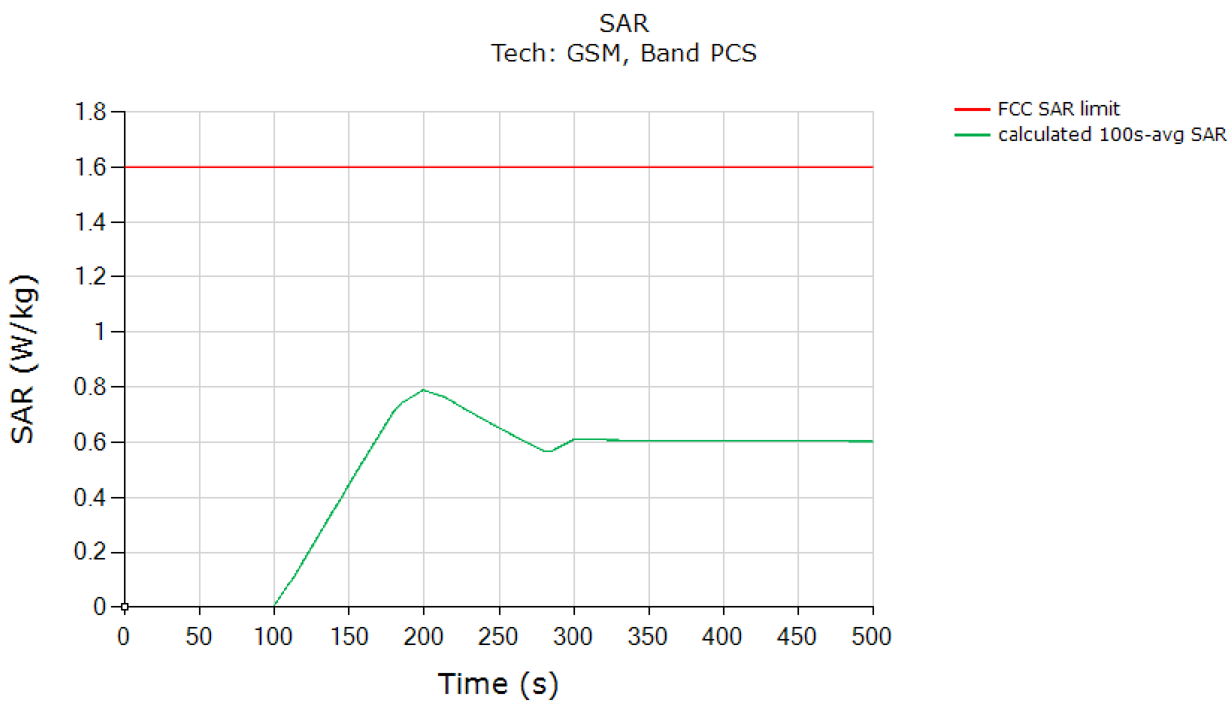



| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged 1gSAR (green curve) | 0.714 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

## 9.1.2 GSM/GPRS/EDGE 1900

Test result for test sequence 1:

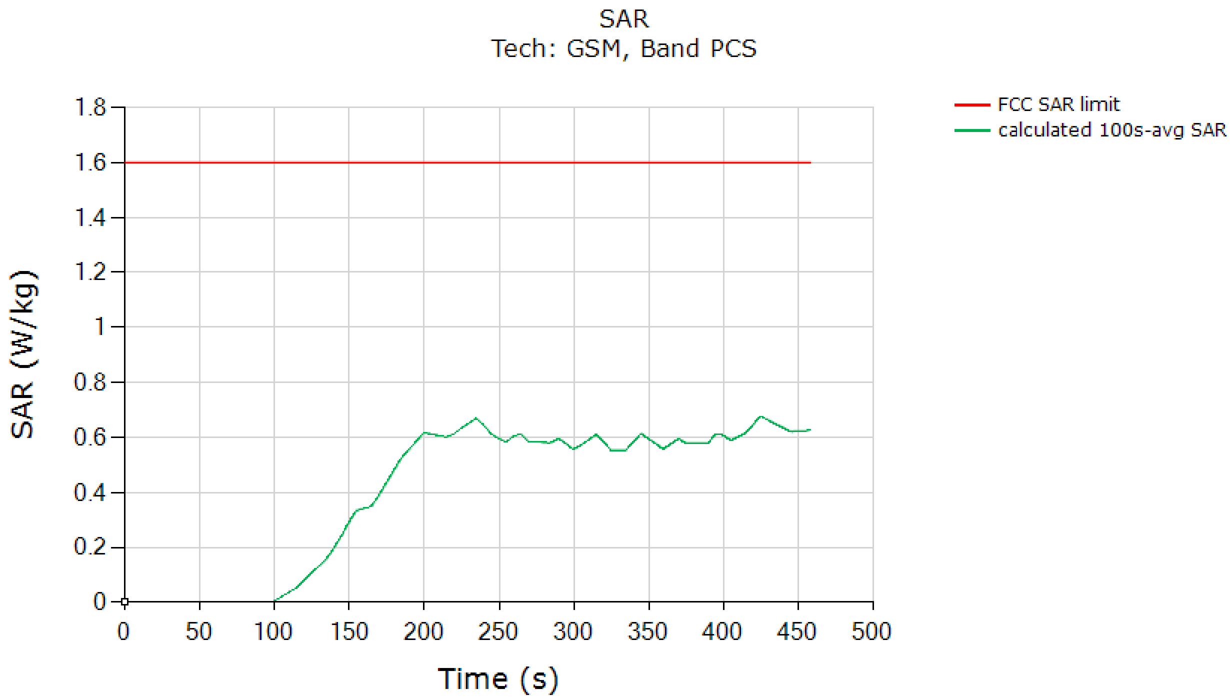
Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged 1gSAR (green curve) | 0.789 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

Test result for test sequence 2:

Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:

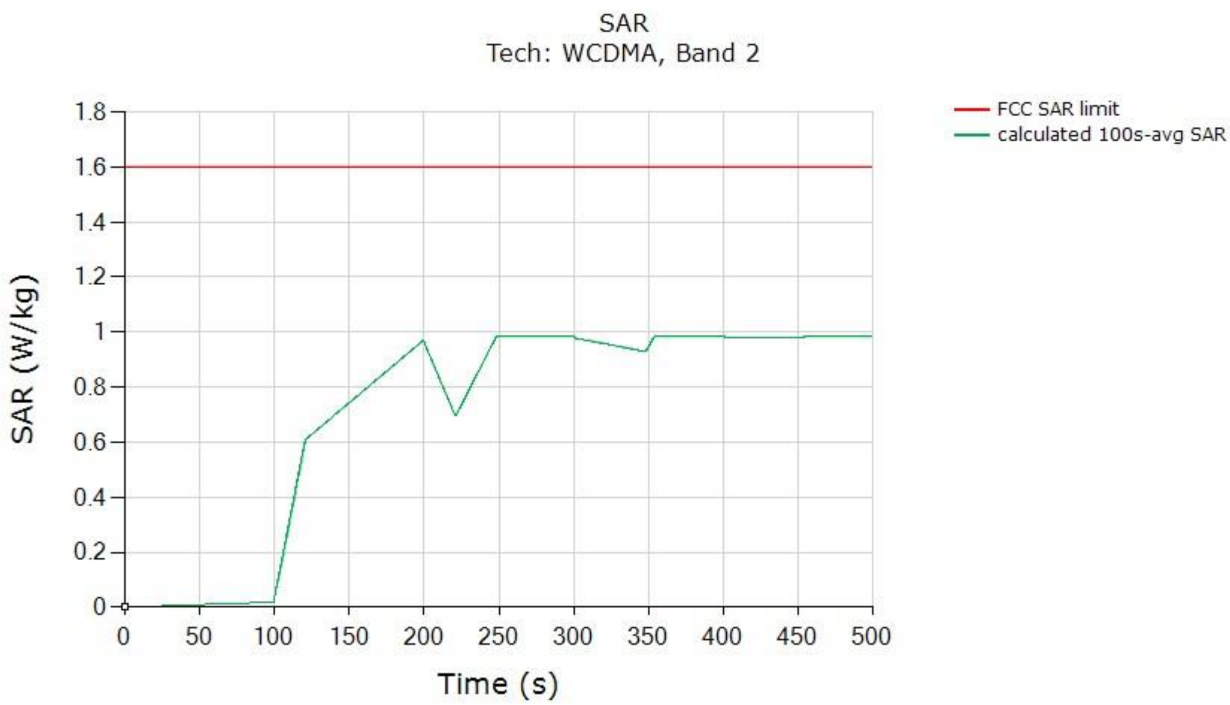



| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged 1gSAR (green curve) | 0.676 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

### 9.1.3 WCDMA Band 2

Test result for test sequence 1:

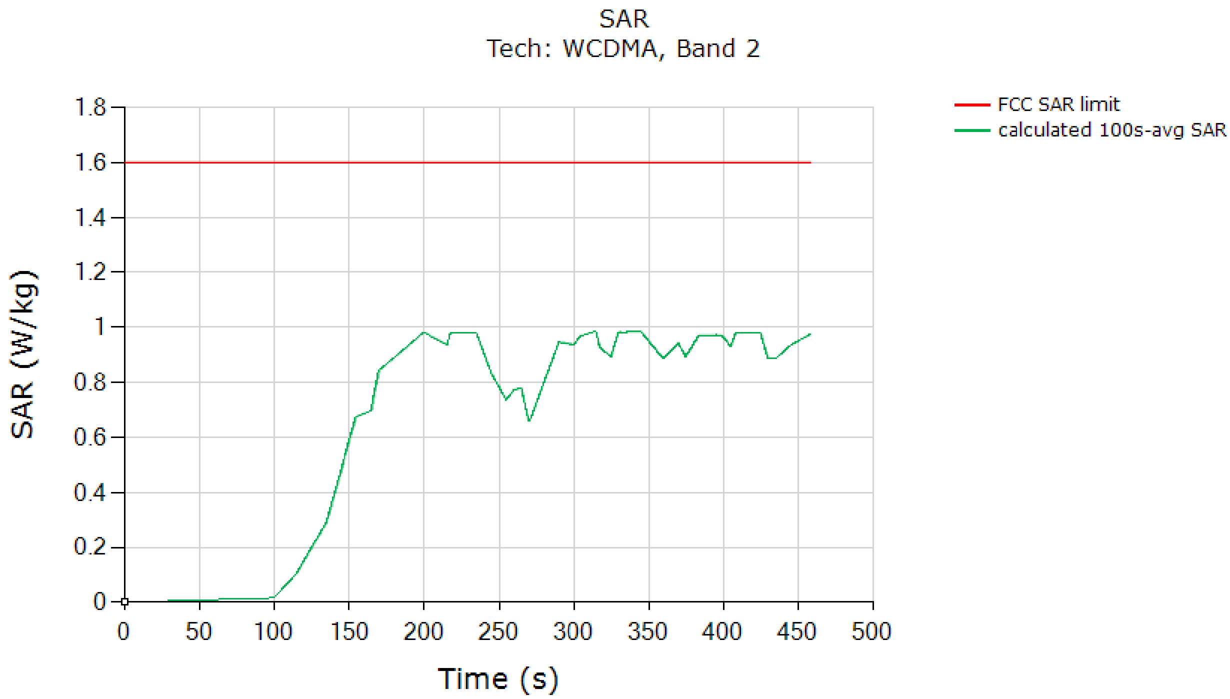
Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged 1gSAR (green curve) | 0.984 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

<u>Test result for test sequence 2:</u>

Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:

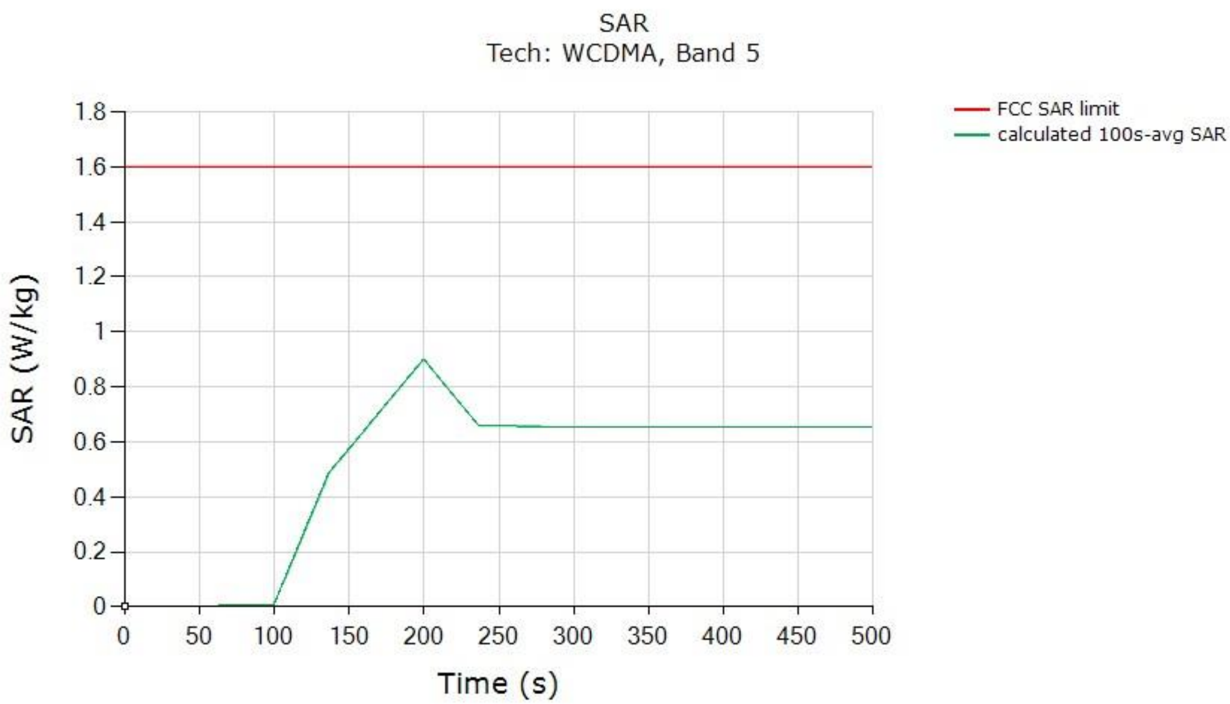



| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged 1gSAR (green curve) | 0.985 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

### 9.1.4 WCDMA Band 5

Test result for test sequence 1:

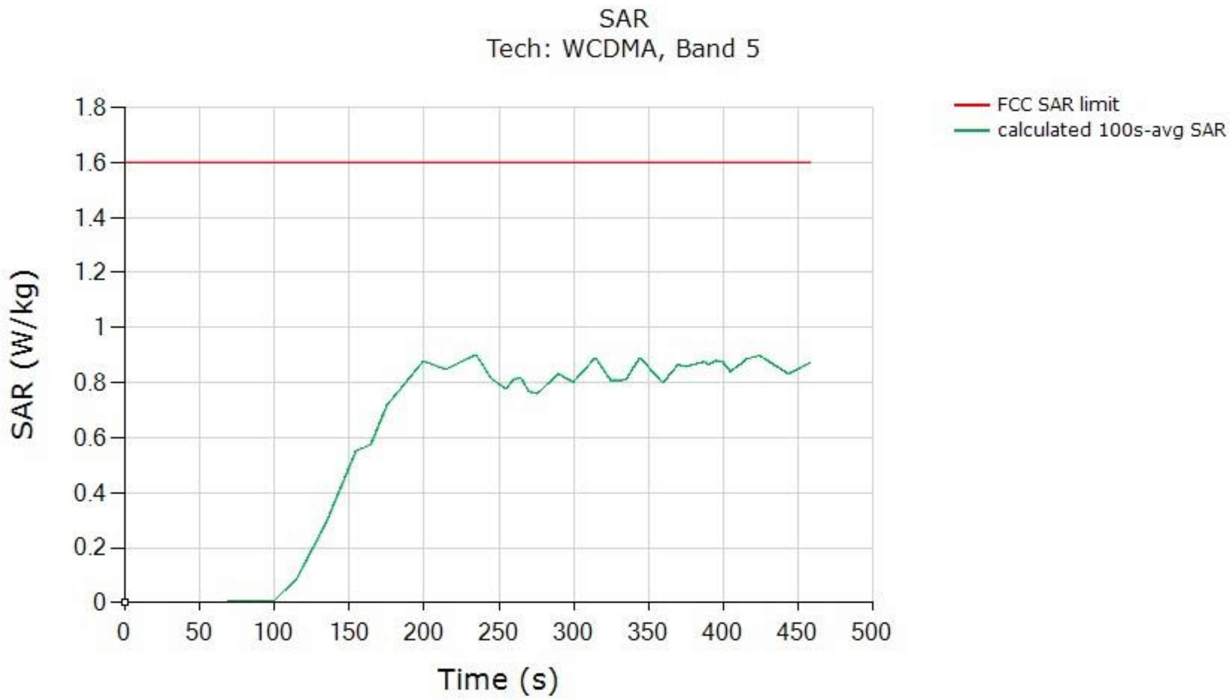
Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged 1gSAR (green curve) | 0.899 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

Test result for test sequence 2:

Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:

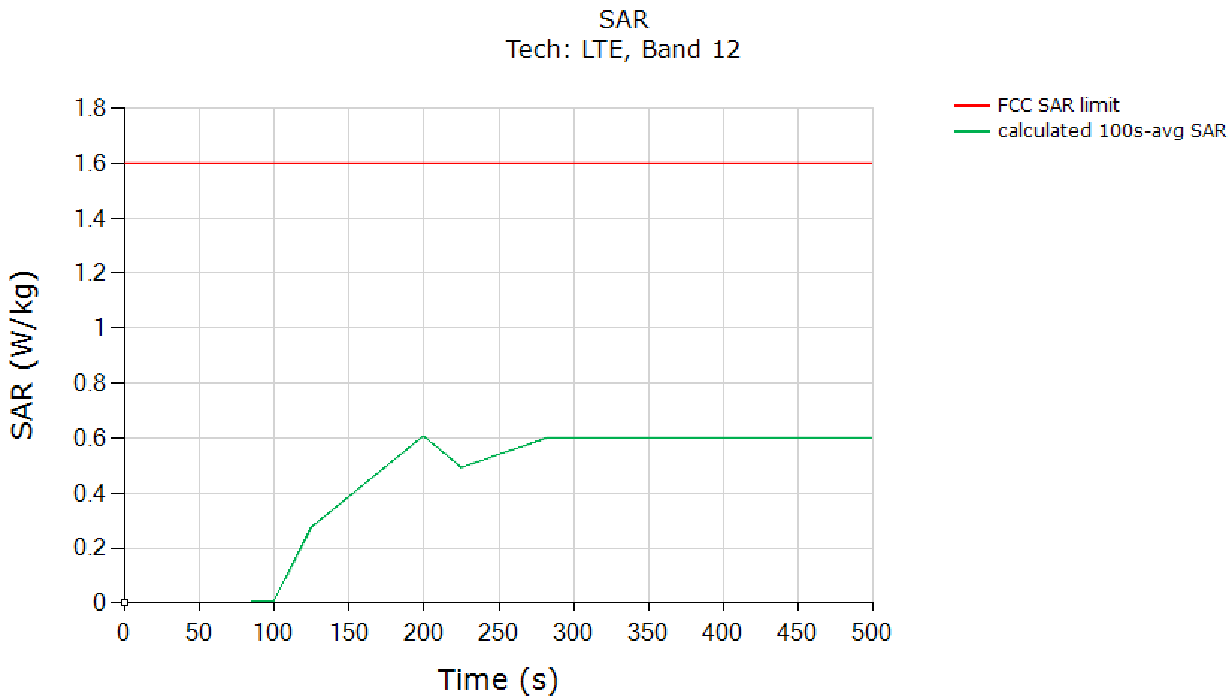



| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged 1gSAR (green curve) | 0.901 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

### 9.1.5 LTE Band 12

Test result for test sequence 1:

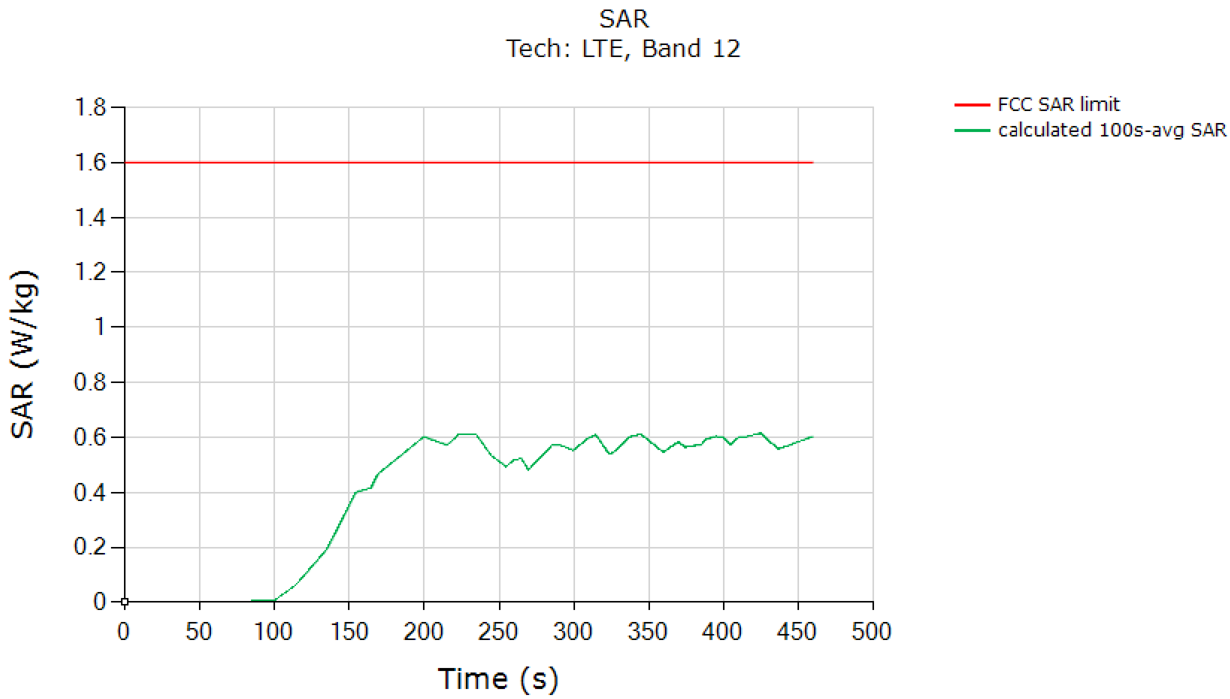
Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged 1gSAR (green curve) | 0.606 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

