FCC 47 CFR § 2.1093

RF EXPOSURE EVALUATION REPORT
(Part 2: Test Under Dynamic Transmission Condition)

FOR

GSM/WCDMA/LTE/5G NR Phone + BT/BLE, DTS/UNII a/b/g/n/ac, and NFC

MODEL NUMBER: SM-A236V

FCC ID: A3LSMA236V

REPORT NUMBER: 4790558569-S1V1

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Revision History

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V1	11/23/2022	Initial Issue	--

Table of Contents

Attestation of Test Results

Applicant Name	SAMSUNG ELECTRONICS CO.,LTD.
FCC ID	A3LSMA236V
Model Number	SM-A236V
Applicable Standards	FCC 47 CFR § 2.1093
Date Tested	11/7/2022 to 11/23/2022
Test Results	Pass

UL Korea, Ltd. tested the above equipment in accordance with the requirements set forth in the above standards. All indications of Pass/Fail in this report are opinions expressed by UL Korea, Ltd. based on interpretations and/or observations of test results. Measurement Uncertainties were not taken into account and are published for informational purposes only. The test results show that the equipment tested is capable of demonstrating compliance with the requirements as documented in this report.

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1. Introduction

The equipment under test (EUT) is SM-A236V (FCC ID : A3LSMA236V), it contains the Qualcomm modems supporting 2G/3G/4G technologies and 5G NR bands (Sub-6 and mmW). these modems are enabled with Qualcomm Smart Transmit feature to control and manage transmitting power in real time and to ensure at all times the time-averaged RF exposure is in compliance with the FCC requirement.

DUT contains embedded file system (EFS) version 16 configured for the Second generation (GEN2).

EFS v16 Verification

Per Qualcomm’s 80-w2112-5 document, embeded file system (EFS) version 16 products are required to be verified for Smart Tx generation for relevant MCC setting. It was confirmed that this DUT contains embedded file system (EFS) version 16 configured for Smart Tx Second generation (GEN2) for Sub6 and mmW with MCC settings for the US market.

EFSv16 Generation	MCC
GEN2_Sub6	310
GEN2_mmW	310

This purpose of the Part 2 report is to demonstrate the EUT complies with FCC RF exposure requirement under Tx varying transmission scenarios, thereby validity of Qualcomm Smart Transmit feature for FCC equipment authorization of A3LSMA236V.

The P_{limit} (For 2G/3G/4G/5G NR Sub-6 and 5G NR mmW) used in this report is determined in Part 0 and Part 1 reports.

1.1 Part.2 Test Case Reduction for Multiple filings

The number of test cases in Part 2 can be reduced in the case of multiple filings using same chipset (2G/3G/4G/5G NR Sub-6) and same EFS version (post full part 2 test on the first filing), the essential test cases in power measurement are required to ensure the Smart Transmit performs as expected in the new design, but the RF exposure measurement can be excluded.

So, This model (SM-A236V) used a same chipset (2G/3G/4G/5G NR Sub-6) and EFS version that had fully tested to Part.2 on first filing. Therefore, This model follow Part.2 Test case reduction procedures according to Qualcomm document (80-W2112-5). Please refer to section.4.1 for test case reduction scenarios.

But 5G NR mmW chipset is not satisfy to Part.2 Test case reduction. So 5G NR mmW verified fully Part.2 test. It means that 5G NR mmW does not apply to Part.2 Test case reduction.

2. Tx Varying Transmission Test Cases and Test Proposal

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

1. During a time-varing Tx power transmission: To prove that the Smart Transmit feature accounts for Tx power variations in time accurately.
2. During a call disconnected and re-establish scenario: To prove that the Smart Transmit feature accounts for history of past Tx power transmissions accurately.
3. During technology/band handover: To prove that the Smart Transmit feature functions correctly during transitions in technology/band.
4. During 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 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).
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.

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 8.

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 < 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 sub-6 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 LTE + 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 $4cm^2$PD*_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:

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

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

- For LTE + mmW transmission:

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

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

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

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 $[pointE(t)]^2$ / $[pointE\_input.power.limit]^2$ versus time.

3. SAR Time Averaging Validation Test Procedures

This chapter provides the test plan and test procedures 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.

3.1. Test sequence determination for validation

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

- Test sequence 1 : request EUT'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 EUT's Tx power to vary with time. This sequence is generated relative to measured P_{max}, measured P_{limit} and Calcuated $P_{reserve}$ (= measured P_{limit} in dBm – *Reserve_power_margin* in dB) of EUT based on measured P_{limit}.

The details for generating these two test sequences is described and listed in Section A.

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 devise, because Smart Transmit feature operates against the actual power level of the "P_{limit}" that was calibrated for the EUT. 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}.

3.2. Test configuration selection criteria for validation Smart Transmit feature

For validating Smart Transmit feature, this section provides a general guidance to select test cases. In practice, an adjustment can be made in test case selection. The justification/clarification may be provide.

3.2.1 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 on 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.

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.

* 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 devise position that correspond to the highest *measured 1g or 10gSAR* 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 1g or 10gSAR* 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 second band for validation test is determined.

3.2.2 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 1g or 10gSAR* at P_{limit} listed in Part 1 report.
- In case of multiple bands having same least P_{limit}, then select the band having the highest *measured 1g or 10gSAR* at P_{limit} in Part 1 report.

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

3.2.3 Test configuration selection for change in technology/band

The selection criteria for this measurement is, for a given antenna, to have EUT 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 1g or 10gSAR* 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 1g or 10gSAR* at P_{limit} in Part 1 report, or vice versa.

This test is performed with the EUT'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 EUT is forced to have Tx power at $P_{reserve}$).

3.2.4 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 EUT, first 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 1g or 10gSAR* at P_{limit} in Part 1 report.

This test is performed with the EUT'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 EUT is forced to have Tx power at $P_{reserve}$).

3.2.5 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 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 EUT'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 EUT is forced to have Tx power at $P_{reserve}$).

3.2.6 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 a different 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 2nd 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 Pmax.

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.

3.2.7 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.

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 + Sub 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 cannot 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. Additional details for testing for LTE+Sub6 NR non-standalone is provided in Section.B.

3.3. 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 2. In practice, an adjustment can be made in these procedures. The justification/clarification may be provide.

3.3.1 Time-varying Tx power transmission scenario

This test is performed with the two pre-defined test sequences described in Section 3.1 for all the technologies and bands selected in Section 3.2.1. 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 Preserve (= measured P_{limit} in dBm – *Reserve_power_margin* in dB) and follow Section 3.1 to generate the test sequences for all the technologies and bands selected in Section 3.2.1. Both test sequence 1 and test sequency 2 are created based on measured P_{max} and measured P_{limit} of the EUT. Test condition to measure P_{max} and P_{limit} is:

   - Measure P_{max} with Smart Transmit disable and callbox set to request maximum power.
   - Measure P_{limit} with Smart Transmit enable and *Reserve_power_margin* set to 0 dB; callbox set to request maximum power.

2. Set *Rerve_power_margin* to actual (intended) value (3dB for this EUT based on Part 1 report) and reset power on EUT to enable Smart Transmit, establish radio link in desired radio configuration, with callbox requesting the EUT'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 A-1 where using 100-secnods 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 0 dBm 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.

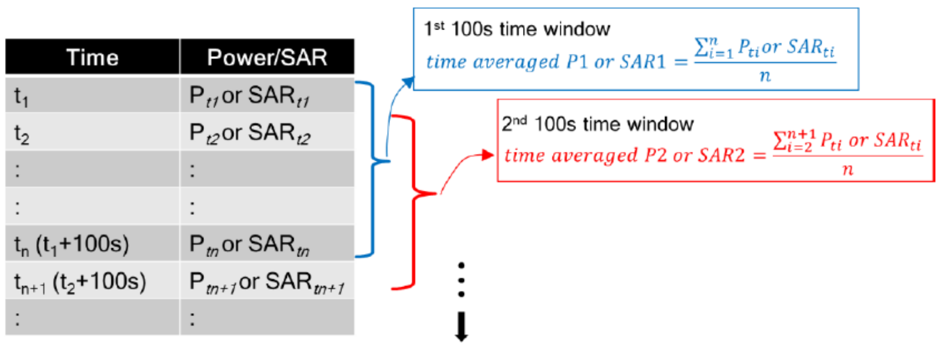


Figure A-1 100s running average illustration

3. Make one plot containing:
   a. Computed time-averaged 1gSAR or 10gSAR versus time determined in Step 2
   b. Corresponding regulatory *1g or 10gSAR*$_{limit}$ limit.

4. Repeated Steps 2 ~ 3 for pre-defined test sequence 2.

5. Repeat Steps 2 ~ 4 for all the selected technologies and bands.

The validation criteria is, at all times, the time-averaged 1gSAR or 10gSAR versus time shown in Step 2 (and plotted in Step 4) shall not exceed regulatory *1g or 10gSAR*$_{limit}$ limit.

3.3.2 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 disconnects and re-establishment needs to be performed during power limit enforcement, i.e., when the EUT'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 regulatory *1g or* $10gSAR_{limit}$ limit.

Test procedure:

1. Measure P_{limit} for the technology/band selected in Section 3.2.2. measure P_{limit} with Smart Transmit enable and *Reserve_power_margin* set to 0 dB; callbox set to request maximum power.
2. Set *Reserve_power_margin* to actual (intended) value and reset power on EUT to enable Smart Transmit.
3. Establish radio link with callbox in the selected technology/band.
4. Request EUT's Tx power at 0 dBm for at least one time window specified for the selected technology/band, followed by requesting EUT'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 EUT'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.
5. Once the measurement is done, extract instantaneous Tx power versus time, and convert the conducted Tx power into 1g or 10gSAR value using Step 1 result, and then perform one time window specified running average to determine time-averaged 1g or 10gSAR value versus time.
6. Make one plot containing: (a) computed time-averaged 1g or 10gSAR versus time determine in Step 4 for the first call, (b) computed time-averaged 1g or 10gSAR versus time determine in Step 4 for the second call, (c) computed time-averaged 1g or 10gSAR of the first call and second call versus time and (d) corresponding regulatory *1g or* $10gSAR_{limit}$ limit.

The validation criteria are, at all times, the combined time-averaged 1gSAR or 10gSAR versus time determined in Step 6c shall not exceed the regulatory *1g or* $10gSAR_{limit}$ limit.

3.3.3 Change in technology and band

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

Similar to the change in call test in Section 3.3.2, to validate the continuity of RF exposure limiting during the transition, the technology and band handover needs to be performed when EUT's Tx power is at $P_{reserve}$ level (i.e., during Tx power enforcement) to make sure that the EUT'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:

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

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

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

where, *conducted_Tx_power_1(t)*, *conducted _Tx_power_*P_{limit_1}, and *1g_or_1gSAR_*P_{limit_1} correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at P_{limit}, and measured *1g SAR* or *10gSAR* value at technology1/band1; *conducted_Tx_power_2(t)*, *conducted _Tx_power_*P_{limit_2}, 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 3.2.3. Measure P_{limit} with Smart Transmit enabled and *Reserve_power_margin* set to 0 dB; callbox set to request maximum power.
2. Set *Reserve_power_margin* to actual(intended) value and reset power on EUT to enable Smart Transmit.
3. Establish radio link with callbox in first technology/band selected.
4. Request EUT's Tx power at 0 dBm for at least one time window specified for the selected technology/band, followed by requesting EUT's Tx power to be at maximum power for about ~60 second, and then switch to second technology/band selected. Continue with callbox requesting EUT's Tx power to be at maximum power for the remaining time of least another full duration of the specified time window. Measure and record Tx power versus time for the full 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 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 the measured worst-case 1gSAR or 10gSAR value at P_{limit} for the corresponding technology/band reported in Part 1 report.
6. Make one plot containing: (a) computed time-averaged 1gSAR or 10gSAR of the first technology/band versus time determined in Step 5, (b) computed time-averaged 1gSAR or 10gSAR of the second technology/band versus time determined in Step 5, (c) combined time-averaged 1g or 10gSAR of the first technology/band and second technology/band versus time determined in Step 5 and (d) corresponding regulatory *1g or 10gSAR*$_{limit}$ limit.

The validation criteria are, at all times, the combined time-averaged 1gSAR or 10gSAR versus time determined in Step 6c shall not exceed the regulatory *1g or 10gSAR*$_{limit}$ limit.

3.3.4 Change in antenna

This test is to demonstrate the correct power control by Smart Transmit during antenna switches from primary to diversity. The test procedure is identical to Section 3.3.3, with switching antenna instead of technology/band. The validation criteria are, at all times, the time-average 1gSAR or 10gSAR versus time shall not exceed the regulatory *1g or 10gSAR*$_{limit}$ limit.

Note: If the EUT does not support multiple transmitting WWAN antennas, the compliance plot for change in antenna should be similar to the plot for change in technology/band.

3.3.5 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 3.3.3, with changing device state instead of technology/band. The validation criteria is, at all times, the time-averaged 1gSAR or 10gSAR versus time shall not exceed the regulatory *1g or 10gSAR*$_{limit}$ limit.

Note: If the EUT does not support multiple device states, the compliance plot for change in device state should be similar to the plot for change in technology/band.

3.3.6 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 window 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:

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

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

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

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 Plimit, 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 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 3.2.6 Measure P_{limit} with Smart Transmit enabled and *Reserve_power_margin* set to 0 dB, callbox set to request maximum power.
2. Set *Reserve_power_margin* to actual (intended) value and enable Smart Transmit.