Test result for test sequence 2:

Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:

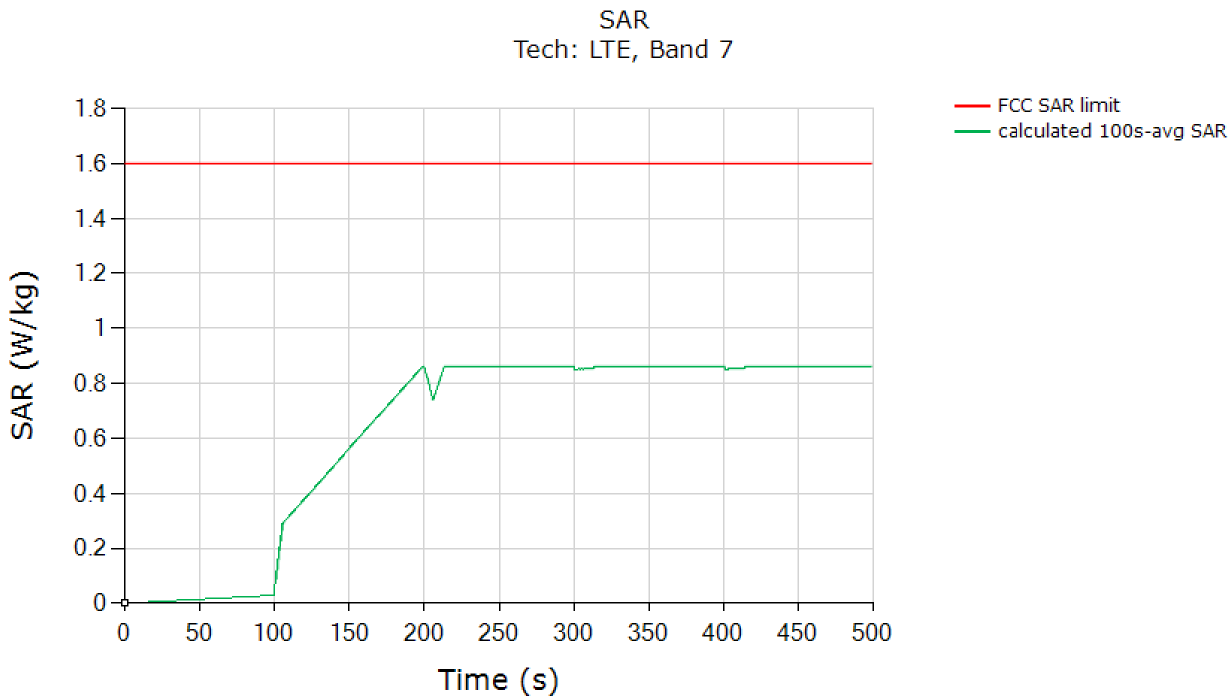



| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged 1gSAR (green curve) | 0.614 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

## 9.1.6 LTE Band 7

<u>Test result for test sequence 1:</u>

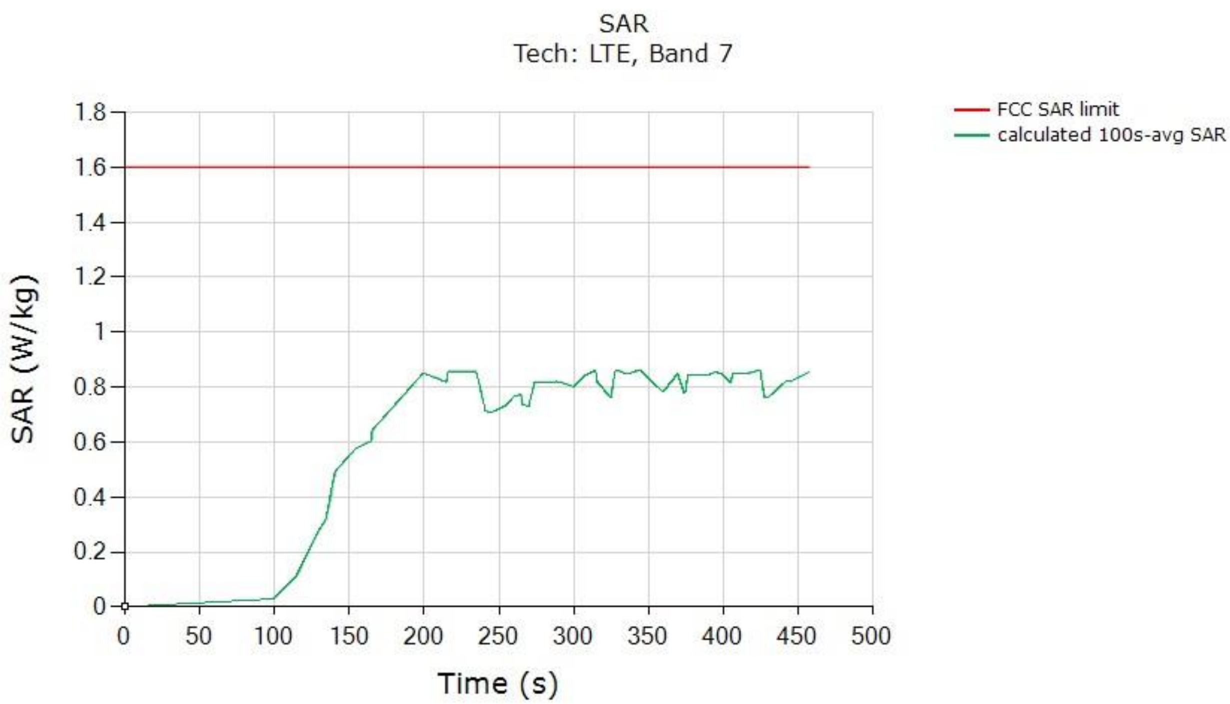
Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged 1gSAR (green curve) | 0.864 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

Test result for test sequence 2:

Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:

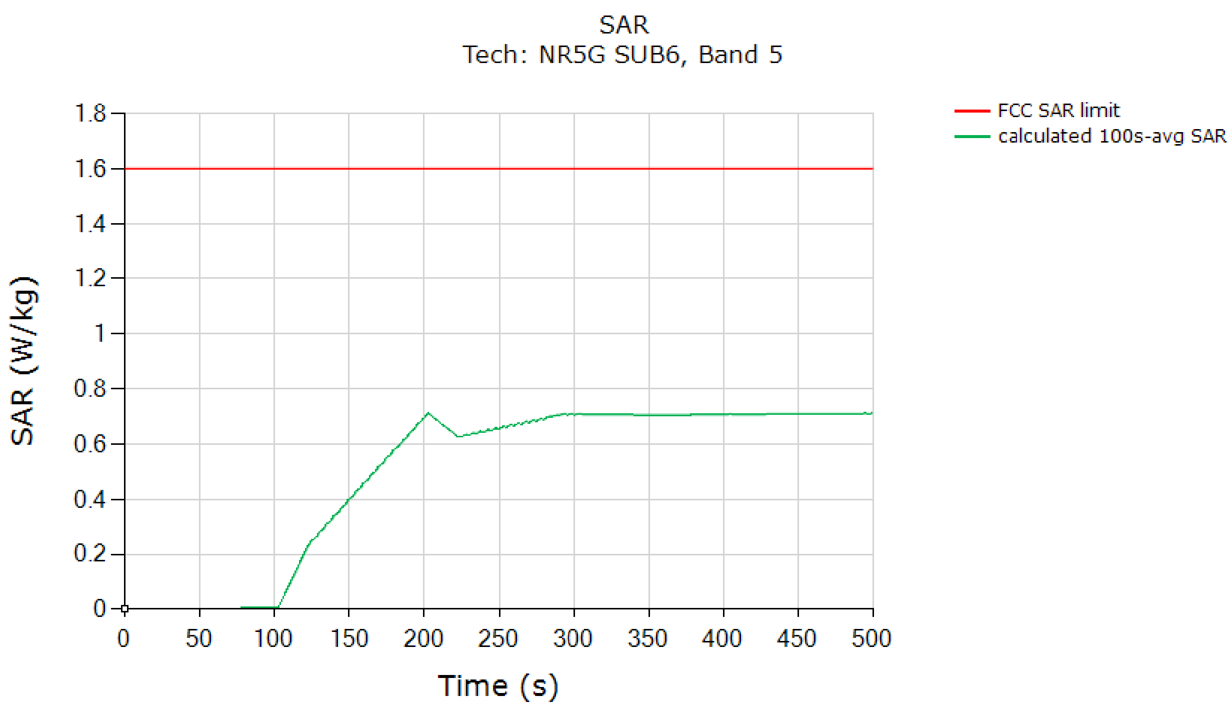



| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged 1gSAR (green curve) | 0.863 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

### 9.1.7 NR n5 SA

Test result for test sequence 1:

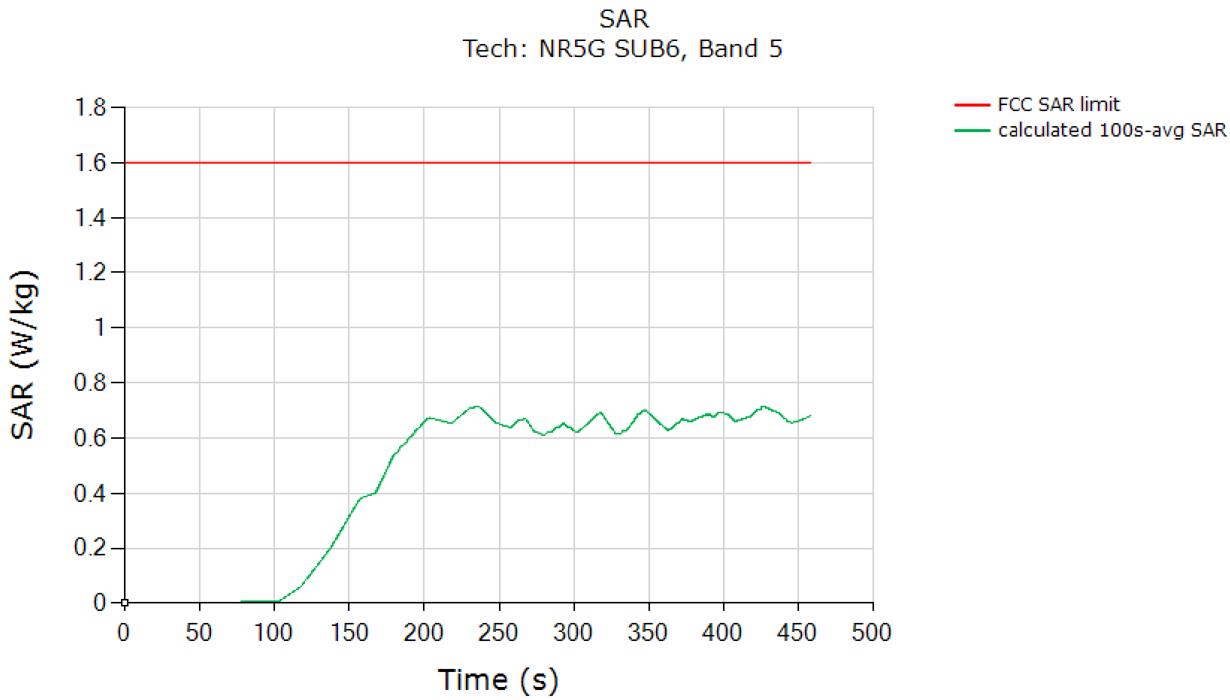
Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged 1gSAR (green curve) | 0.711 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

Test result for test sequence 2:

Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:

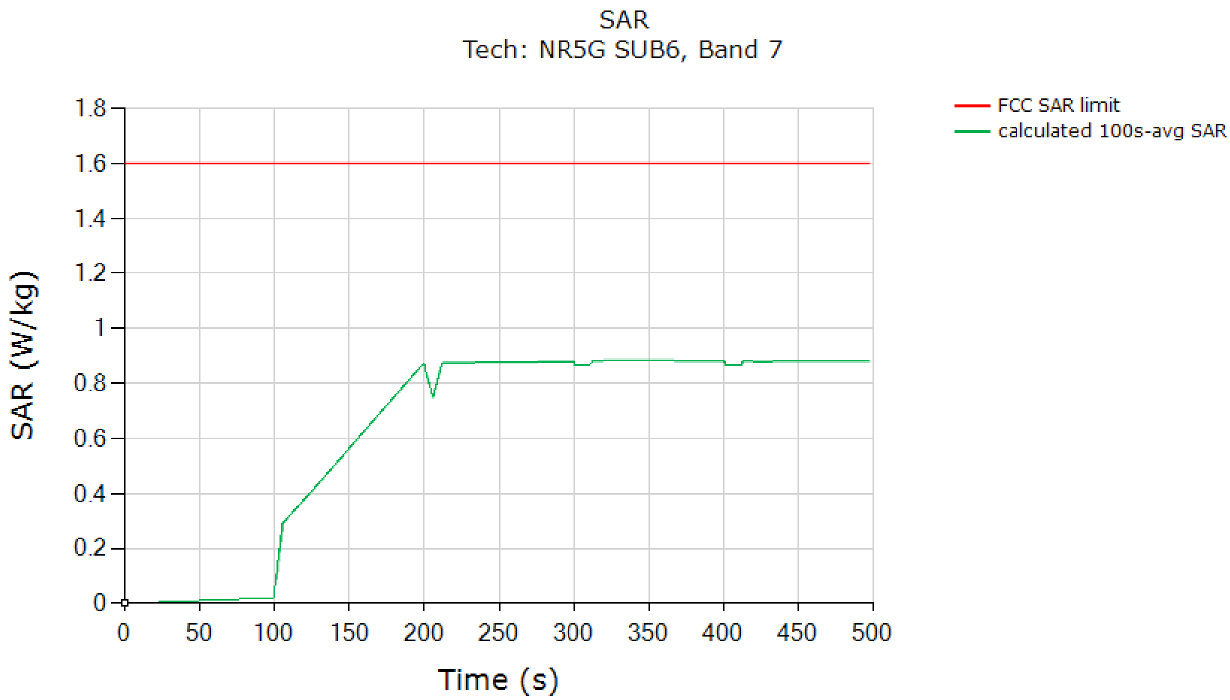



| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged 1gSAR (green curve) | 0.715 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

### 9.1.8 NR n7 SA

Test result for test sequence 1:

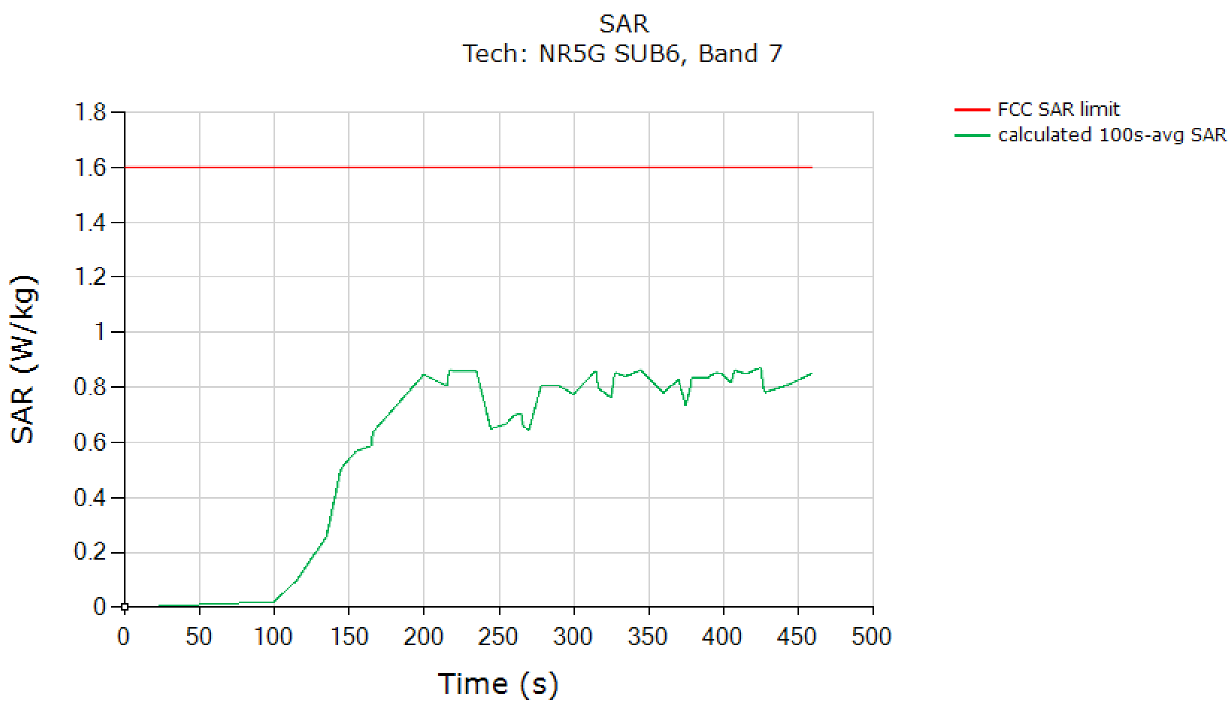
Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged 1gSAR (green curve) | 0.882 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

Test result for test sequence 2:

Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:

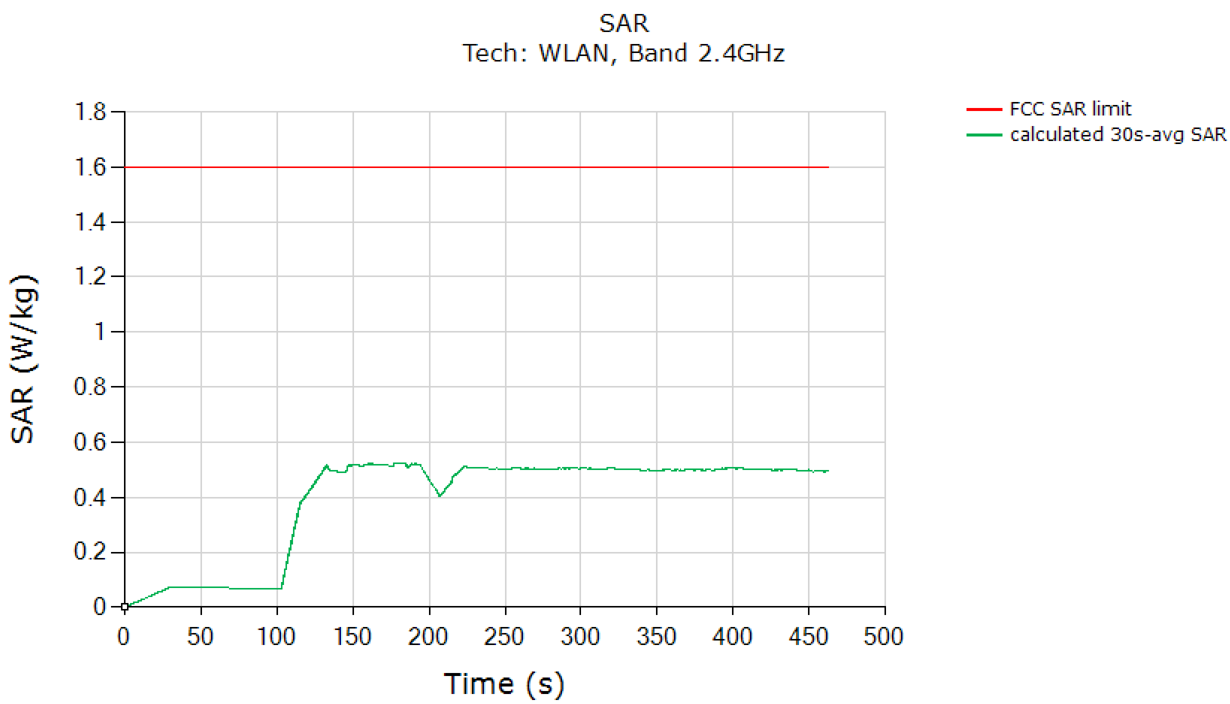



| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged 1gSAR (green curve) | 0.871 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

### 9.1.9 WLAN 2.4GHz

Test result for test sequence:

Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:

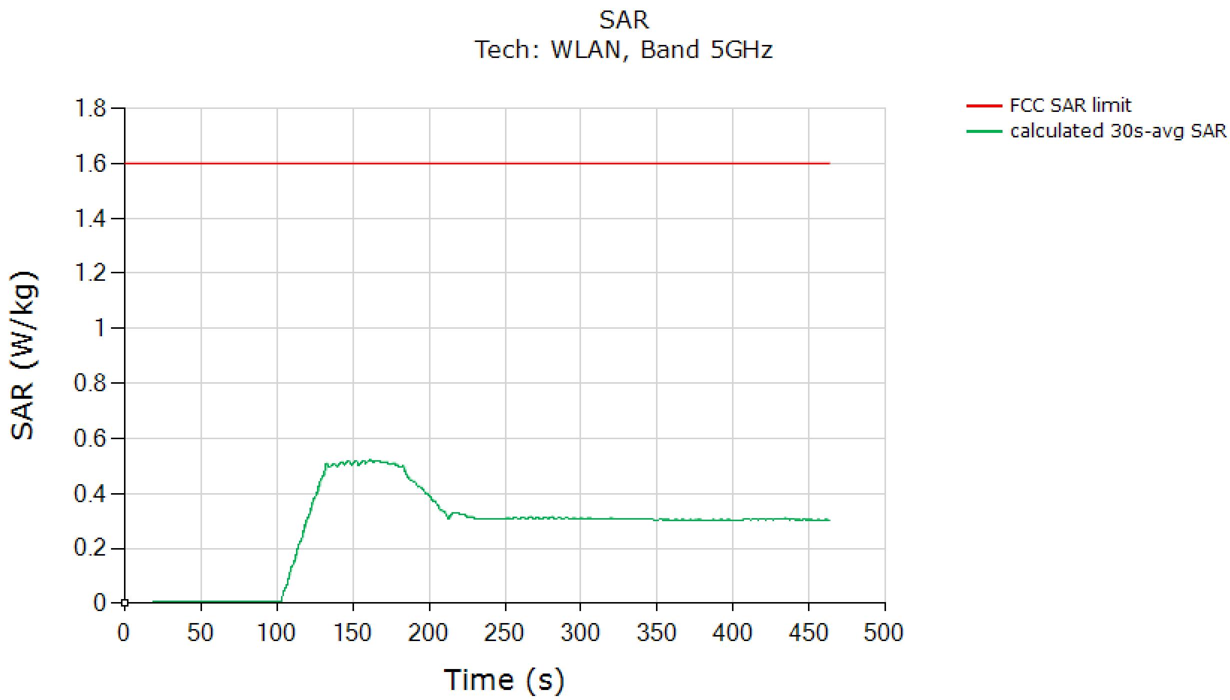



| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 30s-time averaged 1gSAR (green curve) | 0.524 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

### 9.1.10 WLAN 5GHz

Test result for test sequence:

Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:



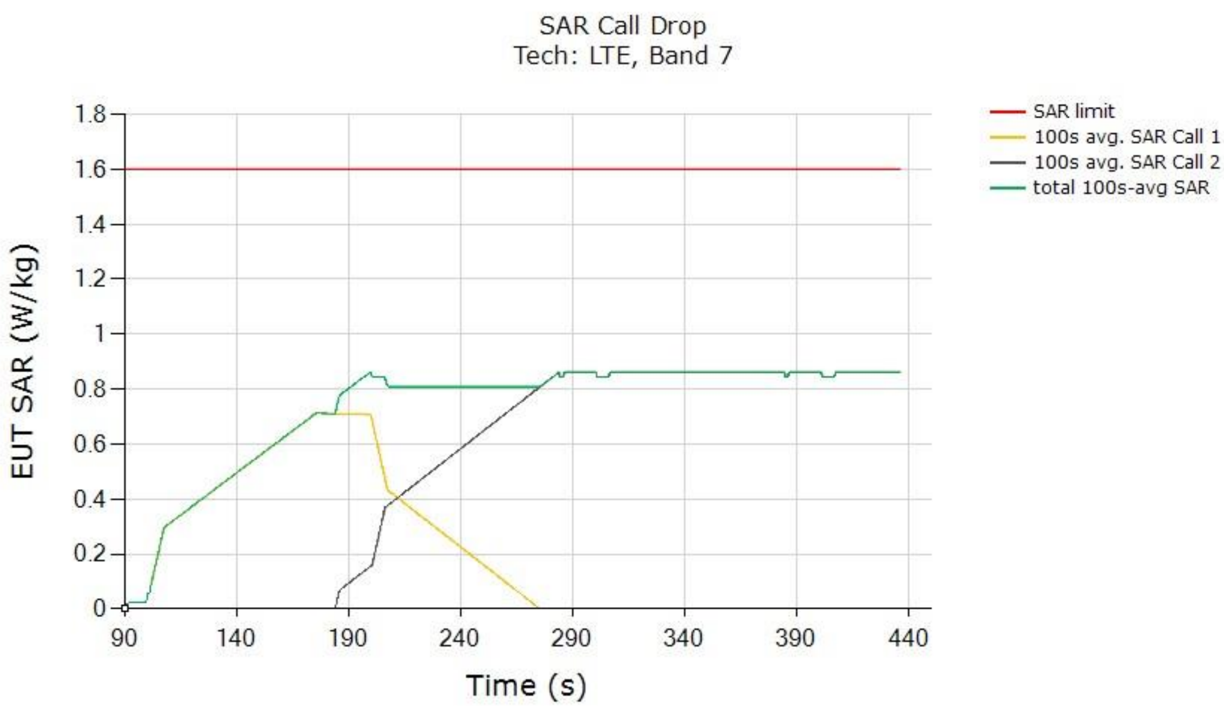

| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 30s-time averaged 1gSAR (green curve) | 0.521 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

## 9.2 Call Drop Test Case

This test was measured LTE Band 7, Antenna F, DSI = 1, and with callbox requesting maximum power. The call drop was manually performed when the DUT is transmitting at $P_{reserve}$ level as shown in the plot below. The measurement setup is shown in Figure 6-1. The detailed test procedure is described in Section 4.3.2.

<u>Call drop test result:</u>

Time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged 1gSAR (green curve) | 0.862 |
| Validated | |

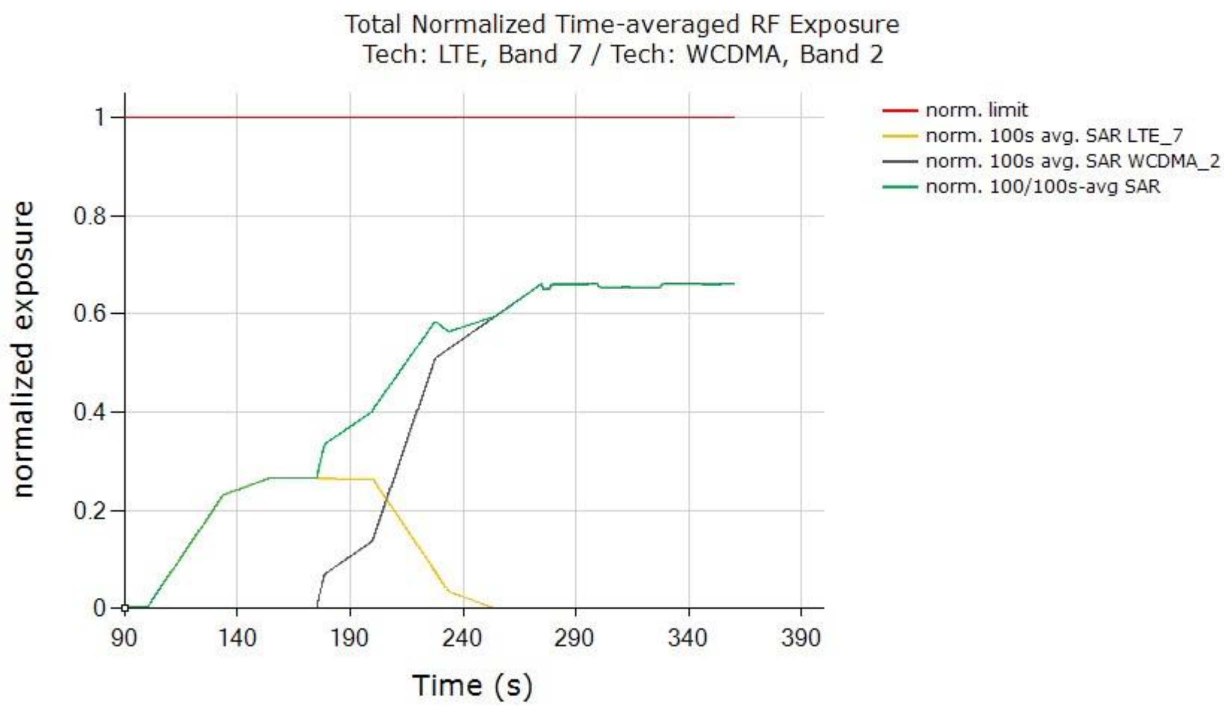
The test result validated the continuity of power limiting in call change scenario.

## 9.3 Change in Technology/Band Test Case

This test was conducted with callbox requesting maximum power, and with a technology switch from LTE Band 7, Antenna B, DSI = 0 to WCDMA Band 2, Antenna A, DSI = 0. Following procedure detailed in Section 4.3.3, and using the measurement setup shown in Figure 6-1, the technology/band switch was performed when the DUT is transmitting at $P_{reserve}$ level as shown in the plot below.

Test result for change in technology/band:

Time-averaged conducted Tx power measurement results were converted into time-averaged normalized SAR values using Equation (6a), (6b) and (6c), and plotted below to demonstrate that the time-averaged normalized SAR versus time does not exceed the normalized FCC limit of 1.0:




| | (W/kg) |
|---|---|
| FCC normalized SAR limit | 1.0 |
| Max 100s-time averaged normalized SAR (green curve) | 0.662 |
| Validated | |

The test result validated the continuity of power limiting in technology/band switch scenario.

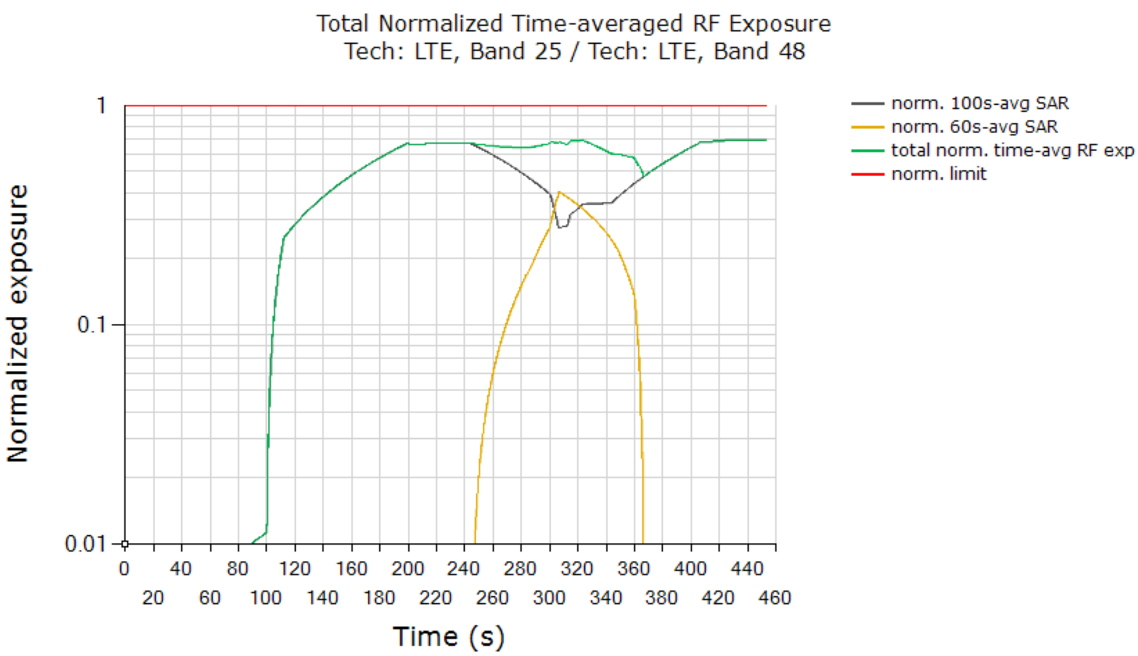
## 9.4 Change in Time window / antenna switch test results

This test was conducted with callbox requesting maximum power, and with time-window/antenna switch between LTE Band 25, Antenna F, DSI = 1 (100s window) and LTE Band 48, Antenna F, DSI = 1 (60s window). Following procedure detailed in Section 4.3.6, and using the measurement setup shown in Figure 6-1(b), the time-window switch via tech/band/antenna switch was performed when the EUT is transmitting at $P_{reserve}$ level.

### 9.4.1 Test case 1: transition from LTE Band 25 to LTE Band 48 (i.e., 100s to 60s), then back to LTE Band 25

Test result for change in time-window (from 100s to 60s to 100s):

All the conducted Tx power measurement results were converted into time-averaged normalized SAR values using Equation (7a), (7b) and (7c), and plotted below to demonstrate that the time-averaged normalized SAR versus time does not exceed the FCC limit of 1 unit. Equation (7a) is used to convert the Tx power of device to obtain 100s-averaged normalized SAR in LTE Band 25 as shown in black curve. Similarly, equation (7b) is used to obtain 60s-averaged normalized SAR in LTE Band 48 as shown in orange curve. Equation (7c) is used to obtain total time-averaged normalized SAR as shown in green curve (i.e., sum of black and orange curves).



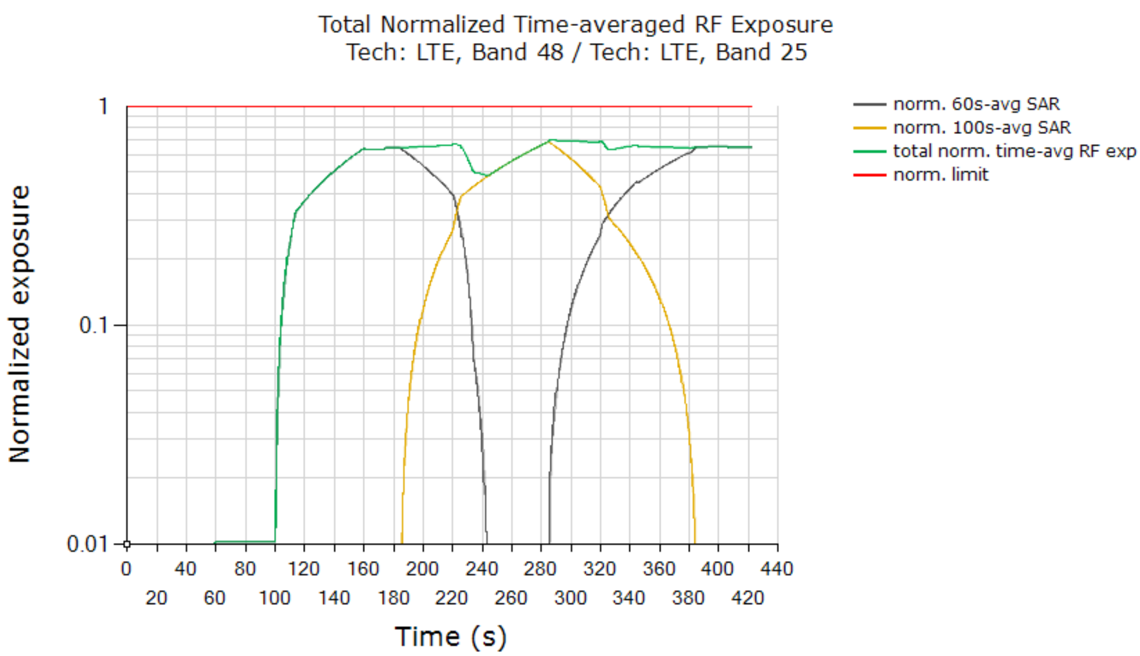

| | (W/kg) |
|---|---|
| FCC normalized total exposure limit | 1.0 |
| Max time averaged normalized SAR (green curve) | 0.693 |
| Validated | |

Plot Notes: Maximum power is requested by callbox for the entire duration of the test, with tech/band switches from 100s-to-60s window at ~245s time stamp, and from 60s-to-100s window at ~310s time stamp. Smart Transmit controls the Tx power during these time-window switches to ensure total time-averaged RF exposure, i.e., sum of black and orange curves given by equation (7c), is always compliant. In time-window switch test, at all times the total time-averaged normalized RF exposure (green curve) should not exceed normalized *SAR_design_target* + 1dB device uncertainty. In this test, with a maximum normalized SAR of 0.693 being ≤ 0.79 (= 1.0/1.6 + 1dB device uncertainty), the above test result validated the continuity of power limiting in time-window switch scenario.

### 9.4.2 Test case 2: transition from LTE Band 48 to LTE Band 25 (i.e., 60s to 100s), then back to LTE Band 48

<u>Test result for change in time-window (from 60s to 100s to 60s):</u>

All the conducted Tx power measurement results were converted into time-averaged normalized SAR values using Equation (7a), (7b) and (7c), and plotted below to demonstrate that the time-averaged normalized SAR versus time does not exceed the FCC limit of 1 unit. Equation (7a) is used to convert the Tx power of device to obtain 60s-averaged normalized SAR in LTE Band 48 as shown in black curve. Similarly, equation (7b) is used to obtain 100s-averaged normalized SAR in LTE Band 25 as shown in orange curve. Equation (7c) is used to obtain total time-averaged normalized SAR as shown in green curve (i.e., sum of black and orange curves).



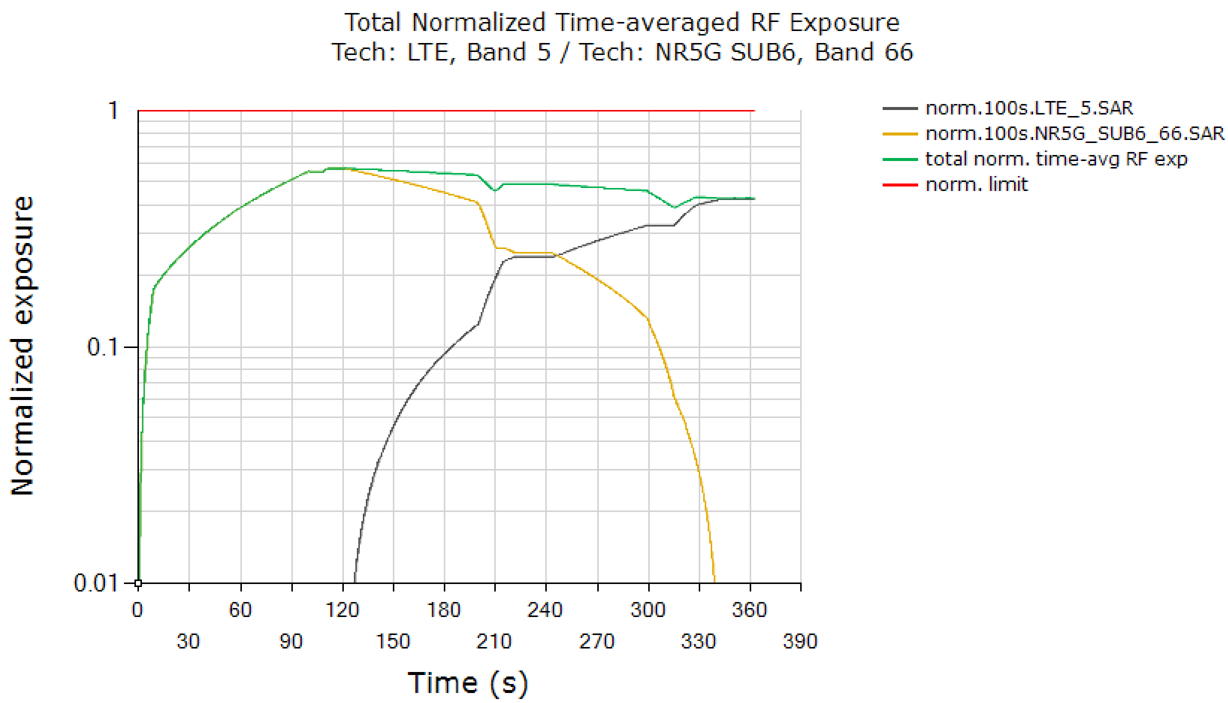

| | (W/kg) |
|---|---|
| FCC normalized total exposure limit | 1.0 |
| Max time averaged normalized SAR (green curve) | 0.701 |
| Validated | |

Plot Notes: Maximum power is requested by callbox for the entire duration of the test, with tech/band switches from 60s-to-100s window at ~190s time stamp, and from 100s-to-60s window at ~290s time stamp. Smart Transmit controls the Tx power during these time-window switches to ensure total time-averaged RF exposure, i.e., sum of black and orange curves given by equation (7c), is always compliant. In time-window switch test, at all times the total time-averaged normalized RF exposure (green curve) should not exceed normalized *SAR_design_target* + 1dB device uncertainty. In this test, with a maximum normalized SAR of 0.701 being ≤ 0.79 (= 1.0/1.6 + 1dB device uncertainty), the above test result validated the continuity of power limiting in time-window switch scenario.

## 9.5 Switch in SAR exposure test results

This test was conducted with callbox requesting maximum power, and with the EUT in LTE Band 5 + Sub6 NR Band n66 call. Following procedure detailed in Section 4.3.7 and Appendix F.2, and using the measurement setup shown in Figure 6-1(c) since LTE and Sub6 NR are on different antenna ports, the SAR exposure switch measurement is performed with the EUT in various SAR exposure scenarios, i.e., in $SAR_{sub6NR}$ only scenario (t =0s ~120s), $SAR_{su6NR}$ + $SAR_{LTE}$ scenario (t =120s ~ 240s) and $SAR_{LTE}$ only scenario (t > 240s).

Plot Notes: All the conducted Tx power measurement results were converted into time-averaged normalized SAR values using Equation (7a), (7b) and (7c), and plotted below to demonstrate that the time-averaged normalized SAR versus time does not exceed the FCC limit of 1 unit. Equation (7a) is used to convert the LTE Tx power of device to obtain 100s-averaged normalized SAR in LTE Band 5 as shown in black curve. Similarly, equation (7b) is used to obtain 100s-averaged normalized SAR in Sub6 NR n66 as shown in orange curve. Equation (7c) is used to obtain total time-averaged normalized SAR as shown in green curve (i.e., sum of black and orange curves).



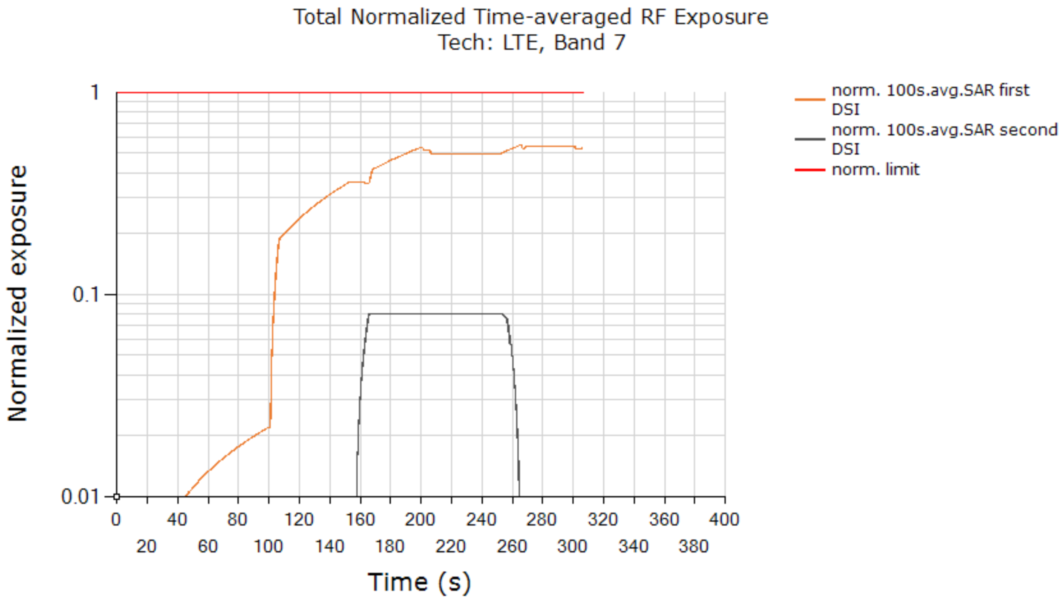
| | (W/kg) |
|---|---|
| FCC normalized total exposure limit | 1.0 |
| Max time averaged normalized SAR (green curve) | 0.570 |
| Validated | |

Plot Notes: Device starts predominantly in Sub6 NR SAR exposure scenario between 0s and 120s, and in LTE SAR + Sub6 NR SAR exposure scenario between 120s and 240s, and in predominantly in LTE SAR exposure scenario after t=240s. Here, Smart Transmit allocates a maximum of 100% of exposure margin (based on 3dB reserve margin setting) for Sub6 NR. This corresponds to a normalized 1gSAR exposure value = 100% * 0.903 W/kg measured SAR at Sub6 NR *Plimit* / 1.6W/kg limit = 0.564 ± 1dB device related uncertainty (see orange curve between 120s). For predominantly LTE SAR exposure scenario, maximum normalized 1gSAR exposure should correspond to 100% exposure margin = 0.692 W/kg measured SAR at LTE *Plimit* / 1.6W/kg limit = 0.433 ± 1dB device related uncertainty (see black curve after t = 240s). Additionally, in SAR exposure switch test, at all times the total time-averaged normalized RF exposure (green curve) should not exceed normalized *SAR_design_target* + 1dB device uncertainty. In this test, with a maximum normalized SAR of 0.570 being ≤ 0.79 (= 1.0/1.6 + 1dB device uncertainty), the above test result validated the continuity of power limiting in SAR exposure switch scenario.

## 9.6 Exposure Category Switch

This test was conducted with callbox requesting maximum power, and with exposure category switch between LTE Band 7, Antenna F, DSI = 1 (Head) and LTE Band 7, Antenna F, DSI = 0 (Non-Head). Following procedure detailed in Section 4.3.8 and using the measurement setup shown in Figure 6-1(a), the exposure category switch was performed when the EUT is transmitting at Preserve level.

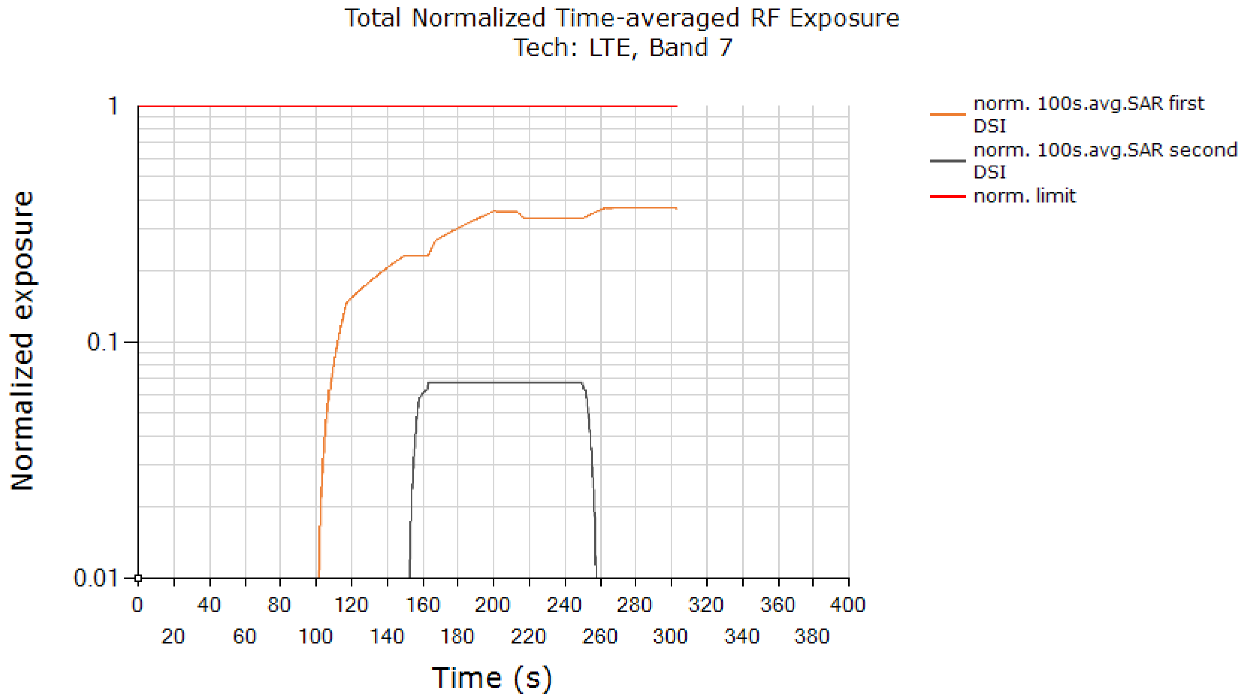
### 9.6.1 Test case 1: Transition from LTE B7 DSI=1 (Head) to LTE B7 DSI=0 (Non-Head), then back to DSI=1 (Head)




| | (W/kg) |
|---|---|
| FCC normalized total exposure limit | 1.0 |
| Max 100s-time averaged normalized SAR (first DSI, orange curve) | 0.551 |
| Validated | |

Plot Notes: Maximum power is requested by callbox for the entire duration of the test, time-averaged exposure in head DSI gradually increases until t~160s where the device is switched from head exposure DSI (first DSI, orange curve) to non-head exposure DSI (second DSI, black curve) as evident from increase in exposure of black curve and no change in orange curve between t~160s and t~170s. At t~170s, device is switched back from non-head exposure to head exposure as evident from increase in exposure of orange curve and no change in black curve. In this test, the time-averaged normalized RF exposure in head exposure DSI (orange curve) did not exceed normalized limit of 1.0 at all times, and is less than normalized SAR of 0.551 being ≤ 0.79 (= 1.0/1.6 + 1dB device uncertainty), validating the exposure continuity when switching between head exposure and non-head exposure categories.

## 9.6.2 Test case 2: Transition from LTE B7 DSI=0 (Non-Head) to LTE B7 DSI=1 (Head), then back to DSI=0 (Non-Head)



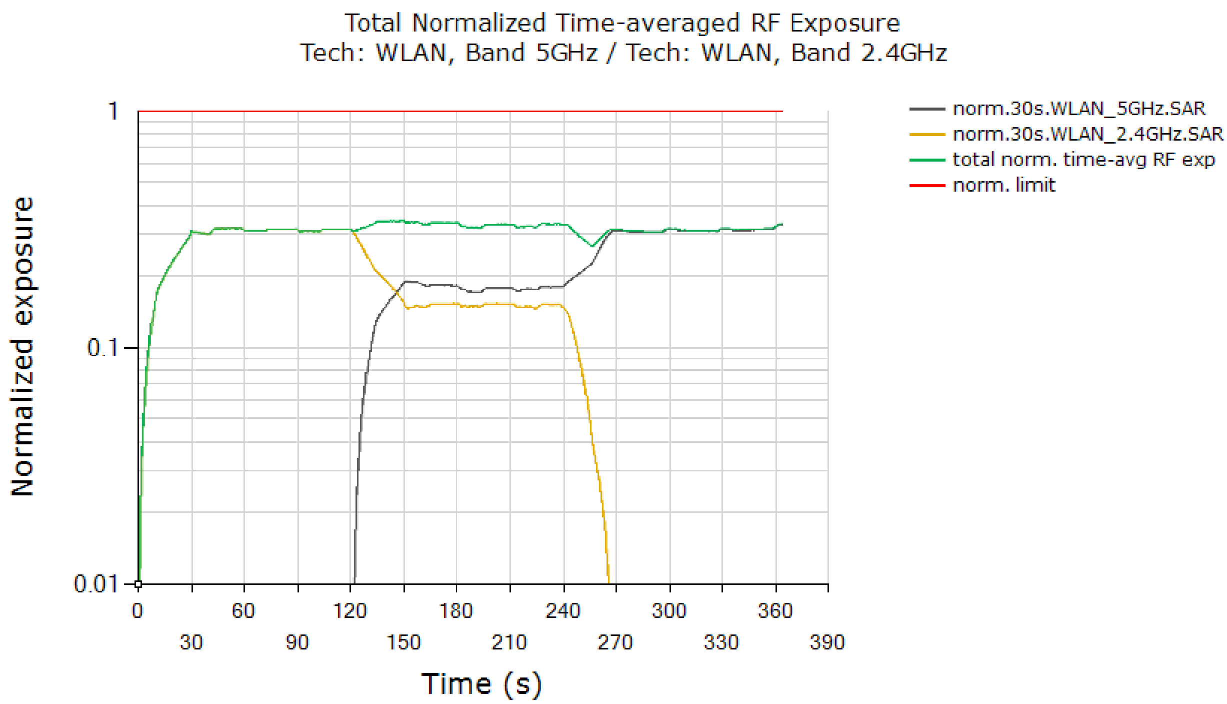

| | (W/kg) |
|---|---|
| FCC normalized total exposure limit | 1.0 |
| Max 100s-time averaged normalized SAR (first DSI, orange curve) | 0.372 |
| Validated | |

Plot Notes: Maximum power is requested by callbox for the entire duration of the test, time-averaged exposure in head DSI gradually increases until t~150s where the device is switched from non-head exposure DSI (first DSI, orange curve) to head exposure DSI (second DSI, black curve) as evident from increase in exposure of black curve and no change in orange curve between t~150s and t~160s. At t~160s, device is switched back from head exposure to non-head exposure as evident from increase in exposure of orange curve and no change in black curve. In this test, the time-averaged normalized RF exposure in head exposure DSI (orange curve) did not exceed normalized limit of 1.0 at all times, and is less than normalized SAR of 0.372 being ≤ 0.79 (= 1.0/1.6 + 1dB device uncertainty), validating the exposure continuity when switching between head exposure and non-head exposure categories.

## 9.7 WLAN Switch in SAR Exposure Test Results

This test was conducted with callbox requesting maximum power, and with the EUT in WLAN 2.4GHz + WLAN 5GHz call. Following procedure detailed in Section 4.3.7, and using the measurement setup shown in Figure 6-1(e) since WLAN channels are sharing the same antenna port, the SAR exposure switch measurement is performed with the EUT in various SAR exposure scenarios, i.e., in $SAR_{WLAN\ 5GHz}$ only scenario (t =0s ~120s), $SAR_{WLAN\ 5GHz}$ + $SAR_{WLAN\ 2.4GHz}$ scenario (t =120s ~ 240s) and $SAR_{WLAN\ 2.4GHz}$ only scenario (t > 240s).

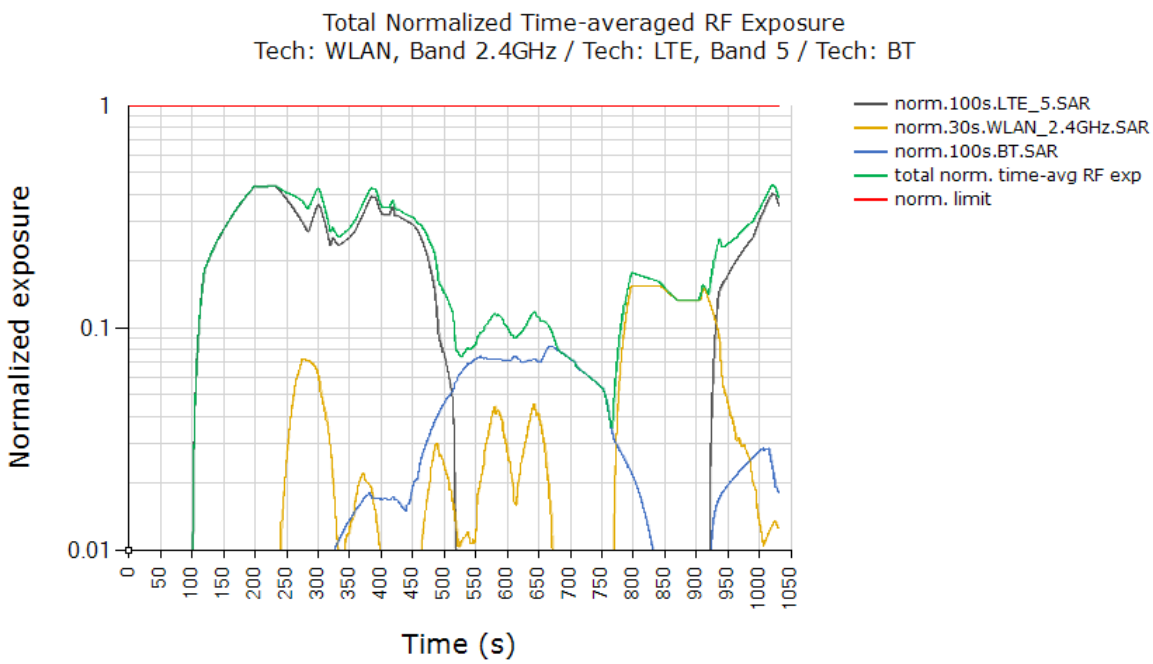
Plot Notes: All the conducted Tx power measurement results were converted into time-averaged normalized SAR values using Equation (7a), (7b) and (7c), and plotted below to demonstrate that the time-averaged normalized SAR versus time does not exceed the FCC limit of 1 unit. Equation (7a) is used to convert the LTE Tx power of device to obtain 100s-averaged normalized SAR in WLAN 2.4GHz as shown in black curve. Similarly, equation (7b) is used to obtain 100s-averaged normalized SAR in WLAN 5GHz as shown in orange curve. Equation (7c) is used to obtain total time-averaged normalized SAR as shown in green curve (i.e., sum of black and orange curves).




| | (W/kg) |
|---|---|
| FCC normalized total exposure limit | 1.0 |
| Max time averaged normalized SAR (green curve) | 0.371 |
| Validated | |

Plot Notes: In this test, the total time-averaged normalized RF exposure (green curve) did not exceed normalized limit of 1.0 at all times, the above test result validated the continuity of power limiting in SAR exposure switch scenario.

## 9.8 System Level Compliance Continuity Test Case




| | (W/kg) |
|---|---|
| FCC normalized total exposure limit | 1.0 |
| Max time averaged normalized SAR (green curve) | 0.441 |
| Validated | |

In this test, the total time-averaged normalized RF exposure (green curve) did not exceed normalized limit of 1.0 at all times, the above test result validated the total RF exposure compliance in system level compliance continuity test scenario.

Note: This test was performed with USB disconnected from DUT per Qualcomm 80-W2112-51 RevAD guidance.

# 10 SYSTEM VERIFICATION (FREQ < 6 GHZ)

## 10.1 Tissue Verification

**Table 10-1**
**Measured Tissue Properties**

| Calibrated for Tests Performed on: | Tissue Type | Tissue Temp During Calibration (˚C) | Measured Frequency (MHz) | Measured Conductivity, σ (S/m) | Measured Dielectric Constant, ε | TARGET Conductivity, σ (S/m) | TARGET Dielectric Constant, ε | % dev σ | % dev ε |
|---|---|---|---|---|---|---|---|---|---|
| 10/23/2023 | 750 Head | 22.9 | 700 | 0.861 | 41.012 | 0.889 | 42.201 | -3.15% | -2.82% |
| | | | 710 | 0.864 | 40.980 | 0.890 | 42.149 | -2.92% | -2.77% |
| | | | 725 | 0.869 | 40.938 | 0.891 | 42.071 | -2.47% | -2.69% |
| | | | 750 | 0.878 | 40.877 | 0.894 | 41.942 | -1.79% | -2.54% |
| | | | 770 | 0.885 | 40.818 | 0.895 | 41.838 | -1.12% | -2.44% |
| | | | 785 | 0.891 | 40.764 | 0.896 | 41.760 | -0.56% | -2.39% |
| | | | 835 | 0.909 | 40.609 | 0.900 | 41.500 | 1.00% | -2.15% |
| | | | 850 | 0.914 | 40.579 | 0.916 | 41.500 | -0.22% | -2.22% |
| 10/23/2023 | 835 Head | 22.9 | 815 | 0.869 | 40.422 | 0.898 | 41.594 | -3.23% | -2.82% |
| | | | 820 | 0.871 | 40.411 | 0.899 | 41.578 | -3.11% | -2.81% |
| | | | 835 | 0.875 | 40.371 | 0.900 | 41.500 | -2.78% | -2.72% |
| | | | 850 | 0.880 | 40.326 | 0.916 | 41.500 | -3.93% | -2.83% |
| 10/06/2023 | 1900 Head | 20.7 | 1850 | 1.375 | 38.243 | 1.400 | 40.000 | -1.79% | -4.39% |
| | | | 1860 | 1.382 | 38.225 | 1.400 | 40.000 | -1.29% | -4.44% |
| | | | 1880 | 1.399 | 38.200 | 1.400 | 40.000 | -0.07% | -4.50% |
| | | | 1900 | 1.413 | 38.194 | 1.400 | 40.000 | 0.93% | -4.51% |
| | | | 1905 | 1.415 | 38.190 | 1.400 | 40.000 | 1.07% | -4.53% |
| | | | 1910 | 1.418 | 38.184 | 1.400 | 40.000 | 1.29% | -4.54% |
| 10/30/2023 | 2450 Head | 20.0 | 2310 | 1.682 | 38.977 | 1.679 | 39.480 | 0.18% | -1.27% |
| | | | 2320 | 1.690 | 38.966 | 1.687 | 39.460 | 0.18% | -1.25% |
| | | | 2400 | 1.749 | 38.864 | 1.756 | 39.289 | -0.40% | -1.08% |
| | | | 2450 | 1.788 | 38.797 | 1.800 | 39.200 | -0.67% | -1.03% |
| | | | 2480 | 1.810 | 38.750 | 1.833 | 39.162 | -1.25% | -1.05% |
| | | | 2500 | 1.827 | 38.711 | 1.855 | 39.136 | -1.51% | -1.09% |
| 10/25/2023 | 2600 Head | 22.2 | 2535 | 1.842 | 38.696 | 1.893 | 39.092 | -2.69% | -1.01% |
| | | | 2550 | 1.854 | 38.684 | 1.909 | 39.073 | -2.88% | -1.00% |
| | | | 2560 | 1.861 | 38.675 | 1.920 | 39.060 | -3.07% | -0.99% |
| | | | 2600 | 1.890 | 38.607 | 1.964 | 39.009 | -3.77% | -1.03% |
| | | | 2650 | 1.933 | 38.522 | 2.018 | 38.945 | -4.21% | -1.09% |
| | | | 2680 | 1.956 | 38.493 | 2.051 | 38.907 | -4.63% | -1.06% |
| 10/30/2023 | 2600 Head | 20.0 | 2535 | 1.858 | 38.662 | 1.893 | 39.092 | -1.85% | -1.10% |
| | | | 2550 | 1.871 | 38.650 | 1.909 | 39.073 | -1.99% | -1.08% |
| | | | 2560 | 1.879 | 38.641 | 1.920 | 39.060 | -2.14% | -1.07% |
| | | | 2600 | 1.909 | 38.564 | 1.964 | 39.009 | -2.80% | -1.14% |
| | | | 2650 | 1.955 | 38.469 | 2.018 | 38.945 | -3.12% | -1.22% |
| | | | 2680 | 1.979 | 38.433 | 2.051 | 38.907 | -3.51% | -1.22% |
| 11/01/2023 | 5250 Head | 20.0 | 5220 | 4.470 | 35.257 | 4.676 | 35.963 | -4.41% | -1.96% |
| | | | 5240 | 4.488 | 35.222 | 4.696 | 35.940 | -4.43% | -2.00% |
| | | | 5250 | 4.495 | 35.205 | 4.706 | 35.929 | -4.48% | -2.02% |
| | | | 5260 | 4.504 | 35.185 | 4.717 | 35.917 | -4.52% | -2.04% |
| | | | 5270 | 4.513 | 35.162 | 4.727 | 35.906 | -4.53% | -2.07% |
| | | | 5280 | 4.525 | 35.137 | 4.737 | 35.894 | -4.48% | -2.11% |

The above measured tissue parameters were used in the DASY software. The DASY software was used to perform interpolation to determine the dielectric parameters at the SAR test device frequencies (per KDB Publication 865664 D01v01r04 and IEEE 1528-2013 6.6.1.2). The tissue parameters listed in the SAR test plots may slightly differ from the table above due to significant digit rounding in the software.

## 10.2 Test System Verification

Prior to SAR assessment, the system is verified to ±10% of the SAR measurement on the reference dipole at the time of calibration by the calibration facility. Full system validation status and result summary can be found in Appendix C.