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 3.2.6.
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 3.2.6. 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 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) computed time-averaged 1g or 10gSAR of the first technology/band (having 100s time window) versus time determined in Step 5, (c) computed time-averaged 1g or 10gSAR of the second technology/band (having 60s time window) versus time determined in Step 5, (c) combined time-averaged 1g or 10gSAR of (a) and (b), and (d) corresponding regulatory *1g* or $10gSAR_{limit}$ limit.

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

7. Establish radio link with callbox in the technology/band having 60s time window selected in Section 3.2.6.
8. 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 3.2.6. Continue with callbox requesting EUT’s Tx power to transmit 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 to transmit at maximum Tx power for at least another 140s. Measure and record Tx power versus time for the entire duration of the test.
9. Repeat above Step 5~6 procedures to generate the corresponding plots

The validation criteria is, at all times, the time-averaged 1gSAR or 10gSAR versus time shall not exceed the regulatory *1g* or $10gSAR_{limit}$ limit.

3.3.7 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. The detailed test procedure for SAR exposure switching in the case of LTE + Sub6 NR non-standalone mode transmission scenarios is provided in Section.B.

Test procedure:

1. Measure conducted Tx power corresponding to P_{limit} for radio 1 and radio 2 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 radio 1 P_{limit} with Smart Transmit enable and *Reserve_Power_margin* set to 0 dB, callbox set to request maximum power.
   - Repeat above step to measure conducted Tx power corresponding to radio2 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 P_{limit} (as radio1 LTE is at all-down bits)
2. Set *Reserve_power_margin* to actual (intended) value, 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 theses 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) computed time-averaged 1g or 10gSAR versus time determined in Step 3, and combined time-averaged 1g or 10gSAR versus time, and (b) corresponding regulatory *1g* or $10gSAR_{limit}$ limit.

The validation criteria is, at all times, the time-averaged 1gSAR or 10gSAR versus time shall not exceed the regulatory *1g* or $10gSAR_{limit}$ limit.

4. PD Time Averaging Validation Test Procedures

This chapter 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.

4.1. 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.

4.2. Test configuration selection criteria for validating Smart Transmit feature

4.2.1 Test configuration selection for time-varying Tx power transmission

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 in any one band/mode/channel per technology is sufficient.

4.2.2 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.

4.2.3 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-average 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 dominant scenario.

4.3. 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 2.

This section provides general conducted power measurement procedures to perform compliance test under dynamic transmission scenarios described in Section 2. In practice, an adjustment can be made in these procedures. The justification/clarification may be provided.

4.3.1 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 2).

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 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 enabled and *Reserve_power_margin* set to 0 dB, callbox set to request maximum power.
2. Set *Reserve_power_margin* to actual (intended) value and reset power on EUT to enable Smart Transmit. With EUT setup for a mmW NR call in the desire/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-upbits 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 = 0 dB).
   c. Record the conducted Tx power of LTE and radiated Tx power of mmW for the full duration of this test of 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 1.6W/kg for 1gSAR or 4.0W/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) 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)).

4.3.2 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 radiate 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 enabled and *Reserve_power_margin* set to 0 dB, callbox set to request maximum power.

2. Set *Reserver_power_margin* to actual (intended) value and reset power in EUT, with EUT 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.
5. 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)).

4.3.3 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 2 are written as below for transmission scenario having change in beam:

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

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

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

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

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 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 enable and *Reserve_power_margin* set to 0 dB, callbox set to request maximum power.
2. Set *Reserve_power_margin* to actual (intended) value and reset power in EUT, With EUT 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 4.3.2. Perform 100s running average to determine normalized 100s-averaged 1gSAR or 10gSAR 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 purpose 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 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., (8d)).

4.4. Test procedures for time-varying PD measurements

The following steps are used to perform the validation through PD measurement for transmission scenario 1 described in Section 2:

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 enabled and *Reserve_power_margin* set to 0 dB, 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 *Reserve_power_margin* to actual value (i.e., intended value) and reset power on EUT, 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 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 in Step 2.c, (ii) 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)).

5. Test Configurations

5.1. WWAN (sub-6) transmission

This P_{limit} values, corresponding to 1.0 or 2.5 W/kg (1-g or 10-g respectively) of *SAR_design_target*, for technologies and bands supported by EUT are derived in Part 0 report and summarized in Table 5-1. Note all P_{limit} power levels entered in Table 5-1 correspond to average power levels plus tolerance after accounting for duty cycle in the case of TDD modulation schemes (for e.g., GSM, LTE TDD).

Table 5-1 : P_{limit} for supported technologies and bands (P_{limit} in EFS file)

Exposure condition			Body-Worn	Product Specific 10-g Without triggering sensor	Product Specific 10-g With triggering sensor	Head (RCV)	Hotspot	Ear-jack	Pmax (Maximum tune-up Power) (dBm)
Spatial-average			1g	10g	10g	1g	1g	10g	
Test distance (mm)			15	11/ 9/ 15/ 0	0	0	10	0	
DSI:			0	0	1	2	3	4	
RF Air Interface	Antenna	Antenn Group	Plimit corresponding to 1.0 W/kg (SAR_design_target) (1g) / 2.5 W/kg (SAR_design_target) (10g)						
GSM 850	Main.1	AG0	29.81	32.59	28.53	29.66	26.91	28.53	25.48
GSM 1900	Main.2	AG0	27.82	23.48	17.49	30.48	17.49	17.49	21.98
WCDMA Band II	Main.2	AG0	27.61	23.97	20.50	31.15	20.50	20.50	23.50
WCDMA Band V	Main.1	AG0	29.44	32.05	28.92	30.91	28.29	28.92	24.20
LTE Band 2	Main.2	AG0	27.60	24.45	21.00	29.41	21.00	21.00	24.00
LTE Band 5	Main.1	AG0	31.51	32.10	26.76	30.94	28.32	26.76	24.50
LTE Band 7	Main.2	AG0	22.00	22.00	20.50	22.00	20.50	20.50	23.50
LTE Band 12	Main.1	AG0	30.09	34.42	27.08	32.62	28.54	27.08	24.50
LTE Band 13	Main.1	AG0	29.10	33.10	28.19	31.83	27.15	28.19	24.50
LTE Band 48	Sub.3	AG0	17.00	17.00	17.00	17.00	17.00	17.00	20.50
LTE Band 66(4)	Main.2	AG0	23.00	23.00	21.00	23.00	21.00	21.00	23.50
NR Band n2	Main.2	AG0	27.79	24.95	21.00	29.94	21.00	21.00	24.00
NR Band n5	Main.1	AG0	29.80	27.20	25.10	30.60	27.33	25.10	24.50
NR Band n66	Main.2	AG0	28.66	28.17	21.00	31.80	21.00	21.00	24.00
NR Band n77 -SRS0- PC3	Sub.3	AG1	17.00	17.00	17.00	17.00	17.00	17.00	24.00
NR Band n77 -SRS1- PC3	Sub.5	AG1	9.50	9.50	9.50	9.50	9.50	9.50	15.50
NR Band n77 -SRS2- PC3	Sub.2	AG1	11.00	11.00	11.00	11.00	11.00	11.00	22.00
NR Band n77 -SRS3- PC3	Main.2	AG0	16.00	16.00	16.00	16.00	16.00	16.00	22.00
NR Band n77 -SRS0- PC2	Sub.3	AG1	17.00	17.00	17.00	17.00	17.00	17.00	26.00
NR Band n77 -SRS1- PC2	Sub.5	AG1	9.50	9.50	9.50	9.50	9.50	9.50	15.50
NR Band n77 -SRS2- PC2	Sub.2	AG1	11.00	11.00	11.00	11.00	11.00	11.00	22.00
NR Band n77 -SRS3- PC2	Main.2	AG0	16.00	16.00	16.00	16.00	16.00	16.00	22.00

* Maximum Tune-up Target Power, P_{max} is configured in NV settings in DUT to limit maximum average transmitting power. The DUT maximum allowed output power is equal to P_{max} + 1.0 dB device uncertainty.

Based on selection criteria described in Section 3.2.1, the selected technologies/bands for testing time-varying test sequences are highlighted in Table 5-1. During Part 2 testing, the *Reserve_power_margin* (dB) is set to 3dB in EFS according to the manufacturer guide.

As Part 1 and Part 2 testing took place in parallel the selected technologies/bands were chosen based upon anticipated values encountered during pretesting before Tx powers were finalized.

The radio configurations used in Part 2 test for selected technologies, bands, DSIs and antennas are listed in Table 5-2. The corresponding worst-case radio configuration 1g SAR or 10g SAR values for selected technology/band/DSI are extracted from Part 1 report and are listed in the last column of Table 5-2.

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 demonstrate remains the same.

Table 5-2 : Radio configurations selected for Part 2 test

Test Case	Test Scenario	Tech	Band	Antenna	DSI	Channel	Freq. (MHz)	RB/RB Offset/Bandwidth (MHz)	Mode	SAR Exposure Scenario	Worst configurations	Part 1 Worst Case Measured SAR at Plimit (W/kg)
1	Test Sequence 1	GSM	1900	Main.2	3	661	1880.0	-	GPRS 4 Slots	Hotspot	Edge 3	0.160
	Test Sequence 2					661	1880.0	-	GPRS 4 Slots			
2	Test Sequence 1	WCDMA	2	Main.2	3	9400	1880.0	-	RMC	Hotspot	Rear	0.420
	Test Sequence 2					9400	1880.0	-	RMC			
3	Test Sequence 1	LTE	48	Sub.3	3	56207	3646.7	1/0/20 MHz	QPSK	Hotspot	Edge 4	0.557
	Test Sequence 2					56207	3646.7	1/0/20 MHz	QPSK			
4	Test Sequence 1	NR	77	Sub.3	3	650000	3750.0	1/137/100 MHz	DFT-s-OFDM QPSK	Hotspot	Rear	0.632
	Test Sequence 2					650000	3750.0	1/137/100 MHz	DFT-s-OFDM QPSK			
5	Change in Call	NR	77	Sub.3	3	650000	3750.0	1/137/100 MHz	DFT-s-OFDM QPSK	Hotspot	Rear	0.632
6	Tech/Band Switch	LTE	48	Sub.3	3	56207	3646.7	1/0/20 MHz	QPSK	Hotspot	Edge 4	0.557
		WCDMA	2	Main.2	3	9400	1880.0	-	RMC	Hotspot	Rear	0.420
7	Time Window/Antennea Switch	LTE	66	Main.2	3	132072	1720.0	1/0/20 MHz	QPSK	Hotspot	Edge 3	0.523
		LTE	48	Sub.3	3	56207	3646.7	1/0/20 MHz	QPSK	Hotspot	Edge 4	0.557
8	DSI Switch	LTE	7	Main.2	3	21350	2560.0	1/99/20 MHz	QPSK	Hotspot	Rear	0.663
				Main.2	0	21350	2560.0	1/99/20 MHz	QPSK	Body-worn	Rear	0.387
9	SAR1 vs SAR2 (EN-DC)	LTE	5	Main.1	3	20525	836.5	1/0/10 MHz	QPSK	Hotspot	Rear	0.446
		NR	2	Main.2	3	380000	1900.0	1/104/20 MHz	DFT-s-OFDM QPSK	Hotspot	Edge 3	0.439

Notes:

For multiple filings with same chipset, the test case reduction proposal for Part 2 testing is:

1. Full set of test the first filing, i.e., both power measurement and RF exposure measurement, are required.
2. For all subsequent filings wih the same chipset and same EFS version, only power measurement (All required scenarios) is required. In the case of scenario (time-varying Tx transmission test), only one band (instead of two bakds) per technology is sufficient.

Above guide are refer to Qualcomm guidance (Section.K in Qualcomm document_80-W2115-5).

Reported SAR values in Part 1 SAR report are tested at P_{limit} + tolerance. Therefore, 100s(or 60s) average SAR is shown to be ± 1.0 dB from SAR design target.

Based on the selection criteria described in Section 3.2, the radio configurations for the Tx varying transmission test cases listed in Section 2 are:

1. Technologies and bands for time-varying Tx power transmission: The test case 1 ~ 4 listed in Table 5-2 are selected to test with the test sequences defined in Section 3.1 in both time-varying conducted power measurement and time-varying SAR measurement.
2. Technology and band for change in call test: NR Band n77 having the lowest P_{limit} among all technologies and bands (test case 5 in Table 5-2) is selected for performing the call drop test in conducted power setup.
3. Technologies and bands for change in technology/band test: Following the guidelines in Section 3.2.3 and 3.2.4, test case 6 in Table 5-2 is selected for handover test from a technology/band/Antenna in Within one technology group (WCDMA Band II, DSI=3, Main.2 Ant), to a technology/band/Antenna in the same DSI within another technology group (LTE Band 48, DSI=3, Sub.3 Ant) in conducted power setup.
4. Technologies and bands for change in time-window/Antenna: Based on selection criteria in Section 3.2.6 and 3.2.4 for a given in DSI = 3 test case 7 in Table 5-2 is selected for time window switch between 100s window (LTE Band 66, DSI=3, Main.2 Ant) and 60s window (LTE Band 48, DSI=3, Sub.3 Ant) in conducted power setup.
5. Technologies and bands for change in DSI: Based on selection criteria in Section 3.2.5, for a given technology and band, test case 8 in Table 5-2 is selected for DSI switch test by establishing a call in LTE Band 7 in DSI=0, and then handing over to DSI =3 exposure scenario in conducted power setup.
6. Technologies and bands for switch in SAR exposure (EN-DC): Based on selection criteria in Section 3.2.7 Scenario 1, test case 9 in Table 5-2 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.

5.2. LTE+mmW NR transmission

Based on the selection criteria described in Section 4.2, the selections for LTE and mmW NR validation test are listed in Table 5-3. The radio configurations used in this test are listed in Table 5-4.