**Table 10-2**
**System Verification Results – 1g**

| System Verification<br>TARGET & MEASURED | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SAR System # | Tissue Frequency (MHz) | Tissue Type | Date | Amb. Temp (°C) | Liquid Temp (°C) | Input Power (W) | Source SN | Probe SN | DAE | Measured $SAR_{1g}$ (W/kg) | 1 W Target $SAR_{1g}$ (W/kg) | 1 W Normalized $SAR_{1g}$ (W/kg) | Deviation $n_{1g}$ (%) |
| M | 750 | HEAD | 10/23/2023 | 22.7 | 21.2 | 0.20 | 1054 | 7410 | 1583 | 1.760 | 8.520 | 8.800 | 3.29% |
| M | 835 | HEAD | 10/23/2023 | 22.7 | 21.2 | 0.20 | 4d047 | 7410 | 1583 | 2.050 | 9.650 | 10.250 | 6.22% |
| M | 835 | HEAD | 11/3/2023 | 22.4 | 20.7 | 0.20 | 4d047 | 7410 | 1583 | 1.950 | 9.650 | 9.750 | 1.04% |
| M | 1900 | HEAD | 10/6/2023 | 22.0 | 20.7 | 0.10 | 5d080 | 7410 | 1583 | 4.070 | 39.600 | 40.700 | 2.78% |
| M | 2450 | HEAD | 10/30/2023 | 20.4 | 20.0 | 0.10 | 981 | 7410 | 1583 | 5.700 | 53.900 | 57.000 | 5.75% |
| M | 2600 | HEAD | 10/25/2023 | 21.4 | 20.6 | 0.10 | 1064 | 7410 | 1583 | 5.830 | 56.400 | 58.300 | 3.37% |
| M | 2600 | HEAD | 10/30/2023 | 20.4 | 20.0 | 0.10 | 1064 | 7410 | 1583 | 5.840 | 56.400 | 58.400 | 3.55% |
| G | 5250 | HEAD | 11/1/2023 | 19.8 | 20.4 | 0.05 | 1191 | 7417 | 665 | 3.840 | 80.400 | 76.800 | -4.48% |

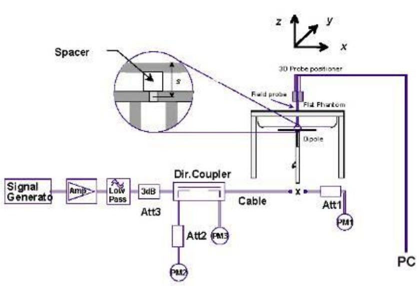



**Figure 10-1**
**System Verification Setup Diagram**

**Figure 10-2**
**System Verification Setup Photo**

# 11 SAR TEST RESULTS (FREQ < 6 GHZ)

## 11.1 Time-varying Tx Power Case

Following Section 4.4 procedure, time-averaged SAR measurements are conducted using a SAR probe at peak location of area scan over 500 seconds. cDASY6 system verification for SAR measurement is provided in Section 10, and the associated SPEAG certificates are attached in Appendix G.

SAR probe integration times depend on the communication signal being tested as defined in the probe calibration parameters.

Since the sampling rate used by cDASY6 for pointSAR measurements is not in user control, the number of points in 100s interval is determined from the scan duration setting in cDASY6 time-average pointSAR measurement by (100s cDASY6_scan_duration * total number of pointSAR values recorded). Running average is performed over these number of points in excel spreadsheet to obtain 100s averaged point SAR.

Following Section 4.4, for each of selected technology/band (listed in Table 8-2):

8. With *Reserve_power_margin* set to 0 dB, area scan is performed at $P_{limit}$, and time-averaged pointSAR measurements are conducted to determine the pointSAR at $P_{limit}$ at peak location, denoted as *point*SAR$_{Plimit}$.
9. With *Reserve_power_margin* set to actual (intended) value, two more time-averaged pointSAR measurements are performed at the same peak location for test sequences 1 and 2.

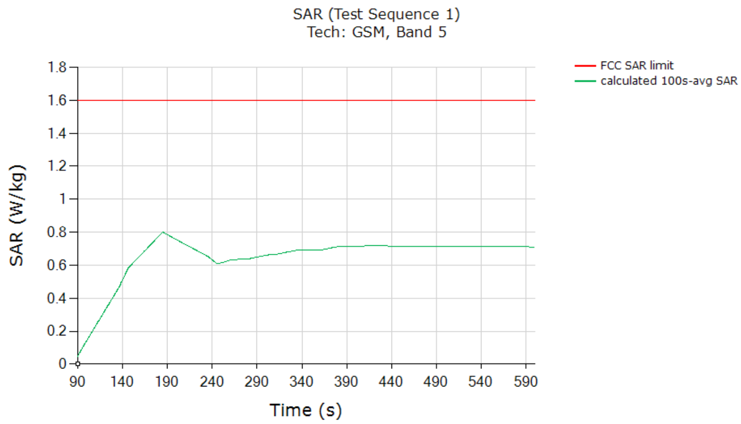
To demonstrate compliance, all the pointSAR measurement results were converted into 1gSAR or 10gSAR values by using Equation (3a), rewritten below:

$$1g\_or\_10gSAR(t) = \frac{pointSAR(t)}{pointSAR\_P_{limit}} * 1g\_or\_10gSAR\_P_{limit} \qquad (3a)$$

where, $pointSAR(t)$, $pointSAR\_P_{limit}$, and $1g\_or\_10gSAR\_P_{limit}$ correspond to the measured instantaneous point SAR, measured point SAR at $P_{limit}$ from above step 1 and 2, and measured *1gSAR* or 10gSAR values at $P_{limit}$ obtained from Part 1 report and listed in Table 8-2 of this report.

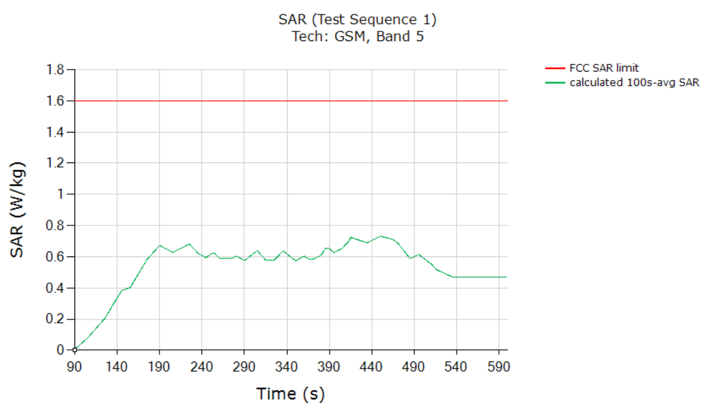
### 11.1.1 GSM/GPRS/EDGE 850

SAR test results for test sequence 1:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged point 1gSAR (green curve) | 0.801 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

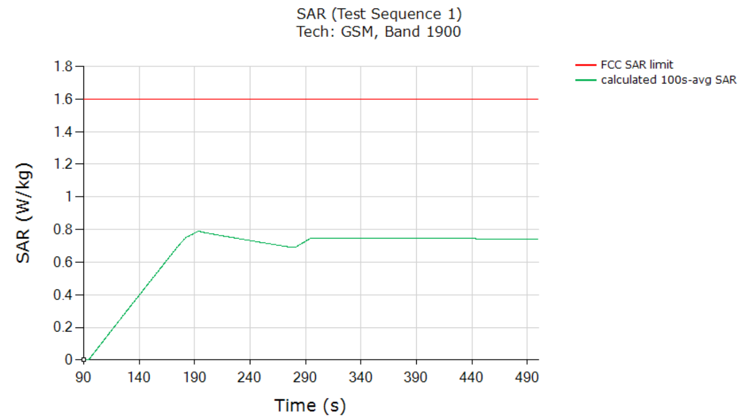
SAR test results for test sequence 2:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged point 1gSAR (green curve) | 0.732 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

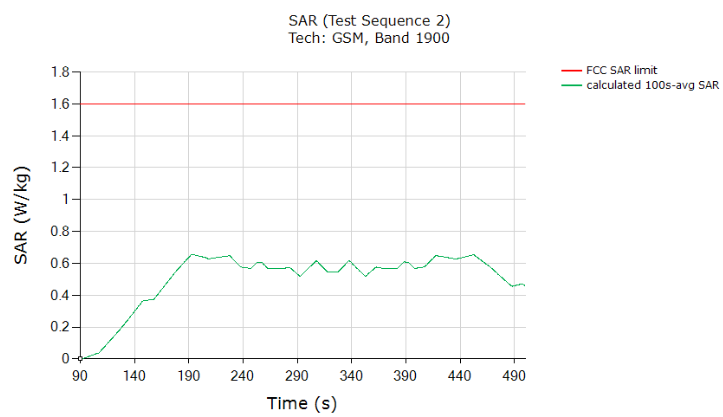
## 11.1.2 GSM/GPRS/EDGE 1900

SAR test results for test sequence 1:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged point 1gSAR (green curve) | 0.792 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

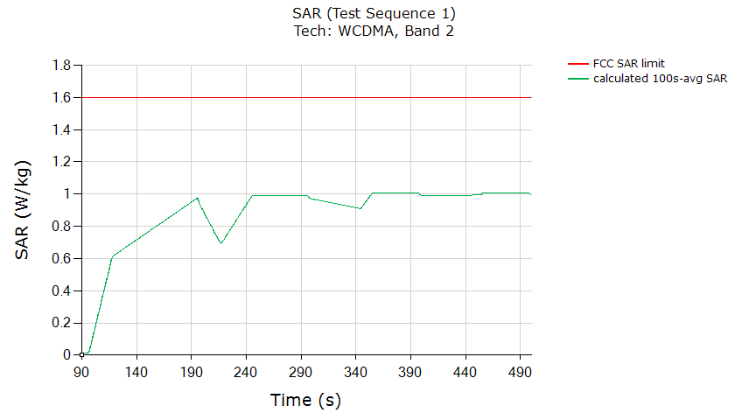
SAR test results for test sequence 2:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged point 1gSAR (green curve) | 0.656 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

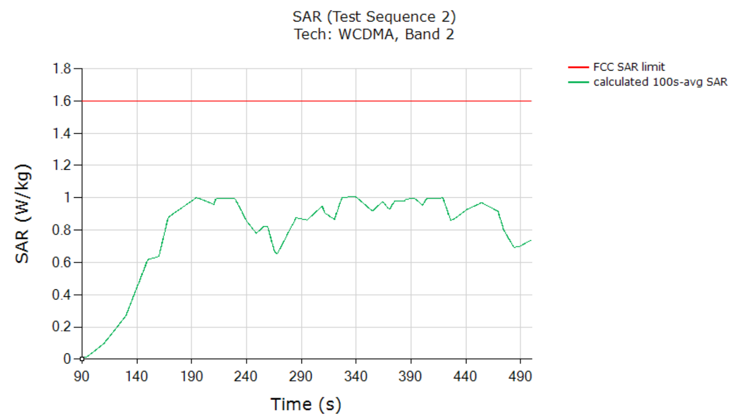
### 11.1.3 WCDMA Band 2

SAR test results for test sequence 1:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged point 1gSAR (green curve) | 1.008 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

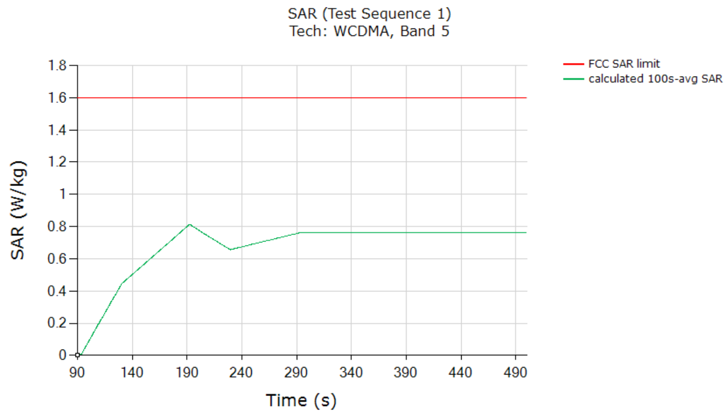
SAR test results for test sequence 2:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged point 1gSAR (green curve) | 1.007 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

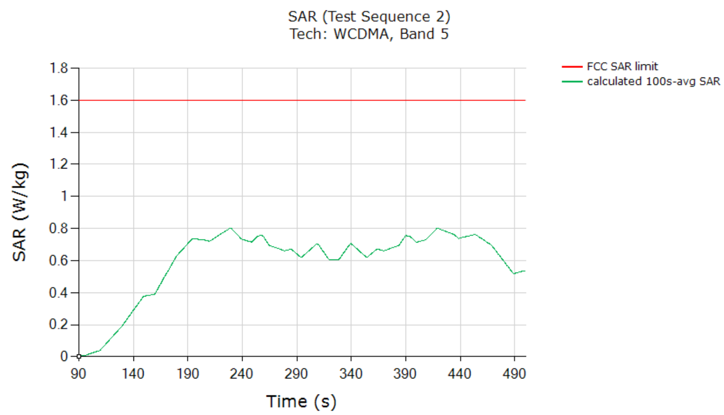
### 11.1.4 WCDMA Band 5

SAR test results for test sequence 1:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged point 1gSAR (green curve) | 0.815 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

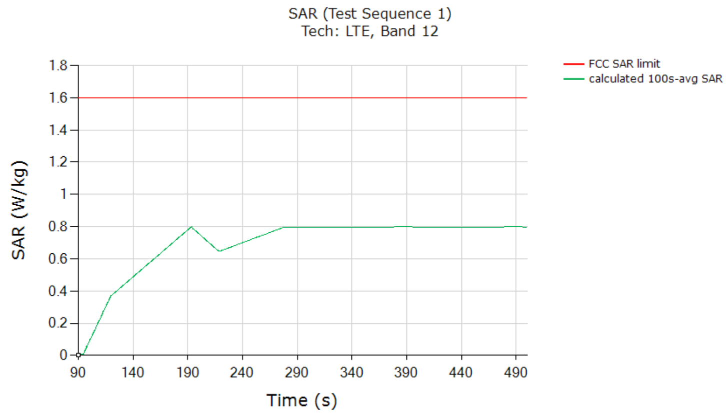
SAR test results for test sequence 2:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged point 1gSAR (green curve) | 0.803 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

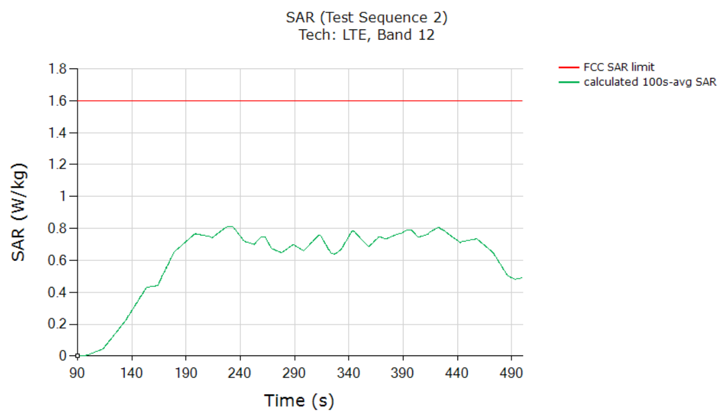
### 11.1.5 LTE Band 12

SAR test results for test sequence 1:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged point 1gSAR (green curve) | 0.799 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

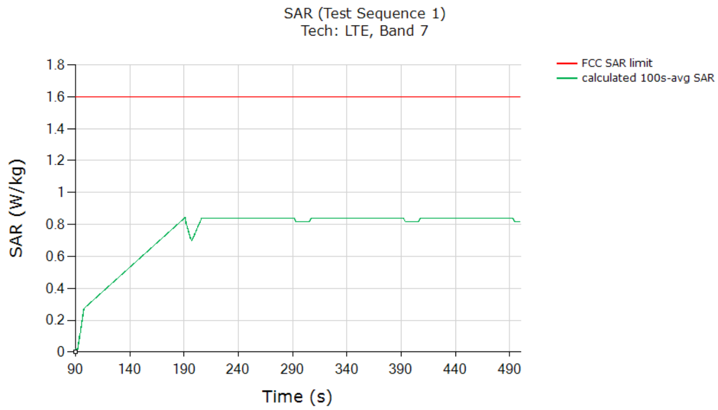
SAR test results for test sequence 2:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged point 1gSAR (green curve) | 0.809 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

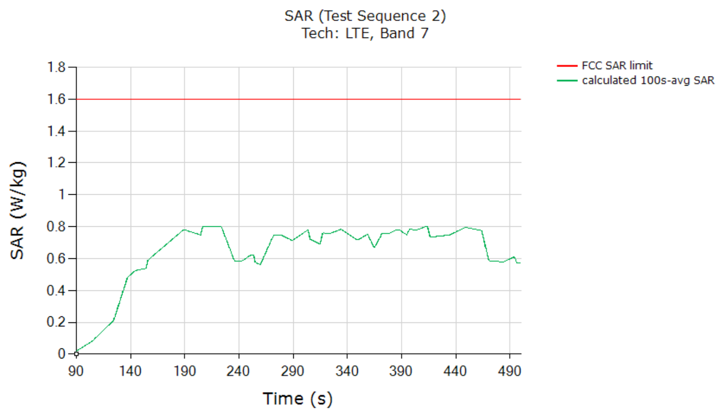
### 11.1.6 LTE Band 7

SAR test results for test sequence 1:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged point 1gSAR (green curve) | 0.843 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

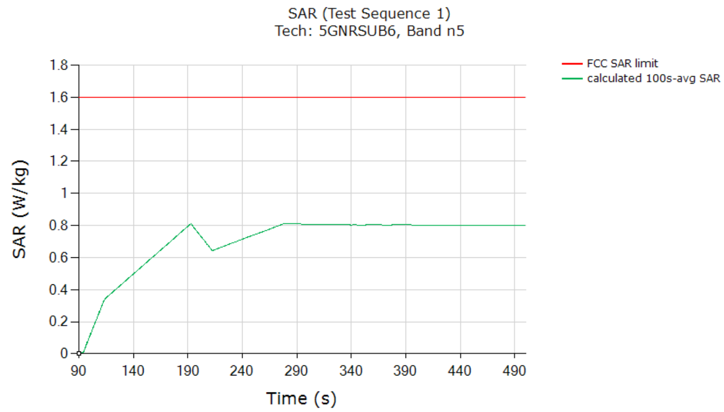
SAR test results for test sequence 2:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged point 1gSAR (green curve) | 0.804 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

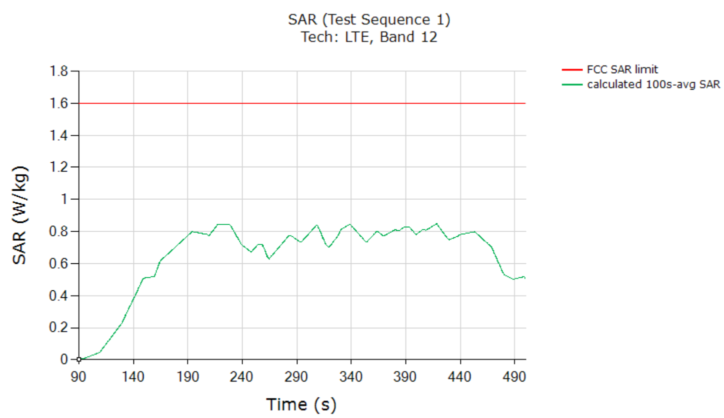
### 11.1.7 NR n5 SA

SAR test results for test sequence 1:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged point 1gSAR (green curve) | 0.812 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

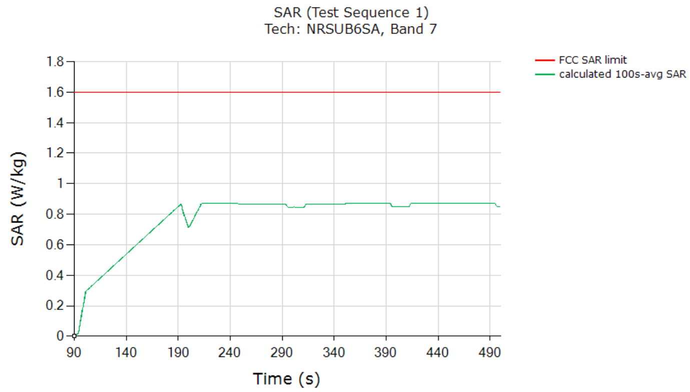
SAR test results for test sequence 2:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged point 1gSAR (green curve) | 0.847 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

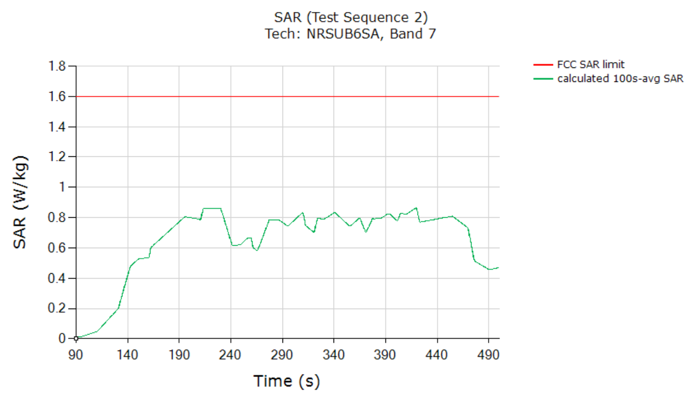
### 11.1.8 NR n7 SA

SAR test results for test sequence 1:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged point 1gSAR (green curve) | 0.871 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