Table 5-3 : Selections for LTE + mmW NR validation measurements

Transmission Scenario	Test	Technology and Band	mmW Beam
Time-varying Tx power test	1. cond. & Rad. Power meas. 2. PD meas.	LTE Band 2 and n261	Beam ID 145
		LTE Band 2 and n260	Beam ID 138
Switch in SAR vs. PD	1. cond. & Rad. Power meas.	LTE Band 2 and n261	Beam ID 145
		LTE Band 2 and n260	Beam ID 138
Beam switch test	1. cond. & Rad. Power meas.	LTE Band 2 and n261	Beam ID 140 to Beam ID 12
		LTE Band 2 and n260	Beam ID 138 to Beam ID 10

Table 5-4 : Test configuration for LTE + mmW NR validation

Tech	Band	Antenna	DSI	Channel	Bandwidth (MHz)	RB Size	RB Offset	Freq (MHz)	Mode	UL Duty Cycle
LTE	2	Main 2 Ant.	3	19100	20	50	0	1900.0	QPSK	100.0%
mmW NR	n261	K-patch	-	2071821	100	66	0	27559.32	CP-OFDM, QPSK	84.3%
	n260	K-patch	-	2278331	100	66	0	39949.92	CP-OFDM, QPSK	84.3%

Note 1, mmW NR was tested using 84.3% UL duty cycle setting test script provided by Qualcomm.

6. Conducted Power Test Results for Sub-6 Smart Transmit Feature Validation

6.1. Measurement setup

<u>GSM / WCDMA / LTE test setup using The Rohde & Schwarz CMW500 callbox</u>

The Rohde & Schwarz CMW500 callbox is used in this test.

Test setup Schematic	Test item(s)	Description(s)	Test setup photh
Figure B-1(a)	Time-varying Tx power transmission test (Section 3.3.1)	Single antenna measurement, one port (RF1 COM) of callbox	**A.1**
	Change in DSI test (Section 3.3.5)		
Figure B-1(b)	Change in technology and band test (Section 3.3.3)	two antenna measurement, one port (RF1 COM) of callbox	**A.2**
	Change in antenna (Section 3.3.4)		
	Change in time-window (Section 3.3.6)		

<u>LTE + Sub6 NR(NSA mode) test setup using The UXM callbox</u>

The UXM callbox is used in this test.

Test setup Schematic	Test item(s)	Description(s)	Test setup photo
Figure B-1(C)	Time-varying Tx power transmission test (Section 3.3.1)	two different techs measurement, two ports (RF1 & RF8 COM) of callbox	**A.3**
	Change in Call test (Section 3.3.2)		
	SAR exposure switch test (EN-DC) (Section 3.3.7)		

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.

Setup photos of Test setup Schematic are list in Appendix A.

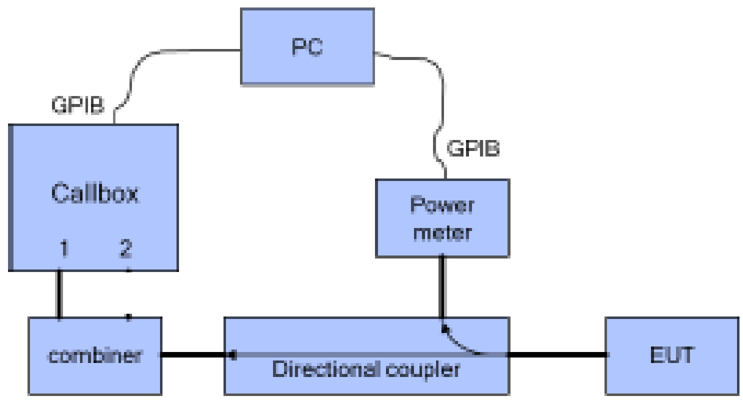


Figure B-1 (a)

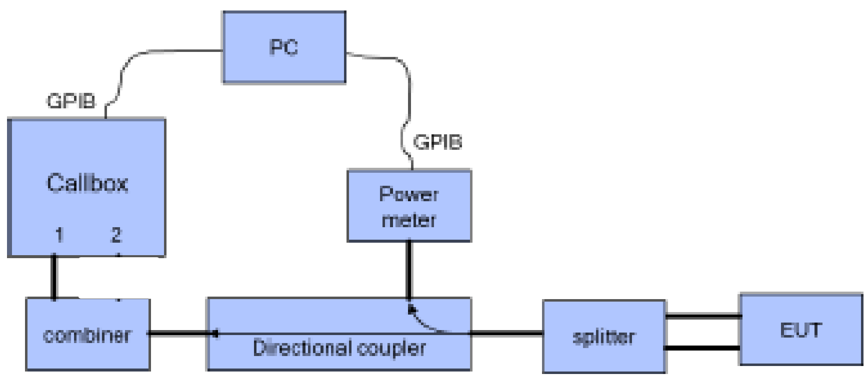


Figure B-1 (b)

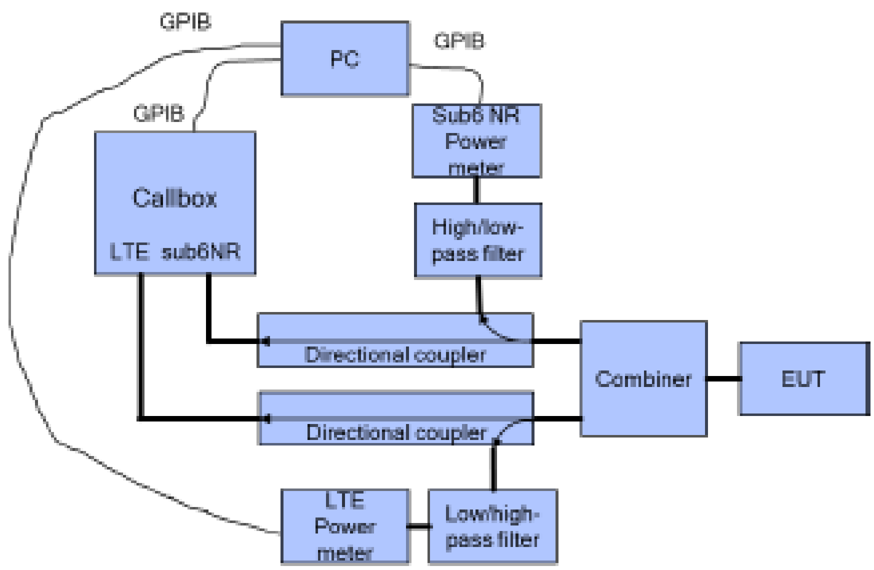


Figure B-1 (c)

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 EUT RF port using the power meter. The commands sent to the callbox to request power are:

- 0 dBm for 100 seconds
- Test sequence 1 or test sequence 2 (defined in Section 3.1 and generated in Section 3.2.1), For 360 seconds
- Stay at the last power level of test sequence 1 or 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 EUT'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 EUT 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 EUT 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 EUT is at $P_{reserve}$ level. See Section 3.3 for detailed test procedure of call drop test, technology/band/antenna switch test and DSI switch test.

6.2. P_{limit} and P_{max} measurement results

This measured Plimit for all the selected radio configurations given in Table 5-2 are listed in below Table 6-1. Pmax 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 3.1.

Table 6-1 : Measured P_{limit} and P_{max} of selected radio configurations
Note: the device uncertainty of P_{max} is +1.0dB/-1.5dB as provided by manufacturer.

Test Case	Test Scenario	Tech	Band	Antenna	DSI	Channel	Freq. (MHz)	RB/RB Offset/Bandwidth (MHz)	Mode	SAR Exposure Scenario	Worst configurations	Part 1 Worst Case Measured SAR at Plimit (W/kg)	Plimit (dBm)	measured Plimit (dBm)	Tune-up Pmax (dBm)	Measured Pmax (dBm)
1	Test Sequence 1	GSM	1900	Main.2	3	661	1880.0	-	GPRS 4 Slots	Hotspot	Edge 3	0.160	17.49	16.61	21.98	20.93
	Test Sequence 2					661	1880.0	-	GPRS 4 Slots							
2	Test Sequence 1	WCDMA	2	Main.2	3	9400	1880.0	-	RMC	Hotspot	Rear	0.420	20.50	20.54	23.50	23.54
	Test Sequence 2					9400	1880.0	-	RMC							
3	Test Sequence 1	LTE	48	Sub.3	3	56207	3646.7	1/0/20 MHz	QPSK	Hotspot	Edge 4	0.557	17.00	17.02	20.50	20.41
	Test Sequence 2					56207	3646.7	1/0/20 MHz	QPSK							
4	Test Sequence 1	NR	77	Sub.3	3	650000	3750.0	1/137/100 MHz	DFT-s-OFDM QPSK	Hotspot	Rear	0.632	17.00	17.16	24.00	22.97
	Test Sequence 2					650000	3750.0	1/137/100 MHz	DFT-s-OFDM QPSK							
5	Change in Call	NR	77	Sub.3	3	650000	3750.0	1/137/100 MHz	DFT-s-OFDM QPSK	Hotspot	Rear	0.632	17.00	17.16	24.00	22.97
6	Tech/Band Switch	LTE	48	Sub.3	3	56207	3646.7	1/0/20 MHz	QPSK	Hotspot	Edge 4	0.557	17.00	17.02	20.50	20.41
		WCDMA	2	Main.2	3	9400	1880.0	-	RMC	Hotspot	Rear	0.420	20.50	20.54	23.50	23.54
7	Time Window/Antennea Switch	LTE	66	Main.2	3	132072	1720.0	1/0/20 MHz	QPSK	Hotspot	Edge 3	0.523	21.00	20.89	23.50	24.08
		LTE	48	Sub.3	3	56207	3646.7	1/0/20 MHz	QPSK	Hotspot	Edge 4	0.557	17.00	17.02	20.50	20.41
8	DSI Switch	LTE	7	Main.2	3	21350	2560.0	1/99/20 MHz	QPSK	Hotspot	Rear	0.663	20.50	20.44	23.50	23.44
				Main.2	0	21350	2560.0	1/99/20 MHz	QPSK	Body-worn	Rear	0.387	22.00	21.95	23.50	23.44
9	SAR1 vs SAR2 (EN-DC)	LTE	5	Main.1	3	20525	836.5	1/0/10 MHz	QPSK	Hotspot	Rear	0.446	24.50	24.12	24.50	24.12
		NR	2	Main.2	3	380000	1900.0	1/104/20 MHz	DFT-s-OFDM QPSK	Hotspot	Edge 3	0.439	21.00	21.06	24.00	24.11

Notes:

1. For GSM, LTE TDD Bands, Tests including duty-cycle transmit are normalized to frame average.
2. NR TDD Pmax and Plimit are measured at 90% duty cycle in call box.

6.3. Time-varying Tx power measurement results (test case 1 - 4 in Table 5-2)

The measurement setup is shown in Figures B-1(a) of GSM/WCDMA/LTE & Figures B-1(c) of NR. 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* value at P_{limit} reported in Part 1 test (listed in Table 5-2 of this report as well). Following the test procedure in Section 3.3, the conducted Tx power measurement for all selected configurations are reported in this section. In all the conducted Tx power plots, the dotted line represents the requested power by callbox (test sequence 1 or test sequence 2), the blue curve represents the instantaneous conducted Tx power measured using power meter, 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.

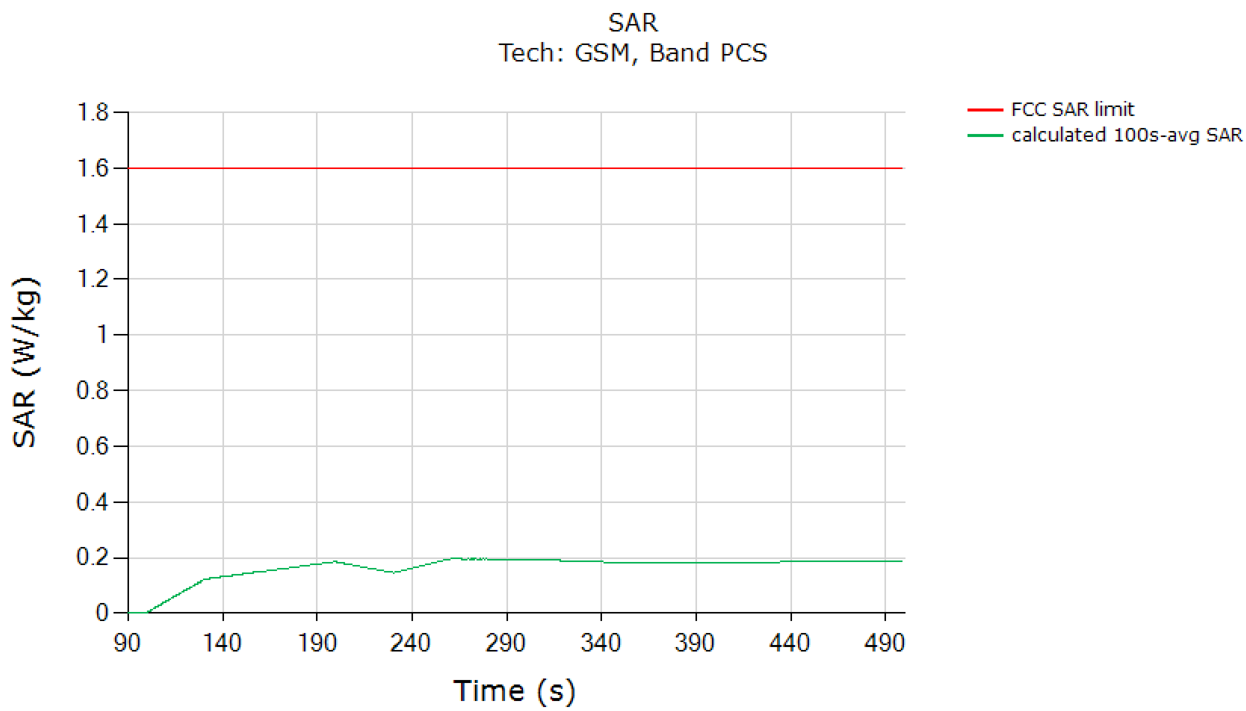
Similarly, in all the 1g or 10gSAR plots (when converted using Eq. (1a)), the green curve represents the 100s/60s-time averaged 1gSAR or 10gSAR value calculated based on instantaneous 1gSAR or 10gSAR; and the red line limit represents the FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

Time-varying Tx power measurements were conducted on test case #1 ~ #4 in Table 5-2, by generating test sequence 1 and test sequence 2 given in Section A using measured P_{limit} and measured Pmax (last two columns of Table 6-1) for each of these test cases. Measurement results for test cases #1 ~ #4 are given in Sections 6.3.1 – 6.3.4.