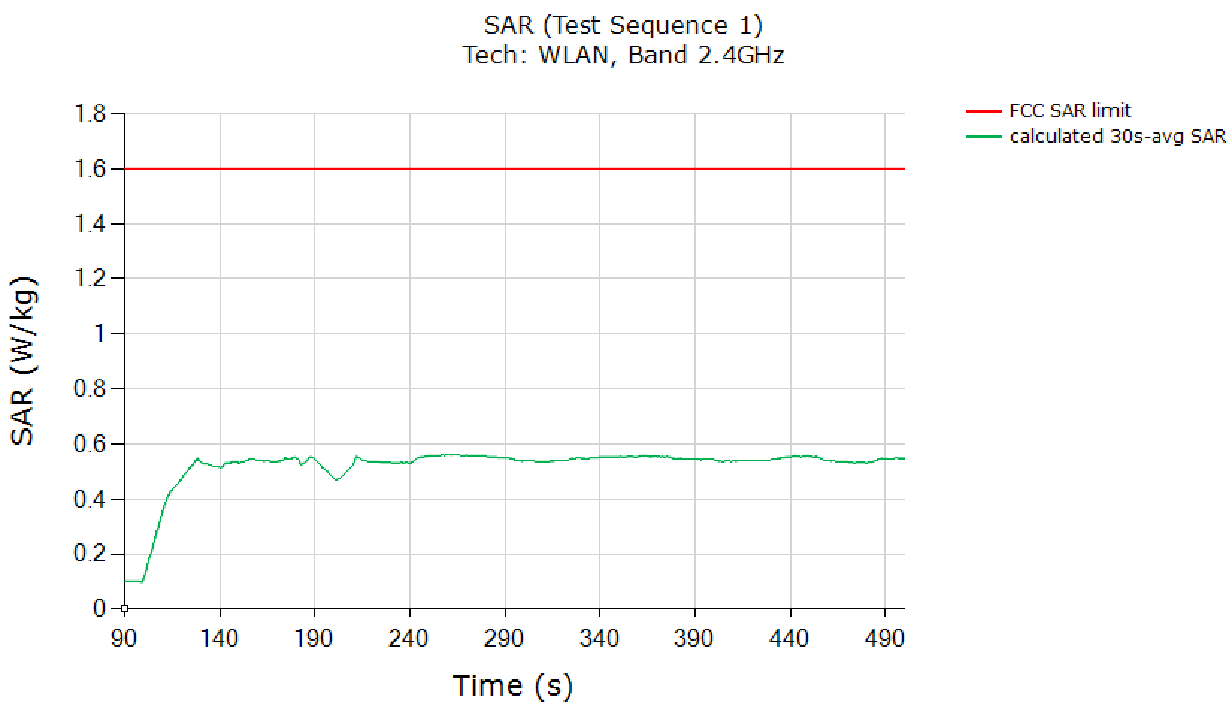
SAR test results for test sequence 2:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 100s-time averaged point 1gSAR (green curve) | 0.865 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

## 11.1.9 WLAN 2.4GHz

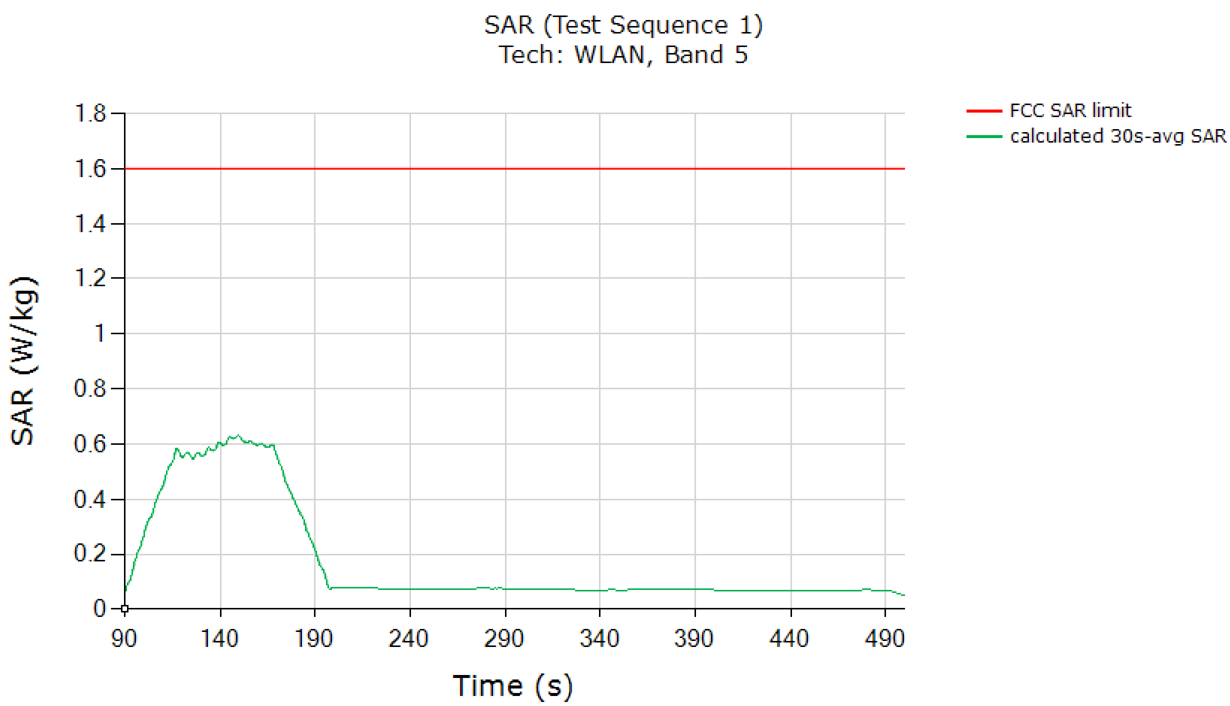
SAR test results for test sequence:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 30s-time averaged point 1gSAR (green curve) | 0.560 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

### 11.1.10 WLAN 5GHz

SAR test results for test sequence:




| | (W/kg) |
|---|---|
| FCC 1gSAR limit | 1.6 |
| Max 30s-time averaged point 1gSAR (green curve) | 0.630 |
| Validated: Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at $P_{limit}$ (last column in Table 8-2). | |

# 12 TEST CONFIGURATIONS (FREQ > 6 GHZ)

## 12.1 LTE + mmW NR transmission

Based on the selection criteria described in Section 5.2, the selections for LTE and mmW NR validation test are listed in Table 12-1. The radio configurations used in this test are listed in Table 12-2.

**Table 12-1**
**Selections for LTE + mmW NR validation measurements**

| Transmission Scenario | Test | Technology and Band | mmWave Beam |
|---|---|---|---|
| Time-varying Tx power test | 1. Cond. & Rad. Power meas.<br>2. PD meas. | LTE Band 2 and n261 | Beam ID 40 |
| | | LTE Band 2 and n260 | Beam ID 40 |
| Switch in SAR vs. PD | 1. Cond. & Rad. Power meas. | LTE Band 2 and n261 | Beam ID 40 |
| | | LTE Band 2 and n260 | Beam ID 40 |
| Beam switch test | 1. Cond. & Rad. Power meas. | LTE Band 2 and n261 | Beam ID 31 to Beam ID 7 |
| | | LTE Band 2 and n260 | Beam ID 40 to Beam ID 9 |

**Table 12-2**
**Test configuration for LTE + mmW NR validation**

| Tech | Band | Antenna | DSI | Channel | Freq (MHz) | RB/RB Offset/Bandwidth (MHz) | Mode | UL Duty Cycle |
|---|---|---|---|---|---|---|---|---|
| LTE | 2 | A | 0 | 18900 | 1880 | 1/0/20 MHz BW | QPSK | 100% |
| mmW NR | n261 | N | - | 2077915 | 27924.96 | 20/22/100 MHz BW | DFT-s-OFDM, QPSK | 75.6%* |
| | n260 | N | - | 2254165 | 38499.96 | 20/22/100 MHz BW | DFT-s-OFDM, QPSK | 75.6%* |

| Tech | Band | Antenna | Beam ID | input.power.limit (dBm) | Measured psPD at input.power.limit | | Measured EIRP at input.power.limit (dBm) | DSI_PD_ratio |
|---|---|---|---|---|---|---|---|---|
| | | | | | 4cm$^2$ psPD (W/m$^2$) | Test Position | | |
| mmW NR | n261 | N | 40 | 3.0 | 7.31 | Right Edge | 14.09 | 1.0 |
| | | N | 7 | 10.1 | 3.68 | Right Edge | 7.75 | |
| mmW NR | n260 | N | 40 | 4.5 | 4.56 | Right Edge | 19.41 | |
| | | N | 9 | 10.6 | 4.31 | Right Edge | 6.76 | |

Smart Transmit EFS version 21 supports DSI applicability feature. With this new enhancement, in simultaneous transmission scenarios involving sub6 radio + mmW radio, for a given DSI, both sub6 exposure and mmW exposure will be evaluated at the DSI corresponding separation distance in TER analysis, but in the same time, the compliance of mmW exposure at 2mm is ensured for all DSI states (**Note: at this time, FCC requires PD compliance at 2mm for all DSI states**). Thus, below two steps are implemented in Smart Transmit with EFS version 20:

1. For TER calcuation, scale PD exposure at 2mm down to the same separation distance at which sub6 exposure is measured for that DSI using '*DSI_PD_ratio*' (see Appendix G.1.3 of 80-W2112-4 Part 1 report for the definition of *DSI_PD_ratio* and its calculation), i.e.,

$$TER\_at\_DSI\_\ distance = \frac{sub6\ exposure}{regulatory\ sub6\ limit} + \frac{PD\ exposure}{regulatory\ PD\ limit} \text{ x } DSI\_PD\_ratio \quad (9a)$$

Where,

$$DSI\_PD\_ratio = \frac{PD\_at\_DSI\_separation\_distance}{PD\_at\_2mm} \quad (9b)$$

2. Below conditions will also be met irrespective of DSI state:

$$\frac{PD\_at\_2mm}{regulatory\_PD\_limit} \leq 1.0 \quad (9c)$$

## 12.2 mmW NR and sub6 NR radiated power test results

To demonstrate the compliance, the conducted Tx power of LTE Band 2 in DSI = 0 is converted to 10gSAR exposure by applying the corresponding worst-case 10g SAR value at $P_{limit}$ as reported in Part 1 report and listed in Table 8-2 of this report.

Similarly, following Step 4 in Section 5.3.1, radiated Tx power of mmW Band n261 and n260 for the beams tested is converted by applying the corresponding measured worst-case 4cm$^2$PD values, and listed in below Table 12-3. Qualcomm Smart Transmit feature operates based on time-averaged Tx power reported on a per symbol basis, which is independent of modulation, channel and bandwidth (RBs), therefore the worst-case 4cm$^2$PD was conducted with the EUT in FTM mode, with CW modulation and 100% duty cycle. cDASY6 system verification for power density measurement is provided in Section 14, and the associated SPEAG certificates are attached in Appendix G.

Both the worst-case 1gSAR and 4cm$^2$PD values used in this section are listed in Table 12-3. The measured EIRP at *input.power.limit* for the beams tested in this section are also listed in Table 12-3.

**Table 12-3**
**Selections for LTE + mmW NR validation measurements**

| Tech | Band | Antenna | Beam ID | input.power.limit (dBm) | Measured psPD at input.power.limit | | Measured EIRP at input.power.limit (dBm) | DSI_PD_ratio |
|---|---|---|---|---|---|---|---|---|
| | | | | | 4cm$^2$ psPD (W/m$^2$) | Test Position | | |
| mmW NR | n261 | N | 40 | 3.0 | 7.31 | Right Edge | 14.09 | 1.0 |
| | | N | 7 | 10.1 | 3.68 | Right Edge | 7.75 | |
| mmW NR | n260 | N | 40 | 4.5 | 4.56 | Right Edge | 19.41 | |
| | | N | 9 | 10.6 | 4.31 | Right Edge | 6.76 | |

| Tech | Band | Antenna | DSI | Measured Plimit (dBm) | Measured 1g SAR at Plimit | |
|---|---|---|---|---|---|---|
| | | | | | 1g SAR (W/kg) | Test Position |
| LTE | 2 | A | 0 | 17.73 | 1.610 | Botton Edge, 10mm |

Smart Transmit EFS version 21 supports DSI applicability feature. With this new enhancement, in simultaneous transmission scenarios involving sub6 radio + mmW radio, for a given DSI, both sub6 exposure and mmW exposure will be evaluated at the DSI corresponding separation distance in TER analysis, but in the same time, the compliance of mmW exposure at 2mm is ensured for all DSI states

(**Note: at this time, FCC requires PD compliance at 2mm for all DSI states**). Thus, below two steps are implemented in Smart Transmit with EFS version 20:

2. For TER calcuation, scale PD exposure at 2mm down to the same separation distance at which sub6 exposure is measured for that DSI using '*DSI_PD_ratio*' (see Appendix G.1.3 of 80-W2112-4 Part 1 report for the definition of *DSI_PD_ratio* and its calculation), i.e.,

$$TER\_at\_DSI\_\,distance = \frac{sub6\ exposure}{regulatory\ sub6\ limit} + \frac{PD\ exposure}{regulatory\ PD\ limit}\ \mathrm{x}\ DSI\_PD\_ratio \qquad (9a)$$

Where,

$$DSI\_PD\_ratio = \frac{PD\_at\_DSI\_separation\_distance}{PD\_at\_2mm} \qquad (9b)$$

3. Below condition will also be met irrespective of DSI state:

$$\frac{PD\_at\_2mm}{regulatory\_PD\_limit} \leq\ 1.0 \qquad (9c)$$

**Figure 12-1**
**4cm² psPD distribution measured at *input.power.limit* of 3.0 dBm on the Right Edge at 10mm for n261 beam 40**

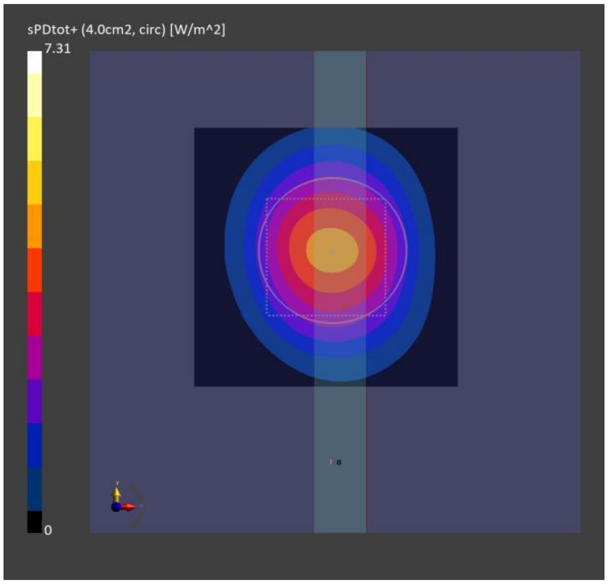
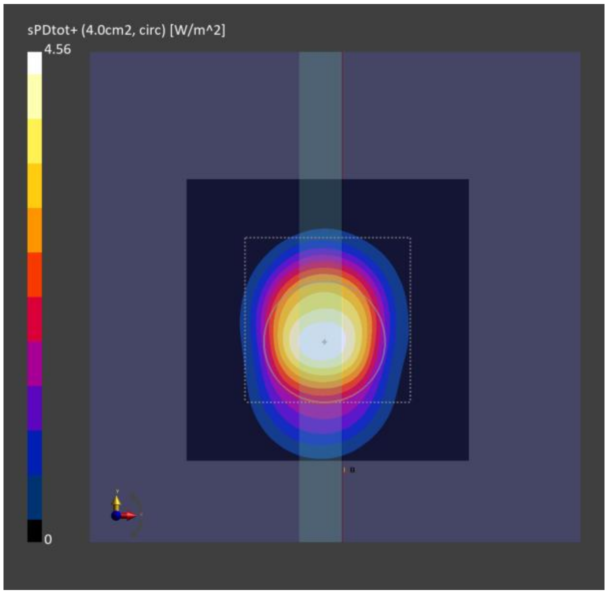



**Figure 12-2**
**4cm² psPD distribution measured at *input.power.limit* of 4.5 dBm on the Right Edge at 10mm for n260 beam 40**

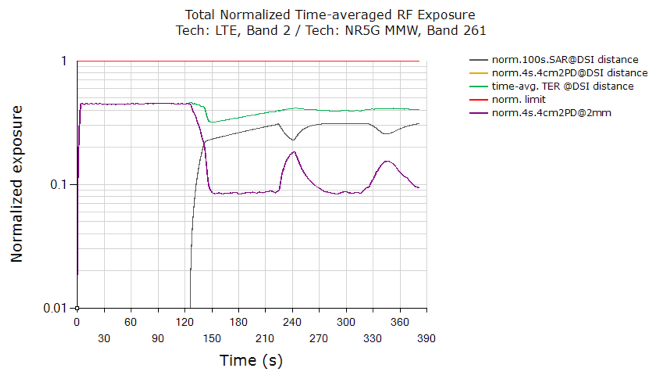


# 13 RADIATED POWER TX CASES (FREQ > 6 GHZ)

## 13.1 Maximum Tx power test results for n261

This test was measured with LTE Band 2 and mmW Band n261 Beam ID 40 by following the detailed test procedure described in Section 5.3.1.

Time-averaged conducted Tx power for LTE Band 2 and radiated Tx power for mmW NR n261 beam 40 are converted into time-averaged 1gSAR and time-averaged 4cm$^2$PD using Equation (2a) and (2b), which are divided by FCC 10gSAR limit of 4.0 W/kg and 4cm$^2$PD limit of 10 W/m$^2$, respectively, to obtain normalized exposures versus time. Below plot shows (a) normalized time-averaged 1gSAR versus time, (b) normalized time-averaged 4cm2-avg.PD versus time, (c) sum of normalized time-averaged 1gSAR and normalized time-averaged 4cm$^2$-avg.PD:




| | |
|---|---|
| FCC requirement for total RF exposure (normalized) | 1.0 |
| Max total normalized time-averaged RF exposure (green curve) | 0.457 |
| Validated | |

Plot notes: As soon as 5G mmW NR call was established, LTE was placed in all-down bits immediately. Between 0s~120s, mmW exposure is the dominant contributor. Here, Smart Transmit feature allocates a maximum of 1.0 for mmW (based on the 3dB reserve setting in Part 1 report). At ~120s time mark, LTE is set to all-up bits, taking away margin from mmW exposure gradually and towards the end of the test, LTE is the dominant contributor towards RF exposure. Table 13-1 shows the calculations for the normalized 4cm$^2$ PD exposure values and the normalized 1g SAR exposure value.

**Table 13-1**

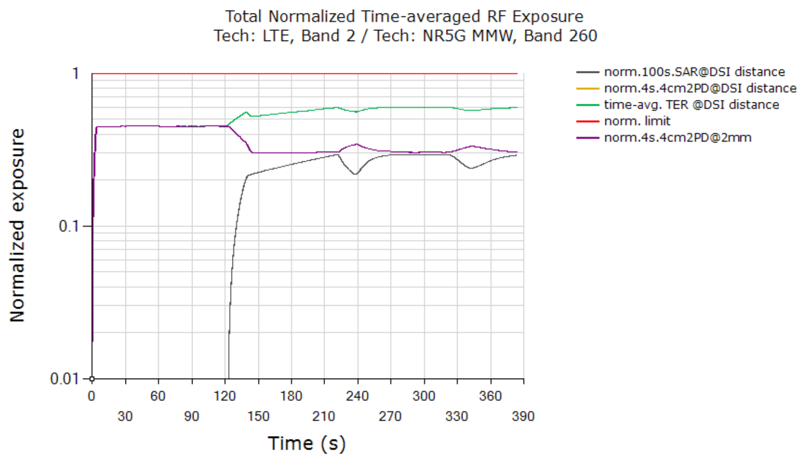
| | Static 4cm$^2$ PD or 10g SAR [W/m$^2$ or W/kg] | Normalized Exposure | Uncertainty [dB] |
|---|---|---|---|
| 0s~120s: NR Green/Orange Curve | 7.31 | 73.1% | 2.0 |
| After ~120s: LTE Black Curve | 1.61 | 40.3% | 1.0 |

As can be seen, the power limiting enforcement is effective and the total normalized time-averaged RF exposure does not exceed 1.0. Therefore, Qualcomm® Smart Transmit time averaging feature is validated.

## 13.2 Maximum Tx power test results for n260

This test was measured with LTE Band 2 and mmW Band n260 Beam ID 40, by following the detailed test procedure described in Section 5.3.1.

Time-averaged conducted Tx power for LTE Band 2 and radiated Tx power for mmW NR n260 beam 40` are converted into time-averaged 1gSAR and time-averaged 4cm²PD using Equation (2a) and (2b), which are divided by FCC 10gSAR limit of 4.0 W/kg and 4cm²PD limit of 10 W/m², respectively, to obtain normalized exposures versus time. Below plot shows (a) normalized time-averaged 10gSAR versus time, (b) normalized time-averaged 4cm2-avg.PD versus time, (c) sum of normalized time-averaged 10gSAR and normalized time-averaged 4cm²-avg.PD:




| | |
|---|---|
| FCC requirement for total RF exposure (normalized) | 1.0 |
| Max total normalized time-averaged RF exposure (green curve) | 0.601 |
| Validated | |

Plot notes: As soon as 5G mmW NR call was established, LTE was placed in all-down bits immediately. Between 0s~120s, mmW exposure is the dominant contributor. Here, Smart Transmit feature allocates a maximum of 1.0 for mmW (based on the 3dB reserve setting in Part 1 report). At ~120s time mark, LTE is set to all-up bits, taking away margin from mmW exposure gradually and towards the end of the test, LTE is the dominant contributor towards RF exposure. Table 13-2 shows the calculations for the normalized 4cm² PD exposure values and the normalized 1g SAR exposure value.

**Table 13-2**

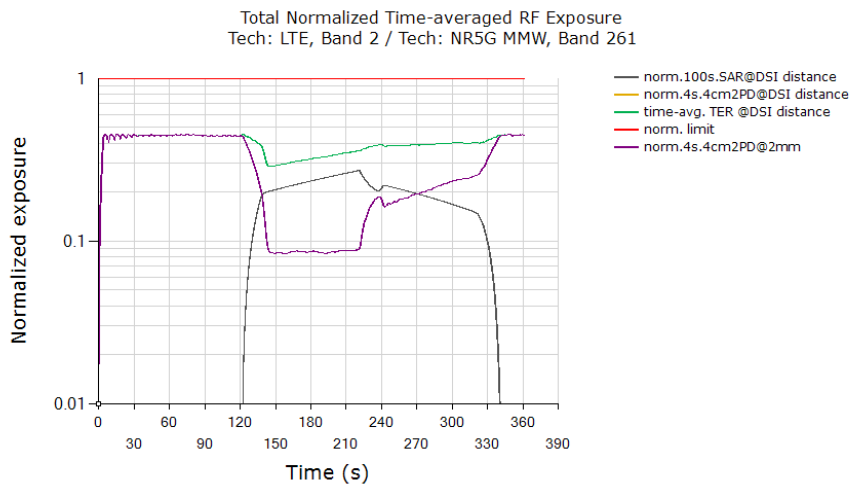
| | Static 4cm² PD or 10g SAR [W/m² or W/kg] | Normalized Exposure | Uncertainty [dB] |
|---|---|---|---|
| 0s~120s: NR Green/Orange Curve | 4.56 | 45.6% | 2.0 |
| After ~120s: LTE Black Curve | 1.61 | 40.3% | 1.0 |

As can be seen, the power limiting enforcement is effective and the total normalized time-averaged RF exposure does not exceed 1.0. Therefore, Qualcomm® Smart Transmit time averaging feature is validated.

## 13.3 Switch in SAR vs. PD exposure test results for n261

This test was measured with LTE Band 2 (DSI = 0) and mmW Band n261 Beam ID 13, by following the detailed test procedure is described in Section 5.3.2.

Normalized time-averaged exposures for LTE (1gSAR) and mmW ($4cm^2$PD), as well as total normalized time-averaged exposure versus time:




| | |
|---|---|
| FCC requirement for total RF exposure (normalized) | 1.0 |
| Max total normalized time-averaged RF exposure (green curve) | 0.455 |
| Validated | |

Plot notes: As soon as 5G mmW NR call was established, LTE was placed in all-down bits immediately. Between 0s~120s, mmW exposure is the dominant contributor. Here, Smart Transmit feature allocates a maximum of 1.0 for mmW). At ~120s time mark, LTE is set to all-up bits, taking away margin from mmW exposure gradually (orange curve for mmW exposure goes down while black curve for LTE exposure goes up). At ~240s time mark, LTE is set to all-down bits, which results in mmW getting back RF margin slowly as seen by gradual increase in mmW exposure (orange curve for mmW exposure goes up while black curve for LTE exposure goes down). Table 13-3 shows the calculations for the normalized $4cm^2$ PD exposure value and the normalized 1g SAR exposure value.

**Table 13-3**

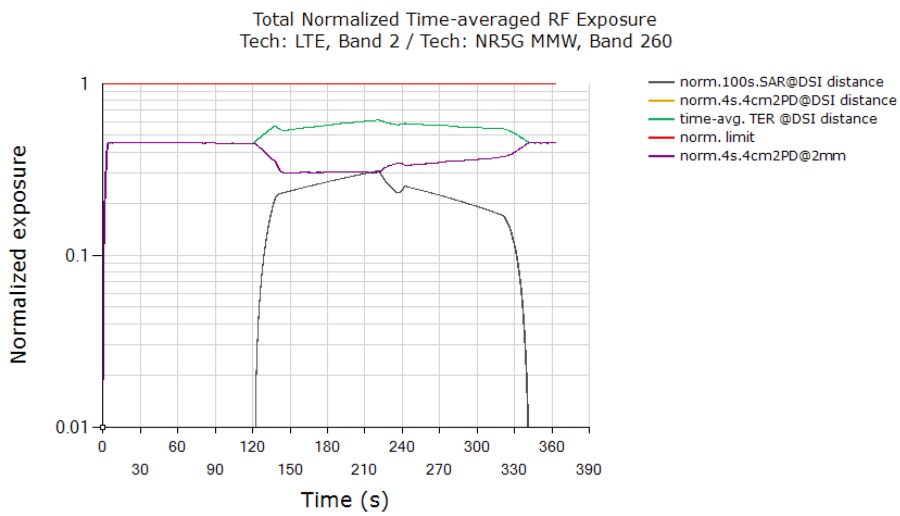
| | Static $4cm^2$ PD or 10g SAR [$W/m^2$ or W/kg] | Normalized Exposure | Uncert [dB] |
|---|---|---|---|
| 0s~120s + After 240s: NR Green/Orange Curve | 7.31 | 73.1% | 2.0 |
| 120s - 240s: LTE Black Curve | 1.61 | 40.3% | 1.0 |

As can be seen, the power limiting enforcement is effective during transmission when SAR and PD exposures are switched, and the total normalized time-averaged RF exposure does not exceed 1.0. Therefore, Qualcomm® Smart Transmit time averaging feature is validated.

## 13.4 Switch in SAR vs. PD exposure test results for n260

This test was measured with LTE Band 2 (DSI = 0) and mmW Band n260 Beam ID 40, by following the detailed test procedure is described in Section 5.3.2.

Normalized time-averaged exposures for LTE (1gSAR) and mmW (4cm²PD), as well as total normalized time-averaged exposure versus time:




| | |
|---|---|
| FCC requirement for total RF exposure (normalized) | 1.0 |
| Max total normalized time-averaged RF exposure (green curve) | 0.618 |
| Validated | |

Plot notes: As soon as 5G mmW NR call was established, LTE was placed in all-down bits immediately. Between 0s~120s, mmW exposure is the dominant contributor. Here, Smart Transmit feature allocates a maximum of 1.0 for mmW). At ~120s time mark, LTE is set to all-up bits, taking away margin from mmW exposure gradually (orange curve for mmW exposure goes down while black curve for LTE exposure goes up). At ~240s time mark, LTE is set to all-down bits, which results in mmW getting back RF margin slowly as seen by gradual increase in mmW exposure (orange curve for mmW exposure goes up while black curve for LTE exposure goes down). Table 13-4 shows the calculations for the normalized 4cm² PD exposure value and the normalized 1g SAR exposure value.

**Table 13-4**

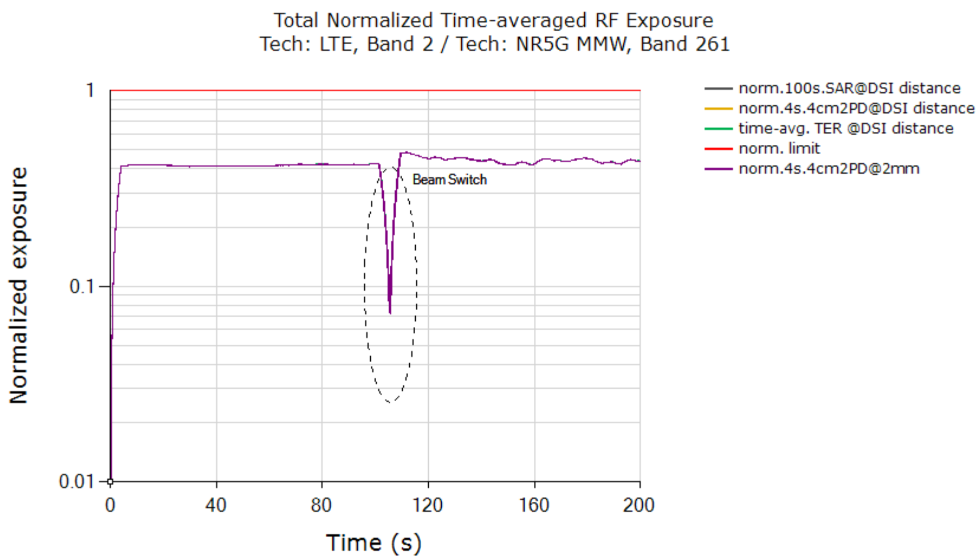
| | Static 4cm² PD or 1g SAR [W/m² or W/kg] | Normalized Exposure | Uncert [dB] |
|---|---|---|---|
| 0s~120s + After 240s: NR Green/Orange Curve | 4.56 | 45.6% | 2.0 |
| 120s - 240s: LTE Black Curve | 0.312 | 40.3% | 1.0 |

As can be seen, the power limiting enforcement is effective during transmission when SAR and PD exposures are switched, and the total normalized time-averaged RF exposure does not exceed 1.0. Therefore, Qualcomm® Smart Transmit time averaging feature is validated.

## 13.5 Change in Beam test results for n261

This test was measured with LTE Band 2 (DSI = 0) and mmW Band n261, with beam switch from Beam ID 31 to Beam ID 7, by following the test procedure is described in Section 5.3.3.

Normalized time-averaged exposures for LTE and mmW ($4cm^2$PD), as well as total normalized time-averaged exposure versus time:




| | |
|---|---|
| FCC requirement for total RF exposure (normalized) | 1.0 |
| Max total normalized time-averaged RF exposure (green curve) | 0.483 |
| Validated | |

Plot notes: 5G mmW NR call was established at ~1s time mark and LTE was placed in all-down bits immediately after 5G mmW NR call was established. For the rest of this test, mmW exposure is the dominant contributor as LTE is left in all-down bits. Here, Smart Transmit feature allocates a maximum of 1.0 for mmW for the first beam (based on 3dB reserve setting in Part 1 report). At ~100s time mark (shown in black dotted ellipse), beam switch takes place and mmW starts transmission from the second beam. Second beam transmits at *input.power.limit* with active power limiting. Table 13-5 shows the calculations for the normalized $4cm^2$ PD exposure values and the difference in EIRPs between two beams.

**Table 13-5**

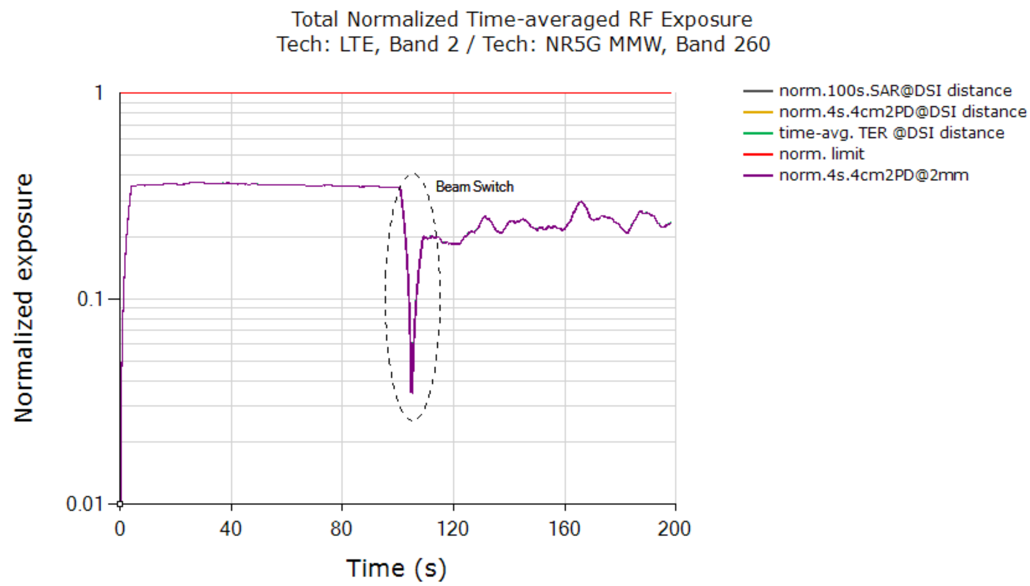
| | Beam ID 31 (0 - 100 sec, before ellipse) | Beam ID 7 (100 - 200 sec, after ellipse) |
|---|---|---|
| Static psPD [$W/m^2$] | 4.83 | 3.11 |
| Input.power.limit [dBm] | 2.5 | 8.5 |

| | | |
|---|---|---|
| Maximum Power [dBm] | 14.5 | |
| Normalized 4cm²PD exposure value [% ± 2.0 dB uncertainty] | 48.3% | 31.1% |
| EIRP Difference [dB ± 2.0 dB uncertainty] | 5.45 | |

## 13.6 Change in Beam test results for n260

This test was measured with LTE Band 2 (DSI = 3) and mmW Band n260, with beam switch from Beam ID 40 to Beam ID 9, by following the test procedure is described in Section 5.3.3.

Normalized time-averaged exposures for LTE and mmW (4cm²PD), as well as total normalized time-averaged exposure versus time:




| | |
|---|---|
| FCC requirement for total RF exposure (normalized) | 1.0 |
| Max total normalized time-averaged RF exposure (green curve) | 0.368 |
| Validated | |

Plot notes: 5G mmW NR call was established at ~1s time mark and LTE was placed in all-down bits immediately after 5G mmW NR call was established. For the rest of this test, mmW exposure is the dominant contributor as LTE is left in all-down bits. Here, Smart Transmit feature allocates a maximum of 1.0 for mmW for the first beam (based on 3dB reserve setting in Part 1 report). At ~100s time mark (shown in black dotted ellipse), beam switch takes place and mmW starts transmission from the second beam. Second beam transmits at *input.power.limit* with active power limiting. Table 13-6 shows the calculations for the normalized 4cm² PD exposure values and the difference in EIRPs between two beams.

**Table 13-6**

| | Beam ID 40 (0 - 100 sec. before ellipse) | Beam ID 9 (100 - 200 sec. after ellipse) |
|---|---|---|

| | | |
|---|---|---|
| Static psPD [W/m$^2$] | 3.68 | 2.97 |
| Input.power.limit [dBm] | 4.5 | 10.6 |
| MTPL [dBm] | 13.5 | |
| Normalized 4cm$^2$PD exposure value [% ± 2.0 dB uncertainty] | 36.8% | 29.7% |
| EIRP Difference [dB ± 2.0 dB uncertainty] | 4.59 dB | |

# 14 SYSTEM VERIFICATION (FREQ > 6 GHZ)

The system was verified to be within ±0.66 dB of the power density targets on the calibration certificate according to the test system specification in the user's manual and calibration facility recommendation. The 0.66 dB deviation threshold represents the expanded uncertainty for system performance checks using SPEAG's mmWave verification sources. The same spatial resolution and measurement region used in the source calibration was applied during the system check.

The measured power density distribution of verification source was also confirmed through visual inspection to have no noticeable differences, both spatially (shape) and numerically (level) from the distribution provided by the manufacturer, per November 2017 TCBC Workshop Notes.

**Table 14-1**
**System Verification Results**

| System Verification | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Syst. | Freq. (GHz) | Date | Source SN | Probe SN | Normal psPD (W/m$^2$ over 4 cm$^2$) | | Deviation (dB) | Total psPD (W/m$^2$ over 4 cm$^2$) | | Deviation (dB) |
| | | | | | measured | target | | measured | target | |
| | 0.00 | 11/6/2023 | 1043 | 9389 | 26.50 | 26.70 | -0.03 | 26.80 | 26.70 | 0.02 |
| | 0.00 | 11/7/2023 | 1043 | 9389 | 28.20 | 26.70 | 0.24 | 28.90 | 26.70 | 0.34 |

Note: A **10 mm distance spacing** was used from the reference horn antenna aperture to the probe element. This includes 4.45 mm from the reference antenna horn aperture to the surface of the verification source plus 5.55 mm from the surface to the probe. The SPEAG software requires a setting of "5.55 mm" for the correct setup.

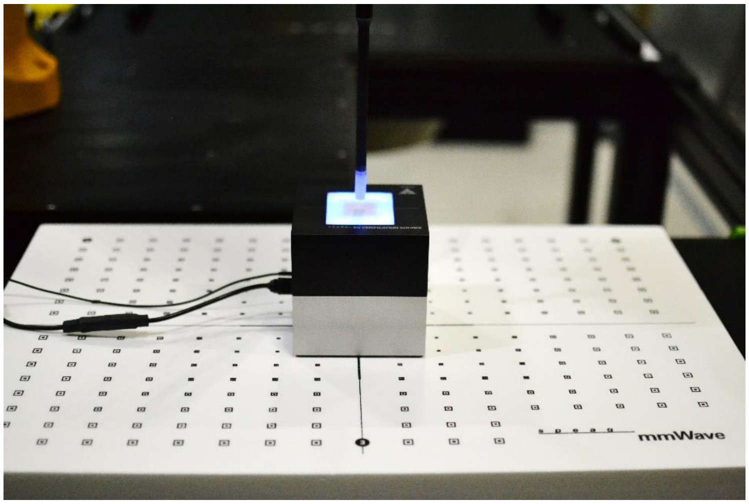



**Figure 14-1**
**System Verification Setup Photo**

# 15 POWER DENSITY TEST RESULTS (FREQ > 6 GHZ)

## 15.1 PD measurement results for maximum power transmission scenario

The following configurations were measured by following the detailed test procedure is described in Section 5.4:

1. LTE Band 2 (DSI = 0) and mmW Band n261 Beam ID 40
2. LTE Band 2 (DSI = 0) and mmW Band n260 Beam ID 40

The measured conducted Tx power of LTE and ratio of $\frac{[pointE(t)]^2}{[pointE\_input.power.limit]^2}$ of mmW is converted into 10gSAR and 4cm²PD value, respectively, using Eq. (4a) and (4b), rewritten below:

$$1g\_or\_10gSAR(t) = \frac{conducted\_Tx\_power(t)}{conducted\_Tx\_power\_P_{limit}} * 1g\_or\_10gSAR\_P_{limit} \quad (4a)$$

$$4cm^2PD(t) = \frac{[pointE(t)]^2}{[pointE\_input.power.limit]^2} * 4cm^2PD\_input.power.limit \quad (4b)$$

$$\frac{\frac{1}{T_{SAR}}\int_{t-T_{SAR}}^{t} 1g\_or\_10gSAR(t)dt}{FCC\ SAR\ limit} + \frac{\frac{1}{T_{PD}}\int_{t-T_{PD}}^{t} 4cm^2PD(t)dt}{FCC\ 4cm^2PD\ limit} \leq 1 \quad (4c)$$

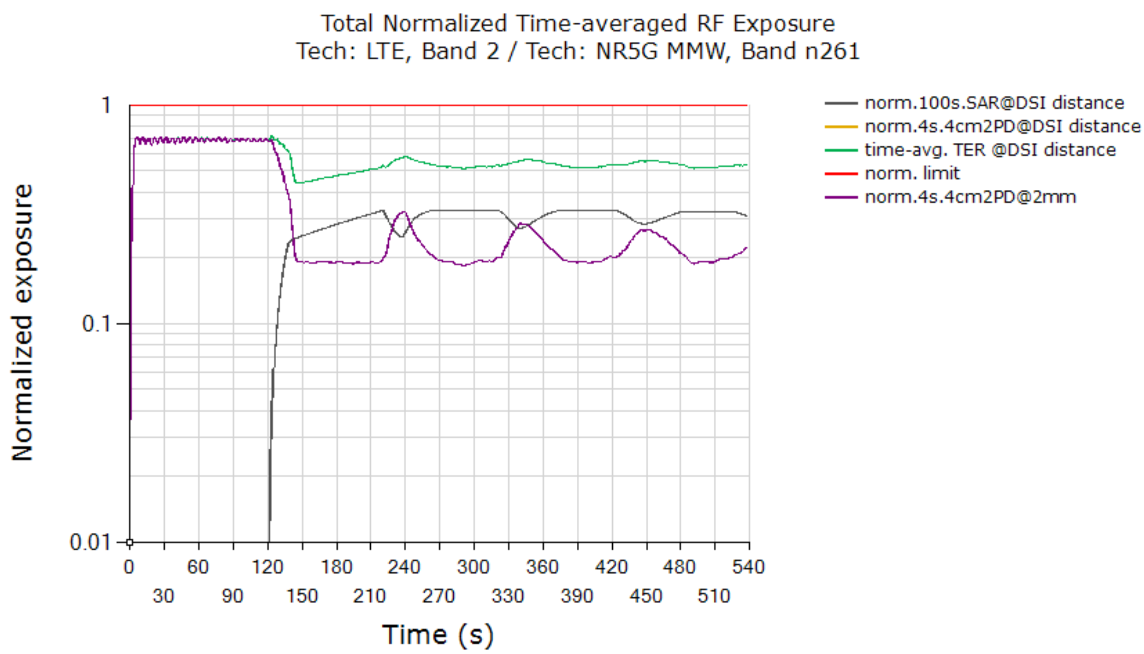
where, $conducted\_Tx\_power(t)$, $conducted\_Tx\_power\_P_{limit}$, and $1g\_or\_10gSAR\_P_{limit}$ correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at $P_{limit}$, and measured 1gSAR or 10gSAR values at $P_{limit}$ corresponding to LTE transmission. Similarly, $pointE(t)$, $pointE\_input.power.limit$, and $4cm^2PD@input.power.limit$ correspond to the measured instantaneous E-field, E-field at *input.power.limit*, and 4cm²PD value at *input.power.limit*. corresponding to mmW transmission.

**NOTE:** cDASY6 system measures relative E-field, and provides ratio of $\frac{[pointE(t)]^2}{[pointE\_input.power.limit]^2}$ versus time.

The radio configurations tested are described in Table 12-1 and Table 12-2. The 1gSAR at $P_{limit}$ for LTE Band 2 DSI = 3, the measured 4cm²PD at *input.power.limit* of mmW n261 beam 13 and n260 beam 14, are all listed in Table 12-3.

### 15.1.1 PD test results for n261

Step 2.e plot (in Section 5.4) for normalized instantaneous and time-averaged exposures for LTE and mmW n261 beam 40.




| | |
|---|---|
| FCC limit for total RF exposure (normalized) | 1.0 |
| Max total normalized time-averaged RF exposure (green curve) | 0.726 |
| Validated | |

Plot notes: LTE was placed in all-down bits immediately after 5G mmW NR call was established. Between 0s~120s, mmW exposure is the dominant contributor. Here, Smart Transmit feature allocates a maximum of 100% for mmW (based on the 3dB reserve setting in Part 1 report). Around the 120s time mark, LTE is set to all-up bits, taking away margin from mmW exposure gradually. Towards the end of the test, LTE is the dominant contributor towards RF exposure. Table 15-1 shows the calculations for the normalized 4cm$^2$ PD exposure values and the normalized 1g SAR exposure value.