6.3.1 GSM Band 1900

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

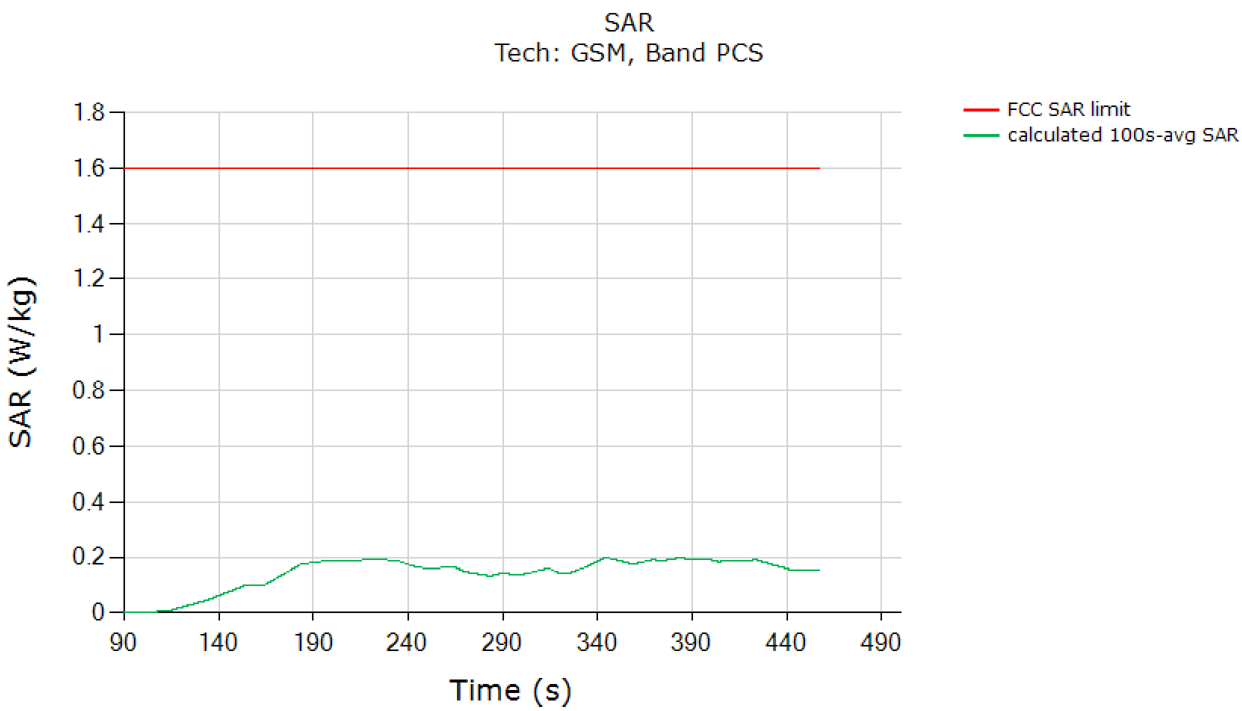
Time-averaged conducted Tx power is converted/calculated into time-averaged SAR using Equation (1a) and plotted below to demonstrate that the time-averaged SAR versus time does not exceed the FCC limit for SAR (1.6W/kg for 1g SAR or 4.0W/kg for 10g SAR):



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.195
Validated : Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (Table 5-2).	

Test result for test sequence 2:

Time-averaged conducted Tx power is converted/calculated into time-averaged SAR using Equation (1a) and plotted below to demonstrate that the time-averaged SAR versus time does not exceed the FCC limit for SAR (1.6W/kg for 1g SAR or 4.0W/kg for 10g SAR):

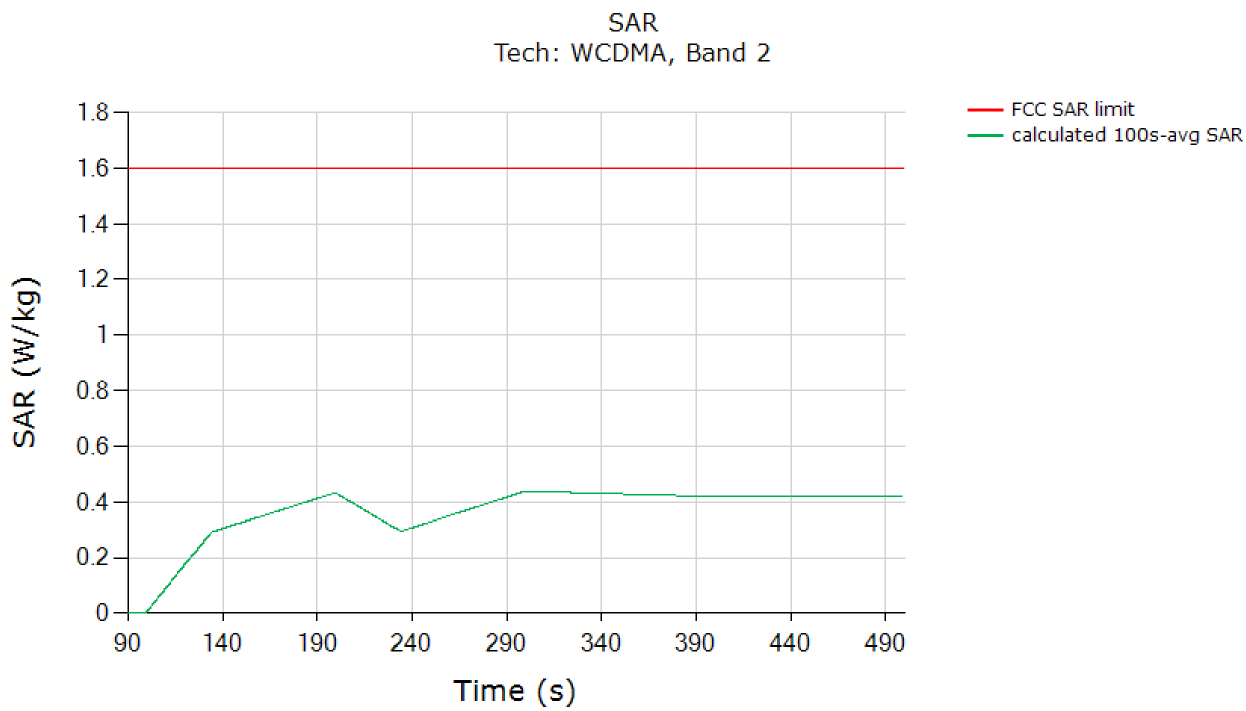


	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.198
Validated : Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (Table 5-2).	

6.3.2 WCDMA Band II

Test result for test sequence 1:

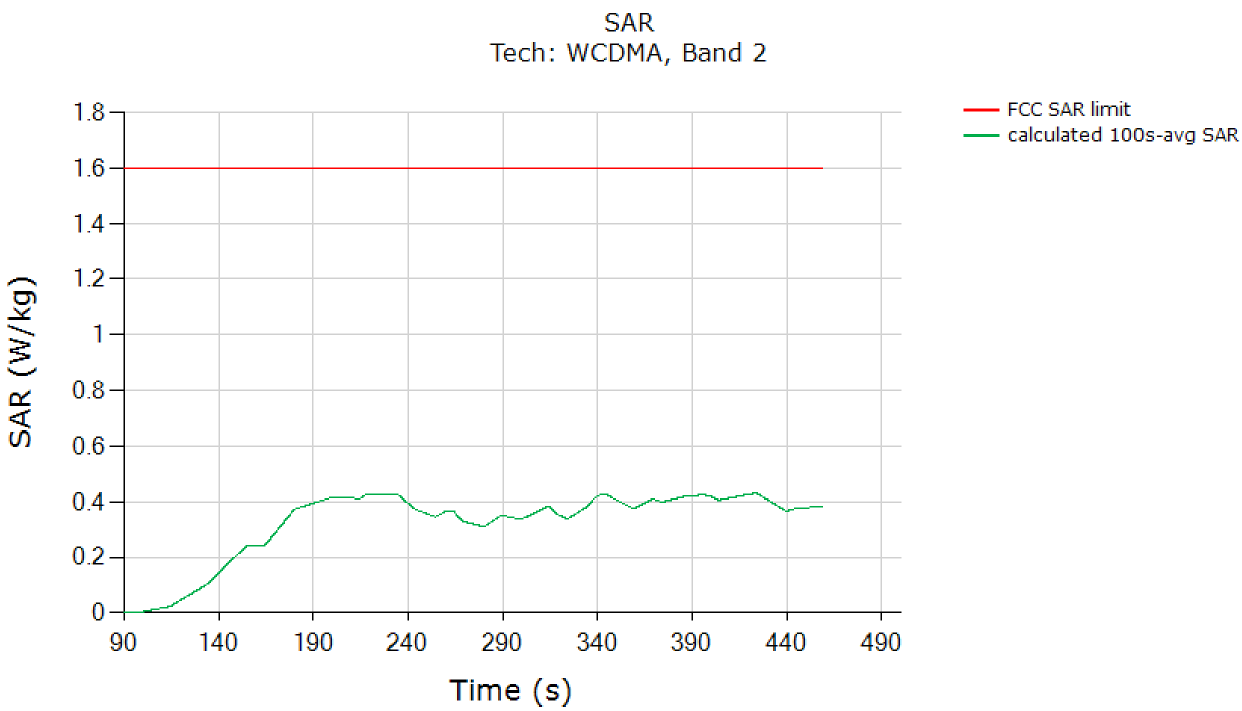
Time-averaged conducted Tx power is converted/calculated into time-averaged SAR using Equation (1a) and plotted below to demonstrate that the time-averaged SAR versus time does not exceed the FCC limit for SAR (1.6W/kg for 1g SAR or 4.0W/kg for 10g SAR):



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.439
Validated : Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (Table 5-2).	

Test result for test sequence 2:

Time-averaged conducted Tx power is converted/calculated into time-averaged SAR using Equation (1a) and plotted below to demonstrate that the time-averaged SAR versus time does not exceed the FCC limit for SAR (1.6W/kg for 1g SAR or 4.0W/kg for 10g SAR):

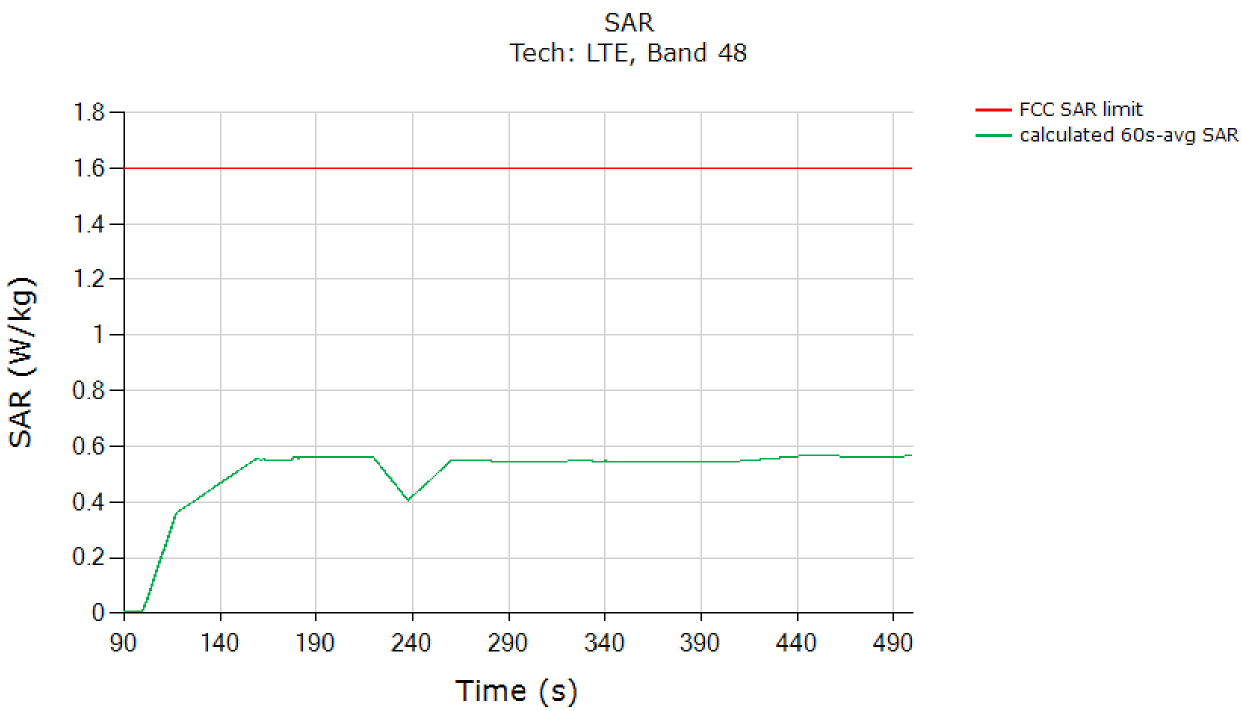


	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.431
Validated : Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (Table 5-2).	