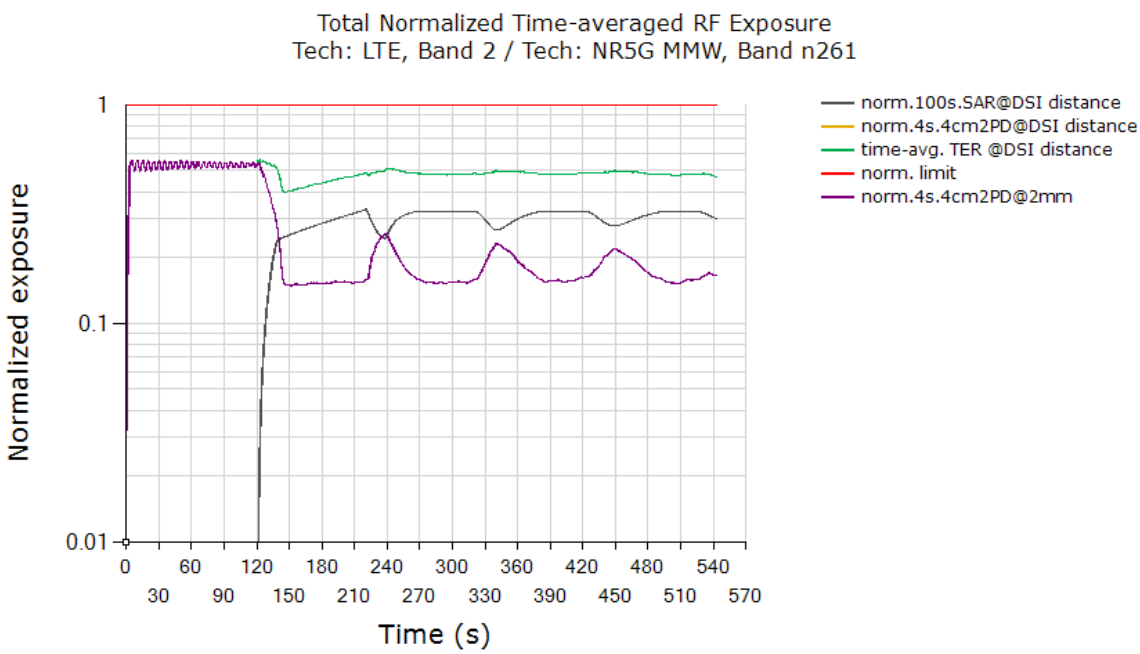
**Table 15-1**

| | Static 4cm$^2$ PD or 10g SAR [W/m$^2$ or W/kg] | Normalized Exposure | Uncertainty [dB] |
|---|---|---|---|
| 0s~120s: NR Green/Orange Curve | 7.31 | 73.1% | 2.0 |
| After ~120s: LTE Black Curve | 1.61 | 40.3% | 1.0 |

As can be seen, the power limiting enforcement is effective and the total normalized time-averaged RF exposure does not exceed 1.0. Therefore, Qualcomm® Smart Transmit time averaging feature is validated.

### 15.1.2 PD test results for n260

Step 2.e plot (in Section 5.4) for normalized instantaneous and time-averaged exposures for LTE and mmW n260 beam 40.




| | |
|---|---|
| FCC limit for total RF exposure | 1.0 |
| Max total normalized time-averaged RF exposure (green curve) | 0.563 |
| Validated | |

Plot notes: LTE was placed in all-down bits immediately after 5G mmW NR call was established. Between 0s~120s, mmW exposure is the dominant contributor. Here, Smart Transmit feature allocates a maximum of 100% for mmW (based on the 3dB reserve setting in Part 1 report). Around the 120s time mark, LTE is set to all-up bits, taking away margin from mmW exposure gradually. Towards the end of the test, LTE is the dominant contributor towards RF exposure. Table 15-2 shows the calculations for the normalized 4cm$^2$ PD exposure values and the normalized 1g SAR exposure value.

**Table 15-2**

| | Static 4cm$^2$ PD or 10g SAR [W/m$^2$ or W/kg] | Normalized Exposure | Uncertainty [dB] |
|---|---|---|---|
| 0s~120s: NR Green/Orange Curve | 4.56 | 45.6% | 2.0 |
| After ~120s: LTE Black Curve | 1.61 | 40.3% | 1.0 |

As can be seen, the power limiting enforcement is effective and the total normalized time-averaged RF exposure does not exceed 1.0. Therefore, Qualcomm® Smart Transmit time averaging feature is validated.

# 16 EQUIPMENT LIST

| Manufacturer | Model | Description | Cal Date | Cal Interval | Cal Due | Serial Number |
|---|---|---|---|---|---|---|
| Agilent | 8594A | (9kHz-2.9GHz) Spectrum Analyzer | N/A | N/A | N/A | 3051A00187 |
| Agilent | E4438C | ESG Vector Signal Generator | 1/18/2023 | Annual | 1/18/2024 | MY47270002 |
| Agilent | N9020A | MXA Signal Analyzer | 3/15/2023 | Annual | 3/15/2024 | US46470561 |
| Agilent | N5182A | MXG Vector Signal Generator | 11/30/2022 | Annual | 11/30/2023 | MY47420603 |
| Agilent | 8753ES | S-Parameter Network Analyzer | 2/8/2023 | Annual | 2/8/2024 | US39170122 |
| Amplifier Research | 15S1G6 | Amplifier | CBT | N/A | CBT | 433972 |
| Amplifier Research | 15S1G6 | Amplifier | CBT | N/A | CBT | 433974 |
| Anritsu | MT8000A | Radio Communication Test Station | 2/9/2023 | Annual | 2/9/2024 | 6272337408 |
| Anritsu | MT8821C | Radio Communication Test Station | 1/10/2023 | Annual | 1/10/2024 | 6201524637 |
| Anritsu | MA24106A | USB Power Sensor | 1/20/2023 | Annual | 1/20/2024 | 2018534 |
| Anritsu | MA24106A | USB Power Sensor | 2/9/2023 | Annual | 2/9/2024 | 1520505 |
| Anritsu | ML2496A | Power Meter | 6/15/2023 | Annual | 6/15/2024 | 1138001 |
| Anritsu | MA2411B | Pulse Power Sensor | 1/10/2023 | Annual | 1/10/2024 | 1315051 |
| Anritsu | MA2411B | Pulse Power Sensor | 6/15/2023 | Annual | 6/15/2024 | 1126066 |
| COMTECH | AR85729-5/5759B | Solid State Amplifier | CBT | N/A | CBT | M3W1A00-1002 |
| COMTech | AR85729-5 | Solid State Amplifier | CBT | N/A | CBT | M1S5A00-009 |
| Control Company | 4025 | Long Stem Thermometer | 9/15/2022 | Biennial | 9/15/2024 | 221767774 |
| Control Company | 4040 | Therm./ Clock/ Humidity Monitor | 1/17/2023 | Annual | 1/17/2024 | 160574418 |
| Control Company | 4025 | Long Stem Thermometer | 9/15/2022 | Biennial | 9/15/2024 | 221767764 |
| K & L | 11SH10-1300/U4000 | High Pass Filter | CBT | N/A | CBT | 11SH10-1300/U4000 - 2 |
| Keysight Technologies | 772D | Dual Directional Coupler | CBT | N/A | CBT | MY52180215 |
| Keysight Technologies | E7515B | UXM 5G Wireless Test Platform | CBT | N/A | CBT | MY59150289 |
| Keysight Technologies | M1740A | mmWave Transceiver | CBT | N/A | CBT | MY59291989 |
| Keysight Technologies | M1740A | mmWave Transceiver | CBT | N/A | CBT | MY59291982 |
| Keysight Technologies | E7770A | Common Interface Unit | CBT | N/A | CBT | MY58290483 |
| Krytar | 110067006 | Directional Coupler, 10 - 67 GHz | CBT | N/A | CBT | 200391 |
| MCL | BW-N6W5+ | 6dB Attenuator | CBT | N/A | CBT | 1139 |
| Mini Circuits | ZA2PD2-63-S+ | Power Splitter | CBT | N/A | CBT | SUU64901930 |
| Mini Circuits | ZAPD-2-272-S+ | Power Splitter | CBT | N/A | CBT | SF702001405 |
| MIniCircuits | NLP-1200+ | Low Pass Filter | CBT | N/A | CBT | VUU78201318 |
| MiniCircuits | SLP-2400+ | Low Pass Filter | CBT | N/A | CBT | R8979500903 |
| MiniCircuits | VLF-6000+ | Low Pass Filter | CBT | N/A | CBT | N/A |
| Mini-Circuits | BW-N20W5+ | DC to 18 GHz Precision Fixed 20 dB Attenuator | CBT | N/A | CBT | N/A |
| Mini-Circuits | NLP-2950+ | Low Pass Filter DC to 2700 MHz | CBT | N/A | CBT | N/A |
| Mini-Circuits | NLP-1200+ | Low Pass Filter DC to 1000 MHz | CBT | N/A | CBT | N/A |
| Mini-Circuits | BW-N20W5 | Power Attenuator | CBT | N/A | CBT | 1226 |
| Narda | 4216-10 | Directional Coupler, 0.5 to 8.0 GHz, 10 dB | CBT | N/A | CBT | 01492 |
| Narda | 4216-10 | Directional Coupler, 0.5 to 8.0 GHz, 10 dB | CBT | N/A | CBT | 01493 |
| Narda | 4772-3 | Attenuator | CBT | N/A | CBT | 9406 |
| Narda | BW-S3W2 | Attenuator | CBT | N/A | CBT | 120 |
| Narda | BW-S10W2+ | Attenuator | CBT | N/A | CBT | 831 |
| Narda | 4014C-6 | 4 - 8 GHz SMA 6 dB Directional Coupler | CBT | N/A | CBT | N/A |
| Newmark System | NSC-G2 | Motion Controller | CBT | N/A | CBT | 1007-D |
| Pasternack | PE2208-6 | Bidirectional Coupler | CBT | N/A | CBT | N/A |
| Pasternack | PE2209-10 | Bidirectional Coupler | CBT | N/A | CBT | N/A |
| Rohde & Schwarz | CMW500 | Radio Communication Tester | 3/8/2023 | Annual | 3/8/2024 | 128635 |
| Rohde & Schwarz | CMW500 | Radio Communication Tester | 8/10/2023 | Annual | 8/10/2024 | 140144 |
| Rohde & Schwarz | NRP8S | 3-Path Dipole Power Sensor | 1/19/2023 | Annual | 1/19/2024 | 109961 |
| Rohde & Schwarz | NRP8S | 3-Path Dipole Power Sensor | 1/19/2024 | Annual | 1/19/2024 | 109960 |
| Rohde & Schwarz | NRP50S | 3-Path Dipole Power Sensor | 1/19/2023 | Annual | 1/19/2024 | 101350 |
| SPEAG | 5G Verification Source 30GHz | 30GHz System Verification Antenna | 2/7/2023 | Annual | 2/7/2024 | 1035 |
| SPEAG | DAK-3.5 | Dielectric Assessment Kit | 12/15/2022 | Annual | 12/15/2023 | 1278 |
| SPEAG | D750V2 | 750 MHz SAR Dipole | 3/14/2022 | Annual | 3/14/2024 | 1054 |
| SPEAG | D835V2 | 835 MHz SAR Dipole | 3/14/2022 | Biennial | 3/14/2024 | 4d047 |
| SPEAG | D1900V2 | 1900 MHz SAR Dipole | 8/8/2022 | Biennial | 8/8/2024 | 5d080 |
| SPEAG | D2450V2 | 2450 MHz SAR Dipole | 11/25/2021 | Biennial | 11/25/2023 | 981 |
| SPEAG | D2600V2 | 2600 MHz SAR Dipole | 6/13/2022 | Biennial | 6/13/2024 | 1064 |
| SPEAG | D5GHzV2 | 5 GHz SAR Dipole | 1/18/2023 | Annual | 1/18/2024 | 1191 |
| SPEAG | DAE4 | Dasy Data Acquisition Electronics | 7/10/2023 | Annual | 7/10/2024 | 1583 |
| SPEAG | DAE4 | Dasy Data Acquisition Electronics | 2/15/2024 | Annual | 2/15/2024 | 665 |
| SPEAG | EUmmWV3 | E-field Probes | 12/13/2022 | Annual | 12/13/2023 | 9389 |
| SPEAG | EX3DV4 | SAR Probe | 7/7/2023 | Annual | 7/7/2024 | 7410 |
| SPEAG | EX3DV4 | SAR Probe | 2/8/2023 | Annual | 2/8/2024 | 7417 |
| Zhuhai Bojay Electronics | BJ8827 | Shielded Test Enclosure | N/A | N/A | N/A | F229647 |

Notes:

1. CBT (Calibrated Before Testing). Prior to testing, the measurement paths containing a cable, amplifier, attenuator, coupler, or filter were connected to a calibrated source (i.e. a signal generator) to determine the losses of the measurement path The power meter offset was then adjusted to compensate for the measurement system losses. This level offset is stored within the power meter before measurements are made. This calibration verification procedure applies to the system verification and output power measurements. The calibrated reading is then taken directly from the power meter after compensation of the losses for all final power measurements.
2. Each equipment item is used solely within its respective calibration period.

# 17 MEASUREMENT UNCERTAINTIES

## For SAR Measurements

| a | c | d | e= f(d,k) | f | g | h = c x f/e | i = c x g/e | k |
|---|---|---|---|---|---|---|---|---|
| Uncertainty Component | Tol. (± %) | Prob. Dist. | Div. | $c_i$ 1gm | $c_i$ 10 gms | 1gm $u_i$ (± %) | 10gms $u_i$ (± %) | $v_i$ |
| **Measurement System** | | | | | | | | |
| Probe Calibration | 6.55 | N | 1 | 1.0 | 1.0 | 6.6 | 6.6 | ∞ |
| Axial Isotropy | 0.25 | N | 1 | 0.7 | 0.7 | 0.2 | 0.2 | ∞ |
| Hemishperical Isotropy | 1.3 | N | 1 | 0.7 | 0.7 | 0.9 | 0.9 | ∞ |
| Boundary Effect | 2.0 | R | 1.73 | 1.0 | 1.0 | 1.2 | 1.2 | ∞ |
| Linearity | 0.3 | N | 1 | 1.0 | 1.0 | 0.3 | 0.3 | ∞ |
| System Detection Limits | 0.25 | R | 1.73 | 1.0 | 1.0 | 0.1 | 0.1 | ∞ |
| Readout Electronics | 0.3 | N | 1 | 1.0 | 1.0 | 0.3 | 0.3 | ∞ |
| Response Time | 0.8 | R | 1.73 | 1.0 | 1.0 | 0.5 | 0.5 | ∞ |
| Integration Time | 2.6 | R | 1.73 | 1.0 | 1.0 | 1.5 | 1.5 | ∞ |
| RF Ambient Conditions - Noise | 3.0 | R | 1.73 | 1.0 | 1.0 | 1.7 | 1.7 | ∞ |
| RF Ambient Conditions - Reflections | 3.0 | R | 1.73 | 1.0 | 1.0 | 1.7 | 1.7 | ∞ |
| Probe Positioner Mechanical Tolerance | 0.4 | R | 1.73 | 1.0 | 1.0 | 0.2 | 0.2 | ∞ |
| Probe Positioning w/ respect to Phantom | 6.7 | R | 1.73 | 1.0 | 1.0 | 3.9 | 3.9 | ∞ |
| Extrapolation, Interpolation & Integration algorithms for Max. SAR Evaluation | 4.0 | R | 1.73 | 1.0 | 1.0 | 2.3 | 2.3 | ∞ |
| **Test Sample Related** | | | | | | | | |
| Test Sample Positioning | 2.7 | N | 1 | 1.0 | 1.0 | 2.7 | 2.7 | 35 |
| Device Holder Uncertainty | 1.67 | N | 1 | 1.0 | 1.0 | 1.7 | 1.7 | 5 |
| Output Power Variation - SAR drift measurement | 5.0 | R | 1.73 | 1.0 | 1.0 | 2.9 | 2.9 | ∞ |
| SAR Scaling | 0.0 | R | 1.73 | 1.0 | 1.0 | 0.0 | 0.0 | ∞ |
| **Phantom & Tissue Parameters** | | | | | | | | |
| Phantom Uncertainty (Shape & Thickness tolerances) | 7.6 | R | 1.73 | 1.0 | 1.0 | 4.4 | 4.4 | ∞ |
| Liquid Conductivity - measurement uncertainty | 4.2 | N | 1 | 0.78 | 0.71 | 3.3 | 3.0 | 10 |
| Liquid Permittivity - measurement uncertainty | 4.1 | N | 1 | 0.23 | 0.26 | 1.0 | 1.1 | 10 |
| Liquid Conductivity - Temperature Uncertainty | 3.4 | R | 1.73 | 0.78 | 0.71 | 1.5 | 1.4 | ∞ |
| Liquid Permittivity - Temperature Unceritainty | 0.6 | R | 1.73 | 0.23 | 0.26 | 0.1 | 0.1 | ∞ |
| Liquid Conductivity - deviation from target values | 5.0 | R | 1.73 | 0.64 | 0.43 | 1.8 | 1.2 | ∞ |
| Liquid Permittivity - deviation from target values | 5.0 | R | 1.73 | 0.60 | 0.49 | 1.7 | 1.4 | ∞ |
| **Combined Standard Uncertainty (k=1)** | | RSS | | | | 11.5 | 11.3 | 60 |
| **Expanded Uncertainty** (95% CONFIDENCE LEVEL) | | k=2 | | | | 23.0 | 22.6 | |

## For PD Measurements

| a | b | c | d | e | f = c x f/e | g |
|---|---|---|---|---|---|---|
| Uncertainty Component | Unc. (± dB) | Prob. Dist. | Div. | $c_i$ | $u_i$ (± dB) | $v_i$ |
| **Measurement System** | | | | | | |
| Calibration | 0.49 | N | 1 | 1 | 0.49 | ∞ |
| Probe Correction | 0.00 | R | 1.73 | 1 | 0.00 | ∞ |
| Frequency Response | 0.20 | R | 1.73 | 1 | 0.12 | ∞ |
| Sensor Cross Coupling | 0.00 | R | 1.73 | 1 | 0.00 | ∞ |
| Isotropy | 0.50 | R | 1.73 | 1 | 0.29 | ∞ |
| Linearity | 0.20 | R | 1.73 | 1 | 0.12 | ∞ |
| Probe Scattering | 0.00 | R | 1.73 | 1 | 0.00 | ∞ |
| Probe Positioning offset | 0.30 | R | 1.73 | 1 | 0.17 | ∞ |
| Probe Positioning Repeatability | 0.04 | R | 1.73 | 1 | 0.02 | ∞ |
| Sensor MechanicalOffset | 0.00 | R | 1.73 | 1 | 0.00 | ∞ |
| Probe Spatial Resolution | 0.00 | R | 1.73 | 1 | 0.00 | ∞ |
| Field Impedence Dependance | 0.00 | R | 1.73 | 1 | 0.00 | ∞ |
| Amplitude and Phase Drift | 0.00 | R | 1.73 | 1 | 0.00 | ∞ |
| Amplitude and Phase Noise | 0.04 | R | 1.73 | 1 | 0.02 | ∞ |
| Measurement Area Truncation | 0.00 | R | 1.73 | 1 | 0.00 | ∞ |
| Data Acquisition | 0.03 | N | 1 | 1 | 0.03 | ∞ |
| Sampling | 0.00 | R | 1.73 | 1 | 0.00 | ∞ |
| Field Reconstruction | 0.60 | R | 1.73 | 1 | 0.35 | ∞ |
| Forward Transformation | 0.00 | R | 1.73 | 1 | 0.00 | ∞ |
| Power Density Scaling | 0.00 | R | 1.73 | 1 | 0.00 | ∞ |
| Spatial Averaging | 0.10 | R | 1.73 | 1 | 0.06 | ∞ |
| System Detection Limit | 0.04 | R | 1.73 | 1 | 0.02 | ∞ |
| **Test Sample Related** | | | | | | |
| Probe Coupling with DUT | 0.00 | R | 1.73 | 1 | 0.00 | ∞ |
| Modulation Response | 0.40 | R | 1.73 | 1 | 0.23 | ∞ |
| Integration Time | 0.00 | R | 1.73 | 1 | 0.00 | ∞ |
| Response Time | 0.00 | R | 1.73 | 1 | 0.00 | ∞ |
| Device Holder Influence | 0.10 | R | 1.73 | 1 | 0.06 | ∞ |
| DUT alignment | 0.00 | R | 1.73 | 1 | 0.00 | ∞ |
| RF Ambient Conditions | 0.04 | R | 1.73 | 1 | 0.02 | ∞ |
| Ambient Reflections | 0.04 | R | 1.73 | 1 | 0.02 | ∞ |
| Immunity/Secondary Reception | 0.00 | R | 1.73 | 1 | 0.00 | ∞ |
| Drift of DUT | 0.21 | R | 1.73 | 1 | 0.12 | ∞ |
| **Combined Standard Uncertainty (k=1)** | | RSS | | | 0.76 | ∞ |
| **Expanded Uncertainty** (95% CONFIDENCE LEVEL) | | k=2 | | | 1.52 | |

# 18 CONCLUSION

## 18.1 Measurement Conclusion

The SAR evaluation indicates that the DUT complies with the RF radiation exposure limits of the FCC and Innovation, Science, and Economic Development Canada, with respect to all parameters subject to this test. These measurements were taken to simulate the RF effects of RF exposure under worst-case conditions. Precise laboratory measures were taken to assure repeatability of the tests. The results and statements relate only to the item(s) tested.

Please note that the absorption and distribution of electromagnetic energy in the body are very complex phenomena that depend on the mass, shape, and size of the body, the orientation of the body with respect to the field vectors, and the electrical properties of both the body and the environment. Other variables that may play a substantial role in possible biological effects are those that characterize the environment (e.g. ambient temperature, air velocity, relative humidity, and body insulation) and those that characterize the individual (e.g. age, gender, activity level, debilitation, or disease). Because various factors may interact with one another to vary the specific biological outcome of an exposure to electromagnetic fields, any protection guide should consider maximal amplification of biological effects as a result of field-body interactions, environmental conditions, and physiological variables. [3]

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