6.3.3 LTE Band 48

Test result for test sequence 1:

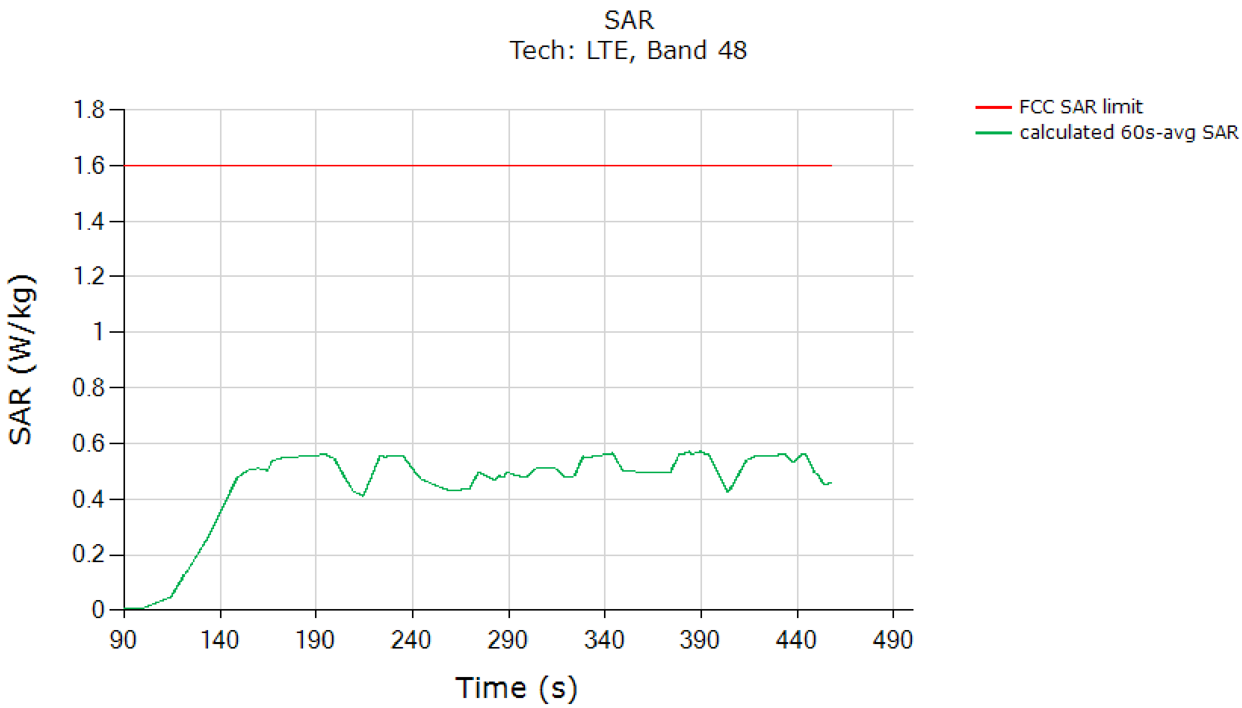
Time-averaged conducted Tx power is converted/calculated into time-averaged SAR using Equation (1a) and plotted below to demonstrate that the time-averaged SAR versus time does not exceed the FCC limit for SAR (1.6W/kg for 1g SAR or 4.0W/kg for 10g SAR):



	(W/kg)
FCC 1gSAR limit	1.6
Max 60s-time averaged 1gSAR (green curve)	0.567
Validated : Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (Table 5-2).	

Test result for test sequence 2:

Time-averaged conducted Tx power is converted/calculated into time-averaged SAR using Equation (1a) and plotted below to demonstrate that the time-averaged SAR versus time does not exceed the FCC limit for SAR (1.6W/kg for 1g SAR or 4.0W/kg for 10g SAR):

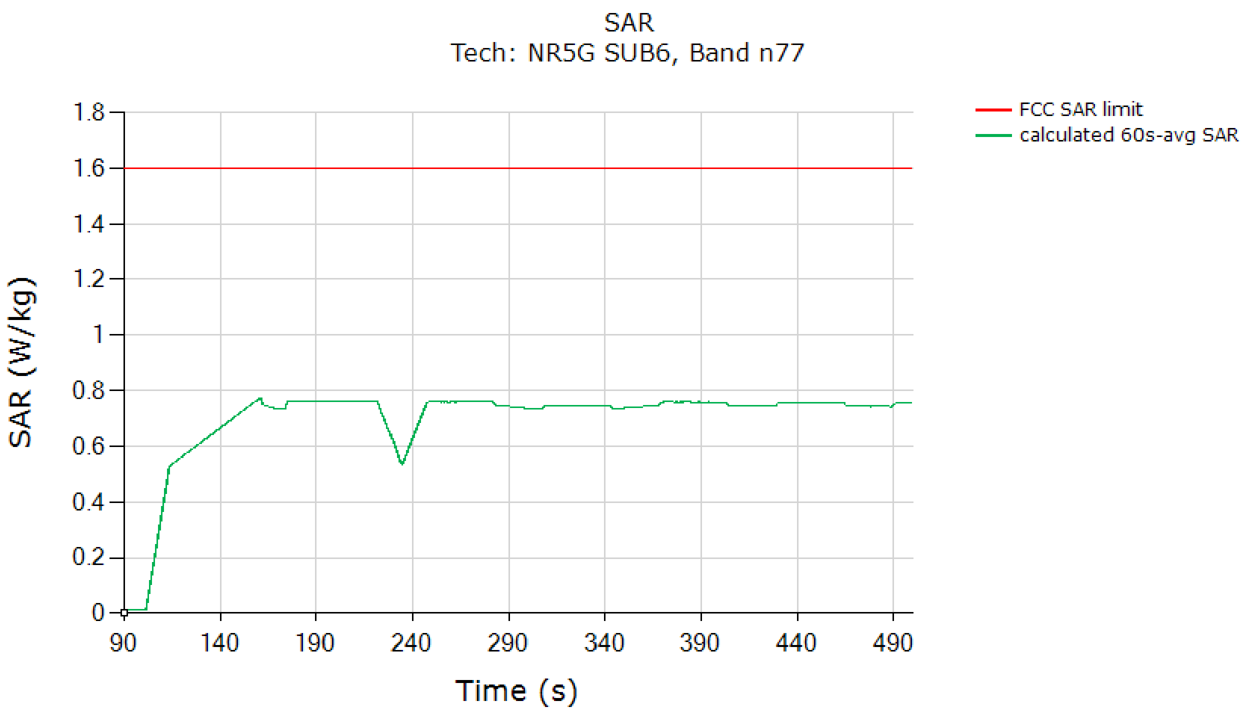


	(W/kg)
FCC 1gSAR limit	1.6
Max 60s-time averaged 1gSAR (green curve)	0.571
Validated : Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (Table 5-2).	

6.3.4 NR Band n77

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

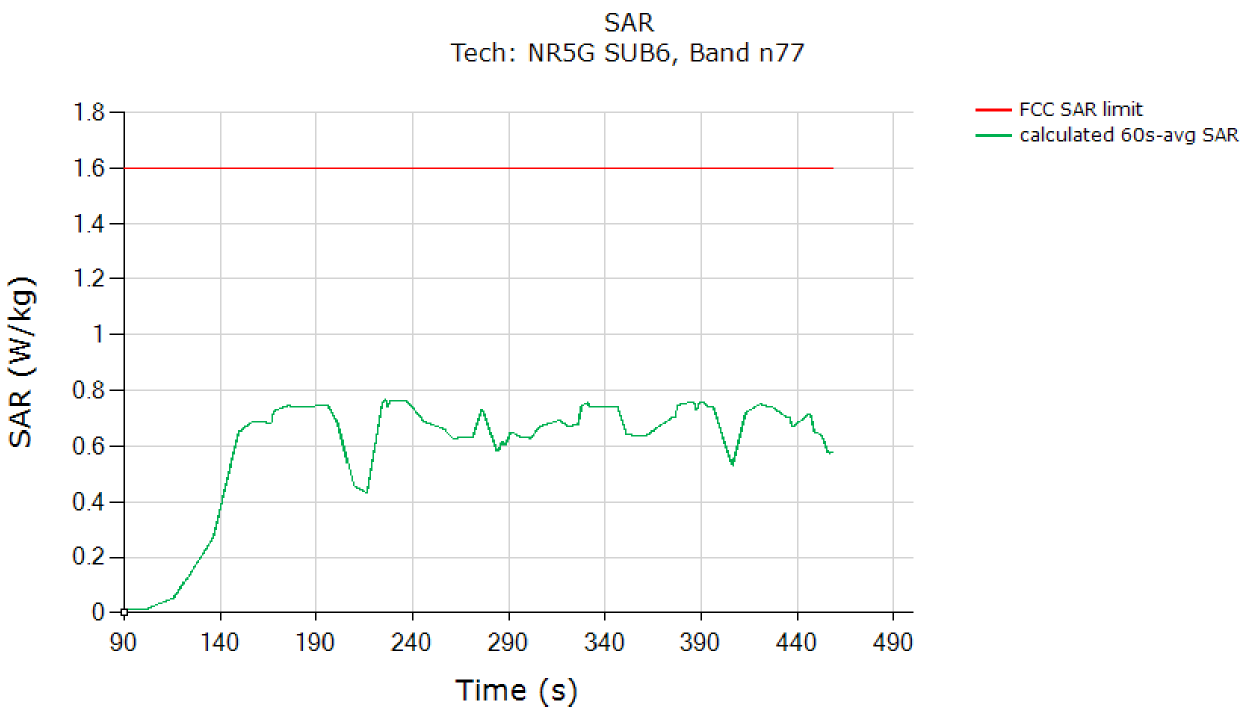
Time-averaged conducted Tx power is converted/calculated into time-averaged SAR using Equation (1a) and plotted below to demonstrate that the time-averaged SAR versus time does not exceed the FCC limit for SAR (1.6W/kg for 1g SAR or 4.0W/kg for 10g SAR):



	(W/kg)
FCC 1gSAR limit	1.6
Max 60s-time averaged 1gSAR (green curve)	0.776
Validated : Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (Table 5-2).	

Test result for test sequence 2:

Time-averaged conducted Tx power is converted/calculated into time-averaged SAR using Equation (1a) and plotted below to demonstrate that the time-averaged SAR versus time does not exceed the FCC limit for SAR (1.6W/kg for 1g SAR or 4.0W/kg for 10g SAR):



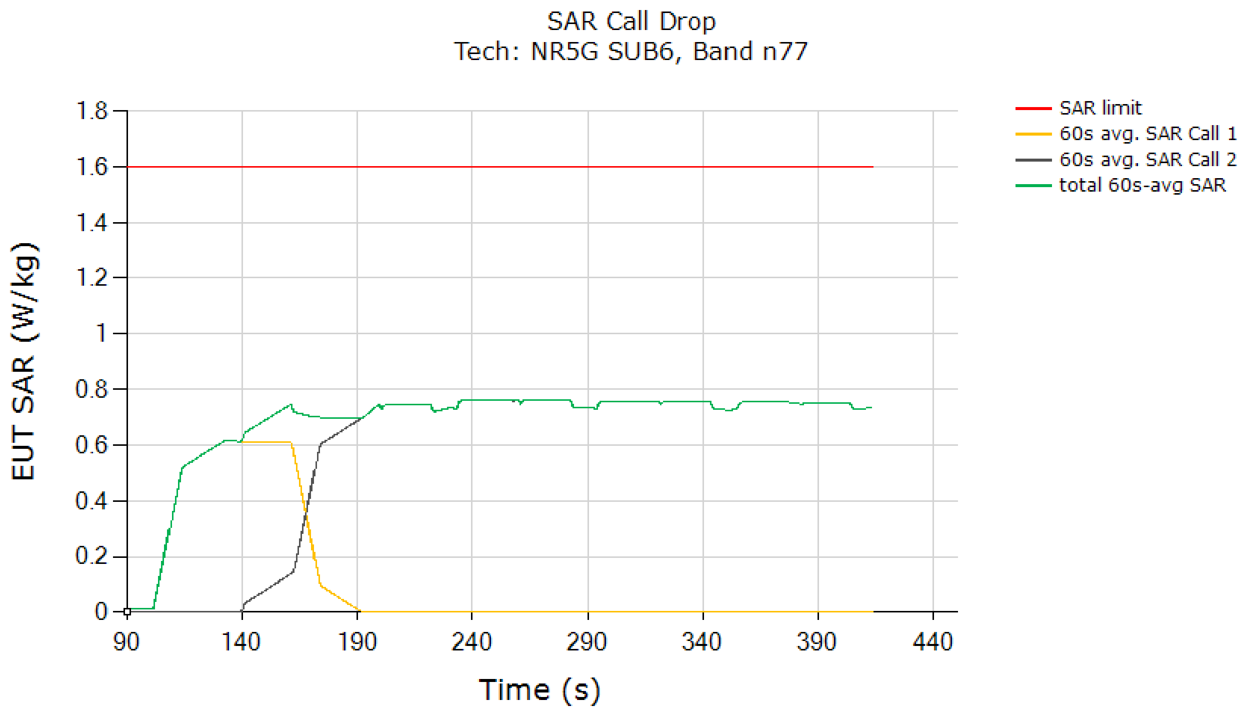
	(W/kg)
FCC 1gSAR limit	1.6
Max 60s-time averaged 1gSAR (green curve)	0.766
Validated : Max time averaged SAR (green curve) is within 1 dB device uncertainty of measured SAR at P_{limit} (Table 5-2).	

6.4. Change in Call Test Results (test case 5 in Table 5-2)

This test was measured with NR Band n77, Sub.3 Ant, DSI =3, and with callbox requesting maximum power. The call drop was manually performed when the EUT is transmitting at $P_{reserve}$ level as shown in the plot below (dotted black region). The measurement setup is shown in Figure B-1(c). The detailed test procedures is described in Section 3.3.2.

Call drop test result:

Time-averaged conducted Tx power is converted/calculated into time-averaged SAR using Equation (1a) and plotted below to demonstrate that the time-averaged SAR versus time does not exceed the FCC limit for SAR(1.6W/kg for 1g SAR or 4.0W/kg for 10g SAR):



	(W/kg)
FCC 1gSAR limit	1.6
Max 60s-time averaged 1gSAR (green curve)	0.763
Validated	

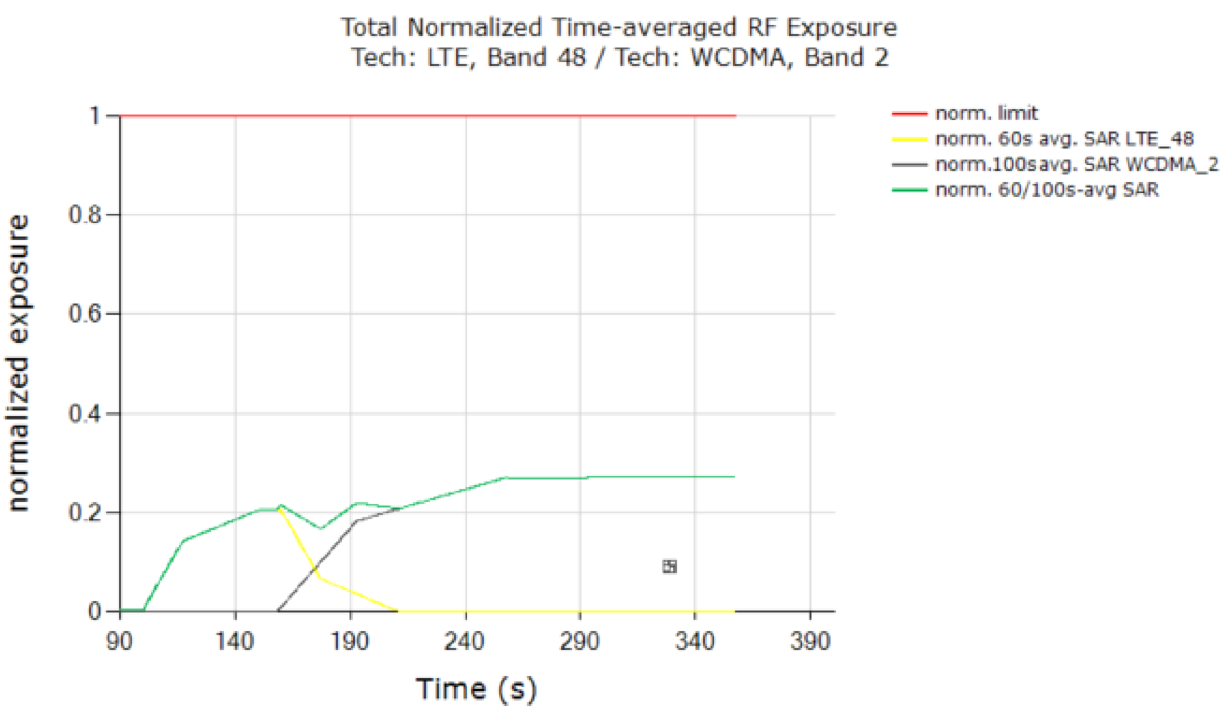
The test result validated the continuity of power limiting in call change scenario.

6.5. Change in technology/band test results (test case 6 in Table 5-2)

This test was conducted with callbox requesting maximum power, and with technology switch from LTE Band 48, Sub.3 Ant, DSI =3 to WCDMA Band II, Main.2 Ant, DSI = 3. Following procedure detailed in Section 3.3.3, and using the measurement setup shown in Figure B-1 (b), the technology/band switch was performed when the EUT is transmitting at $P_{reserve}$ level as shown in the plot below (dotted black region).

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-average 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)	0.272
Validated	

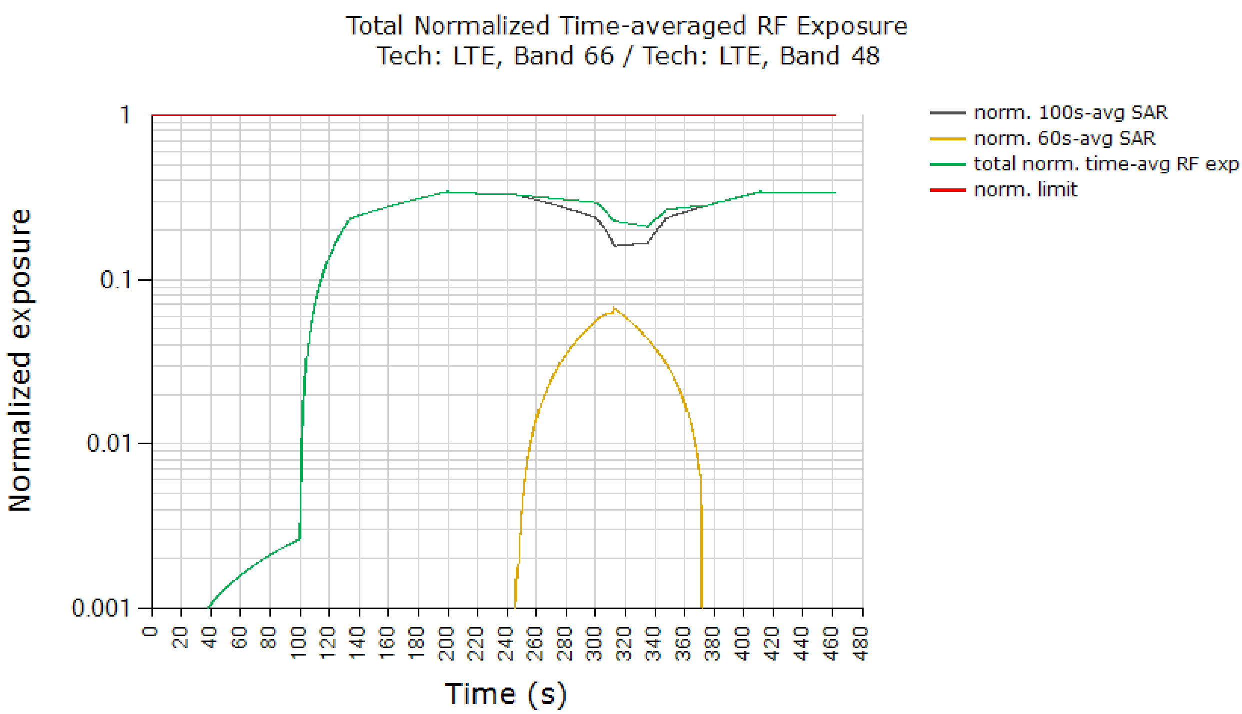
The test result validated the continuity of power limiting in technology/band switch scenario.

6.6. Change in Time Window/Antenna test results (test case 7 in Table 5-2)

This test was conducted with callbox requesting maximum power, and with time-window/antenna switch between LTE Band 66, Main.2 Ant, DSI = 3 (100s window) and LTE Band 48, Sub.3 Ant, DSI = 3 (60s window). Following procedure detailed in Section 3.3.6, and using the measurement setup shown in Figure B-1(b), the time-window switch via tech/band/antenna switch was performed when the EUT is transmitting at $P_{reserve}$ level.

<u>Test case.1) Test result for change in time-window (from 100s to 60s to 100s):</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 1.0 unit. Equation (7a) is used to convert the Tx power of device to obtain 100s-averaged normalized SAR in LTE Band 66 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).

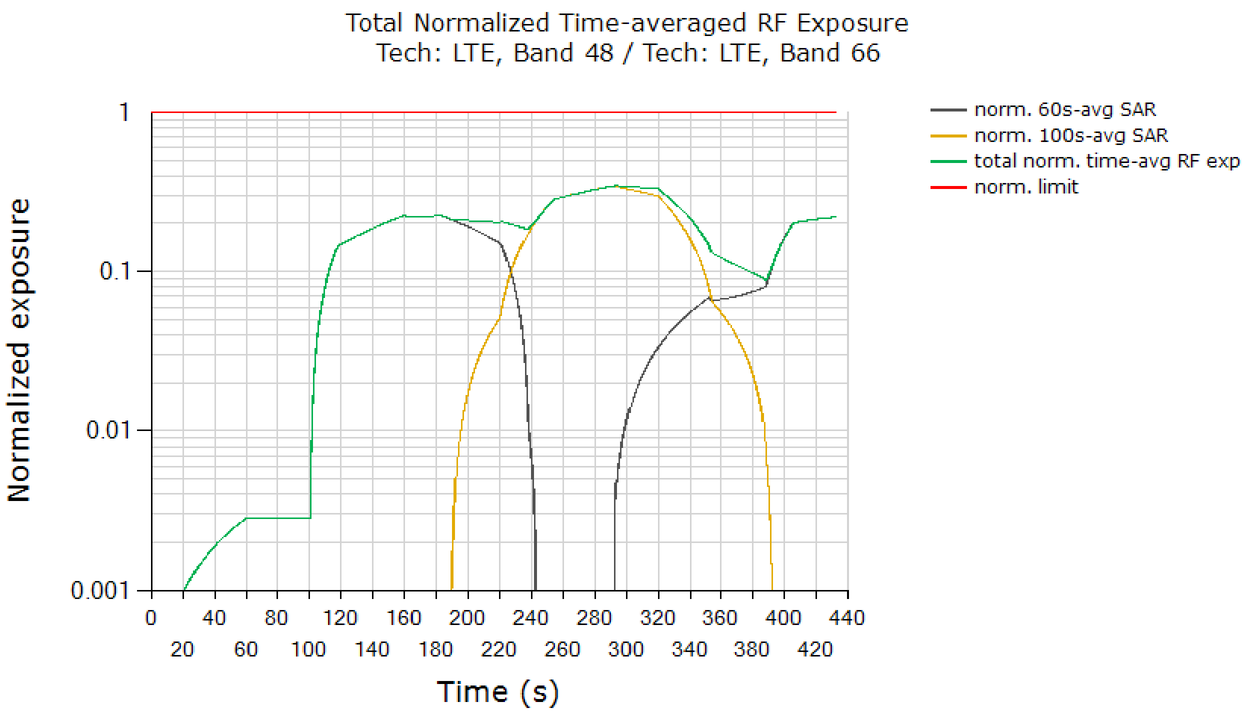


	(W/kg)
FCC normalized total exposure limit	1.0
Max time averaged normalized SAR (green curve)	0.344
Validated	

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 ~312s 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* + 1.0 dB device uncertainty. In this test, with a maximum normalized SAR of 0.344 being ≤ 0.79 (=1.0/1.6 + 1.0 dB device uncertainty), the above test result validated the continuity of power limiting in time=window switch scenario.

Test case.2) Test result for change in time-window (from 60s to 100s to 60s):

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 1.0 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 66 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)	0.347
Validated	

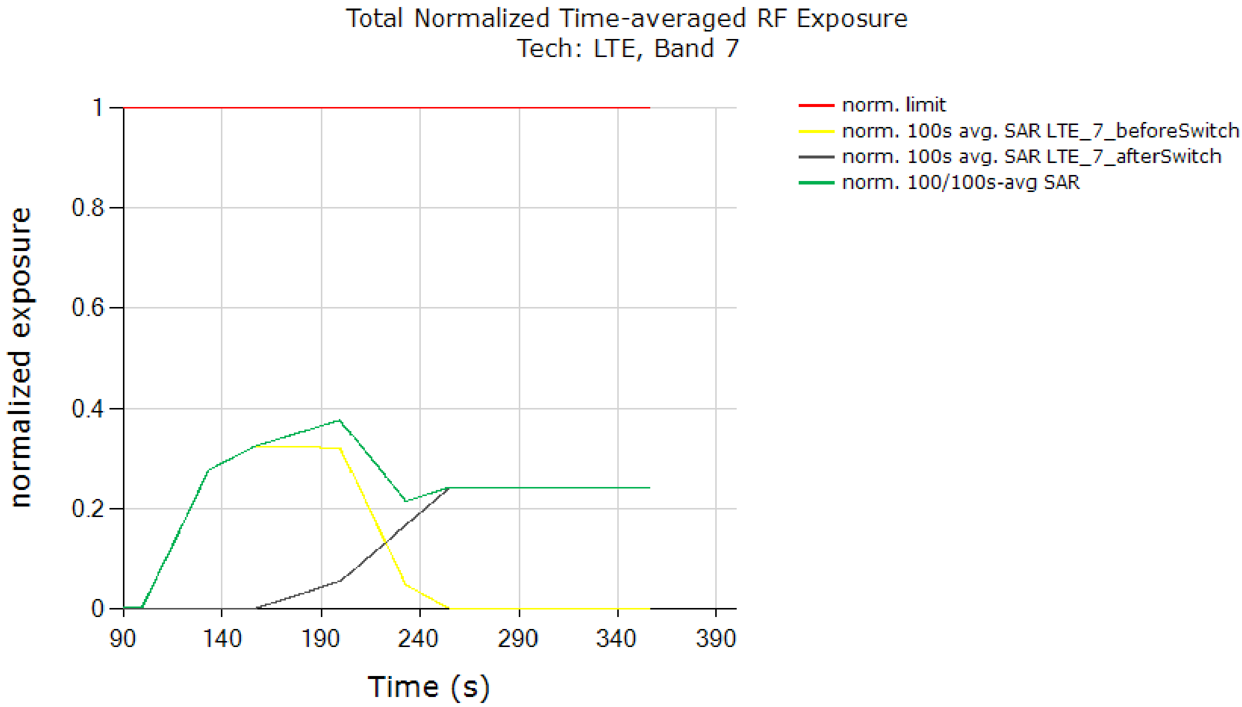
Plot Notes: Maximum power is requested by callbox for the entire duration of the test, with tech/band switches from 60s-to-100s window at ~184s time stamp, and from 100s-to-60s window at ~292s time stamp. Smart Transmit controls the Tx power during these time-window switches to ensure total time-averaged 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* + 1.0 dB device uncertainty. In this test, with a maximum normalized SAR of 0.347 being ≤ 0.79 (=1.0/1.6 + 1.0 dB device uncertainty), the above test result validated the continuity of power limiting in time=window switch scenario.

6.7. Change in DSI test results (test case 8 in Table 5-2)

This test was conducted with callbox requesting maximum power, and with DSI switch from LTE Band 7 DSI = 3 to DSI = 0. Following procedure detailed in Section 3.3.5 using the measurement setup shown in Figure B-1(a), the DSI switch was performed when the EUT is transmitting at $P_{reserve}$ level as shown in the plot below (dotted black circle).

Test result for change in DSI:

All the 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-average normalized SAR versus time does not exceed the normalized FCC limit of 1.0 unit.

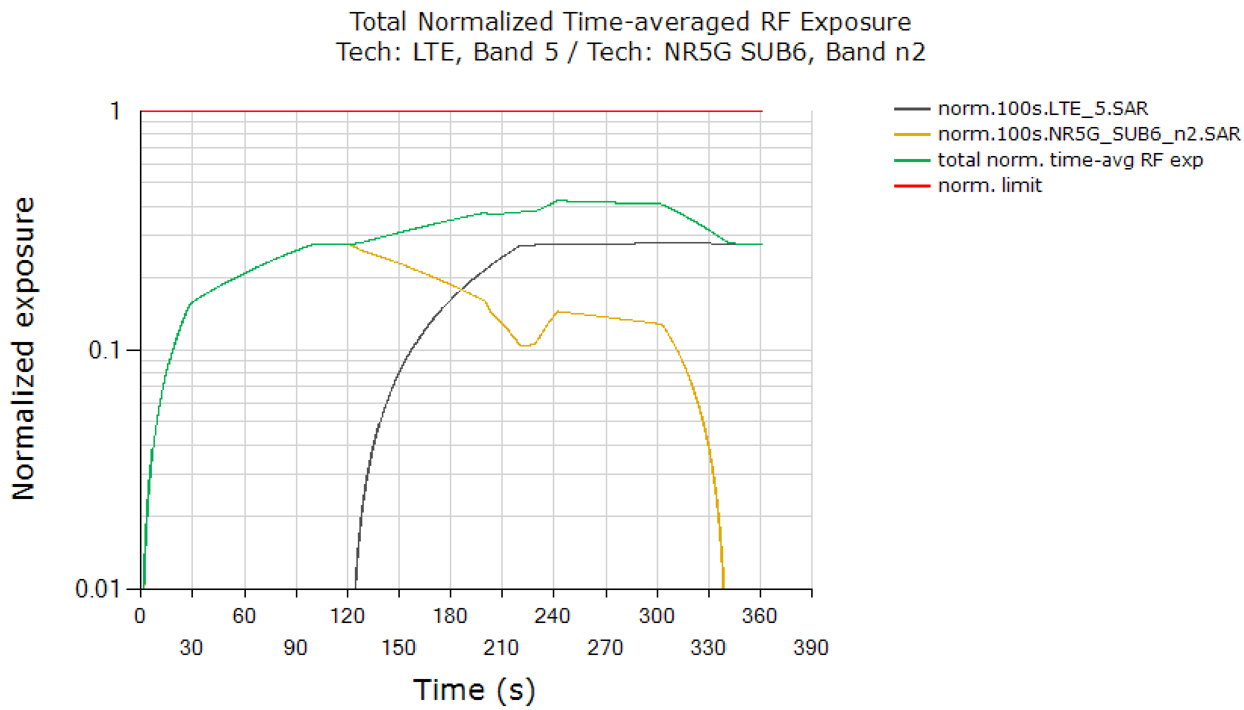


	(W/kg)
FCC normalized SAR limit	1.0
Max 100s-time averaged normalized SAR (green curve)	0.377
Validated	

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

6.8. Switch in SAR exposure test result of LTE + NR (test case 9 in Table 5-2)

This test was conducted with callbox requesting maximum power, and with the EUT in LTE Band 5 + Sub6 NR Band n2 call. Following procedure detailed in Section 3.3.7 and Section B.2, and using the Measurement setup shown in Figure B-1(d) since LTE and Sub6 NR are sharing the same antenna port, the SAR exposure switch measurement is performed with the EUT in various SAR exposure scenarios, 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 1.0 unit. Equation (7a) is used to convert the LTE Tx power of device to obtain 100s-averaged normalized SAR in LTE Band 5 as show in black curve. Similarly, equation (7b) is used to obtain 100s-averaged normalized SAR in Sub6 NR Band n2 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 100s-time averaged normalized SAR (green curve)	0.420
Validated	

Plot Notes: Device starts predominantly in Sub6 NR SAR exposure scenario between 0s and 120s, and LTE SAR + Sub6 NR SAR exposure scenario between 120s and 240s, and in predominantly in LTE SAR exposure scenario after t=240s, Here, This corresponds to a normalized 1gSAR exposure value = 0.439 W/kg measured SAR at Sub6 NR P_{limit} /1.6 W/kg limit = 0.274 ± 1.0dB device related uncertainty (see orange curve between 0s~120s). For predominantly LTE SAR exposure scenario, maximum normalized 1gSAR exposure should correspond to 100% exposure margin = 0.446 W/kg measured SAR at LTE P_{limit} / 1.6 W/kg limit = 0.279 ± 1.0dB 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* + 1.0dB device uncertainty. In this test, with a maximum normalized SAR of 0.420 being ≤ 0.79 (= 1.0/1.6 + 1.0dB device uncertainty), the above test result validated the continuity of power limiting in SAR exposure switch scenario.

7. Radiated Power Test Results for mmW Smart Transmit Feature Validation

7.1. Measurement setup

The keysight Technologies E7515B UXM callbox is used in this test. The schematic of the setup is shown in Figure C-1 (A.4 in Appendix A). 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 NR50S power sensor and NRP2 power meter. Note here that the isolation if the directional coupler may not be sufficient to attenuate the downlink signal from the callbox, which will result in high noise floor making 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 C-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 NRP50S power sensor and NRP2 power meter. 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 C-1 is used for the test scenario 1, 5 and 8 described in Section 2. The test procedures described in Section 4 are followed. The path losses from the EUT to both the power meters are calibrated and used as offset in the power meter.

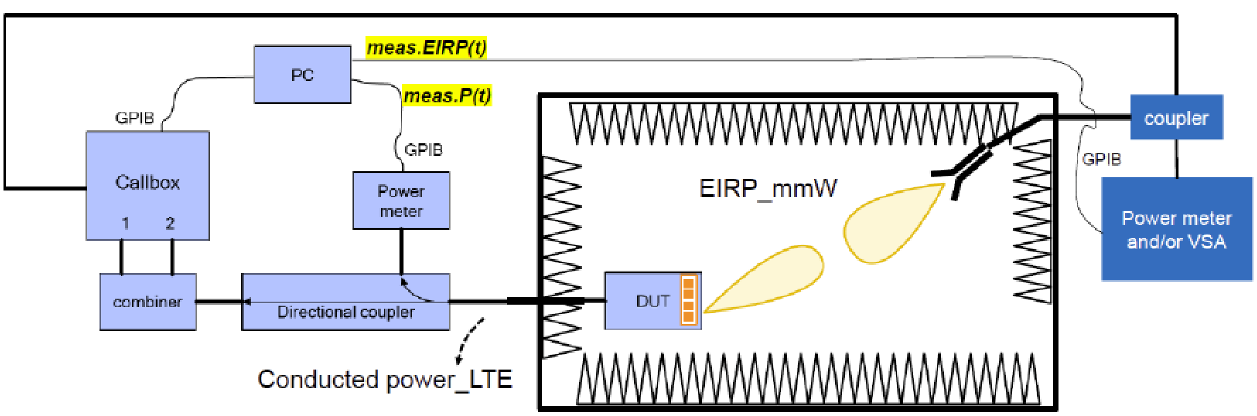


Figure C-1 mmW NR radiated power measurement setup

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, conducted Tx power recording for LTE 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 4.3.1 to 4.3.3.

7.2. mmW NR radiated power test results
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To demonstrate the compliance, the connected Tx power of LTE Band 2 in DSI = 3 is converted to 1gSAR exposure by applying the corresponding worst-case 1gSAR value at P_{limit} as reported in Part 1 report and listed in Table 5-2 of this report.

Similarly, following Step 4 in Section 4.3.1, radiated Tx power of mmW Bane n261 and n260 for the beams tested is converted by applying the corresponding worst-case $4cm^2$PD values measured in UL lab, and listed in below Table 8-1. The measured EIRP at *input.power.limit* for the beams tested in this section are also listed in Table 8-1. 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.

Both the worst-case 1gSAR and $4cm^2$PD values used in this section are listed in Table 8-1. The measured EIRP at *input.power.limit* for the beams tested in this section are also listed in Table 8-1.

Table 8-1: EIRP measured at *input.power.limit* for the selected configurations

Test Case	Test Scenario	Antenna	mmW Band	mmW Beam ID	input.power.limit (dBm)	Configuratrion	Meas. 4cm2PD at input.power.limit (W/m^2)	Meas. EIRP at input.power.limit (dBm)
1	Max.Power Test	K-patch	n261	Beam ID 145	2.5	Edge 2	6.36	8.90
2	SAR vs. PD Switch			Beam ID 145	2.5	Edge 2	6.36	8.90
3	Beam Switch			Beam ID 140	2.6	Edge 2	5.20	9.02
				Beam ID 12	2.9	Edge 2	5.20	8.84
4	Max.Power Test	K-patch	n260	Beam ID 138	3.4	Edge 2	5.78	11.20
5	SAR vs. PD Switch			Beam ID 138	3.4	Edge 2	5.78	11.20
6	Beam Switch			Beam ID 138	3.4	Edge 2	5.78	11.20
				Beam ID 10	3.3	Edge 2	4.28	6.52

Tech	Antenna	Band	DSI	Configuration	meas. Plimit (dBm)	meas 1g SAR at Plimit (W/kg)
LTE Anchor	Main.2	2	3	Edge 3	21.1	0.556

The $4cm^2$-averaged PD distributions for the highest PD value per band, as listed in Table 8-1, are plotted below:

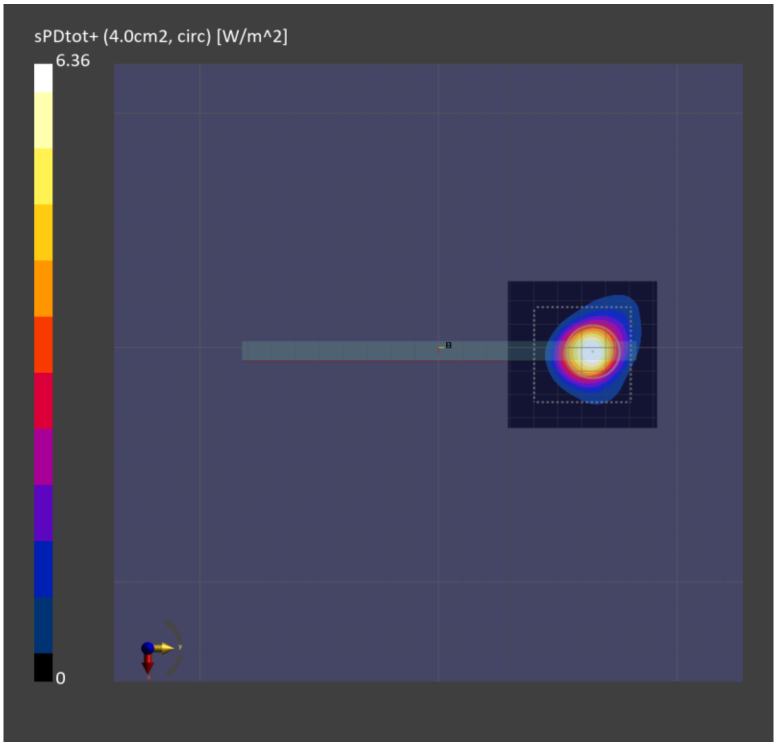


Figure C-2 4cm²-averaged power density distribution measured at *input.power.limit* of 2.5 dBm on the Edge2 Surface n261 beam ID 145.

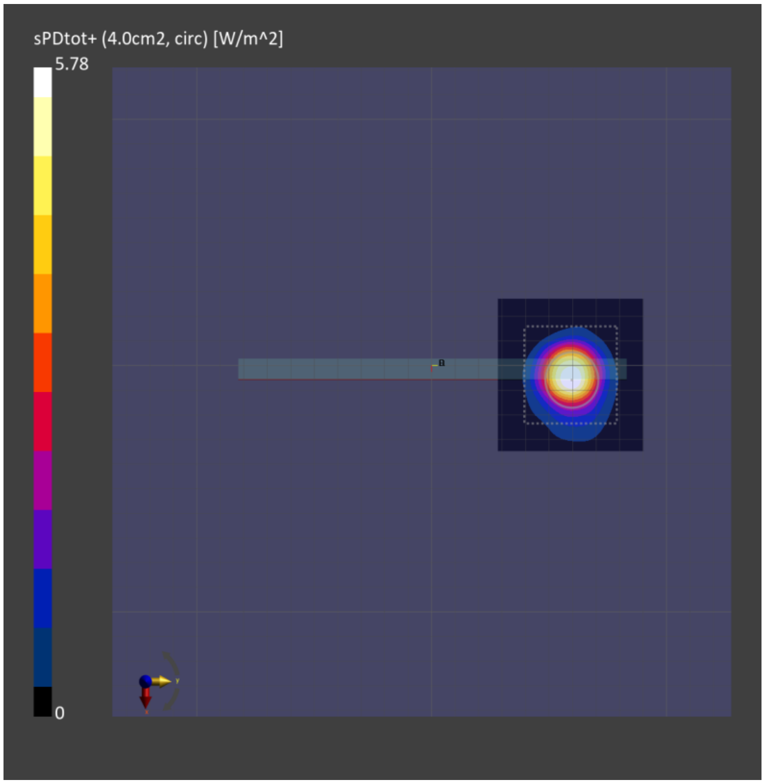


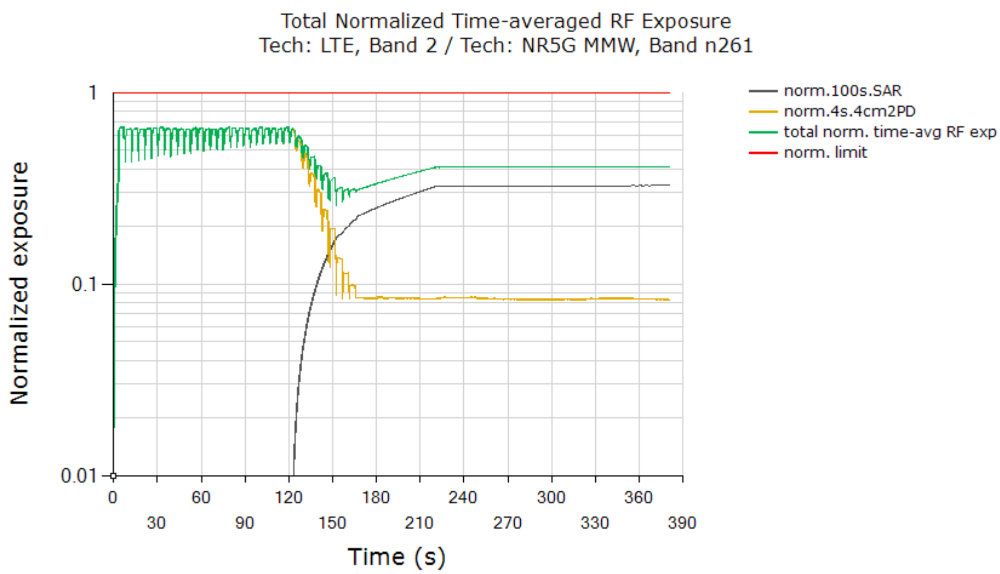
Figure C-3 4cm²-averaged power density distribution measured at *input.power.limit* of 3.4 dBm on the Edge2 Surface n260 beam ID 138.

7.2.1 Maximum Tx power test results for n261

This test was measured with LTE Band 2 and mmW band n261 Beam ID 145, by following the detailed test procedure described in Section 4.3.1.

Time-averaged conducted Tx power for LTE Band 2 and radiated Tx power for mmW Band n261 Beam ID 145 are converted into time-averaged 1gSAR and time-averaged 4cm^{2}PD using Equation (2a) and (2b), which are divided by FCC 1gSAR limit 1.6 W/kg and 4cm^{2}PD limit of 10 W/m^2, respectively, to obtain normalized exposures versus time. **Plot** shows (a) normalized time-averaged 1gSAR versus time, (b) normalized time-averaged 4cm^2-avg.PD versus time, (c) sum of normalized time-averaged 1gSAR and normalized time-averaged 4cm^2-avg.PD:

Plot : Normalized time-averaged exposure 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)	0.665
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 100% for mmW. From Table 8-1, this corresponds to a normalized 4cm^{2}PD exposure value for Beam ID 145 of (100% * 6.36 W/m^2)/(10 W/m^2) = 63.6% ± 2.1dB device related uncertainty (See green/orange curve between 0s ~ 120s). At ~120s time mark, LTE is set to all-up bits, taking away margin from mmW exposure gradually. Towards the end of test, LTE is the dominant contributor towards RF exposure, i.e., corresponding normalized 1gSAR exposure value of (100% * 0.556 W/kg)/(1.6 W/kg) = 34.8% ± 1.0dB design related uncertainty (See black curve approaching this level toward end of the test).

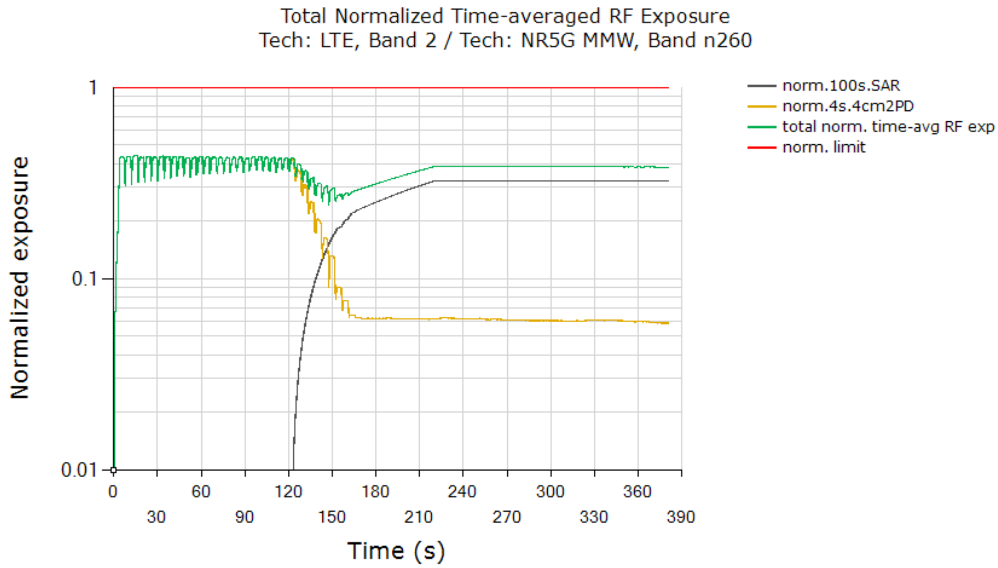
As can be seen, the power limiting enforcement is effective and the total normalized time-averaged RF exposure does not exceed 1.0. Therefore, Qualcomm Smart Transmit time averaging feature is validated.

7.2.2 Maximum Tx power test results for n260

This test was measured with LTE Band 2 and mmW band n260 Beam ID 138, by following the detailed test procedure described in Section 4.3.1.

Time-averaged conducted Tx power for LTE Band 2 and radiated Tx power for mmW Band n260 Beam ID 138 are converted into time-averaged 1gSAR and time-averaged 4cm^{2}PD using Equation (2a) and (2b), which are divided by FCC 1gSAR limit 1.6 W/kg and 4cm^{2}PD limit of 10 W/m^2, respectively, to obtain normalized exposures versus time. **Plot** shows (a) normalized time-averaged 1gSAR versus time, (b) normalized time-averaged 4cm^2-avg.PD versus time, (c) sum of normalized time-averaged 1gSAR and normalized time-averaged 4cm^2-avg.PD:

Plot : Normalized time-averaged exposure 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)	0.442
Validated	

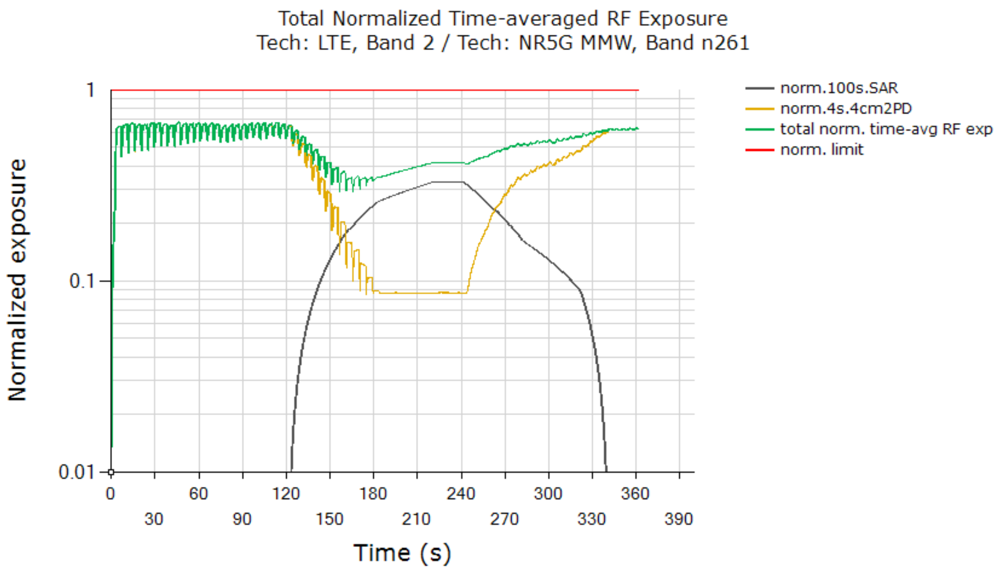
Plot notes: As soon as 5G mmW NR call was established, LTE was placed in all-down bits immediately. Between 0s ~ 120s, mmW exposure is the dominant contributor. Here, Smart Transmit feature allocates a maximum of 100% for mmW. From Table 8-1, this corresponds to a normalized 4cm^{2}PD exposure value for Beam ID 138 of (100% * 5.78 W/m^2)/(10 W/m^2) = 57.8% ± 2.1dB device related uncertainty (See green/orange curve between 0s ~ 120s). At ~120s time mark, LTE is set to all-up bits, taking away margin from mmW exposure gradually. Towards the end of test, LTE is the dominant contributor towards RF exposure, i.e., corresponding normalized 1gSAR exposure value of (100% * 0.556 W/kg)/(1.6 W/kg) = 34.8% ± 1.0dB design related uncertainty (See black curve approaching this level toward end of the test).

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.

7.2.3 Switch in SAR vs. PD exposure test results for n261

This test was measured with LTE Band 2 and mmW band n261 Beam ID 145, by following the detailed test procedure is described in Section 4.3.2.

Plot : Normalized time-averaged exposure 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)	0.681
Validated	

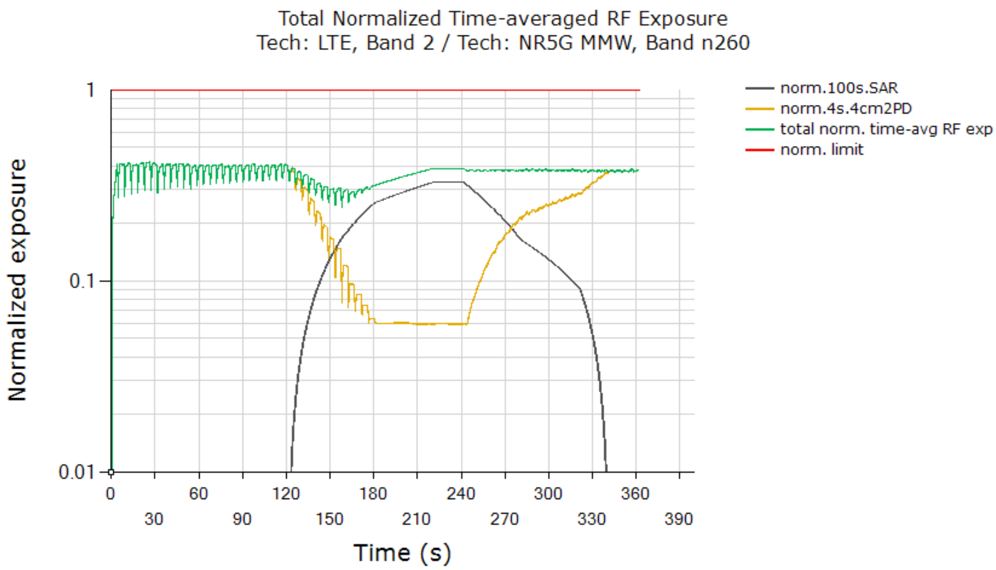
Plot notes: As soon as 5G mmW NR call was established, LTE was placed in all-down bits immediately. Between 0s ~ 120s, mmW exposure is the dominant contributor. Here, Smart Transmit feature allocates a maximum of 100% for mmW. From Table 8-1, this corresponds to a normalized 4cm^{2}PD exposure value for Beam ID 145 of (100% * 6.36 W/m^2)/(10W/m^2) = 63.6% ± 2.1dB device related uncertainty (See orange/green curve between 0s ~ 120s). 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 ~ 200s 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). The calculated maximum RF exposure from LTE corresponds to normalized 1gSAR exposure value of (100% * 0.556 W/kg)/(1.6 W/kg) = 34.8% ± 1.0dB design related uncertainty (note that this level will be achieved by green and black curves if LTE remains in all-up bits for longer time duration which was already demonstrated in maximum Tx power test in Section 8.2.1).

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.

7.2.4 Switch in SAR vs. PD exposure test results for n260

This test was measured with LTE Band 2 and mmW band n260 Beam ID 138, by following the detailed test procedure is described in Section 4.3.2.

Plot : Normalized time-averaged exposure 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)	0.422
Validated	

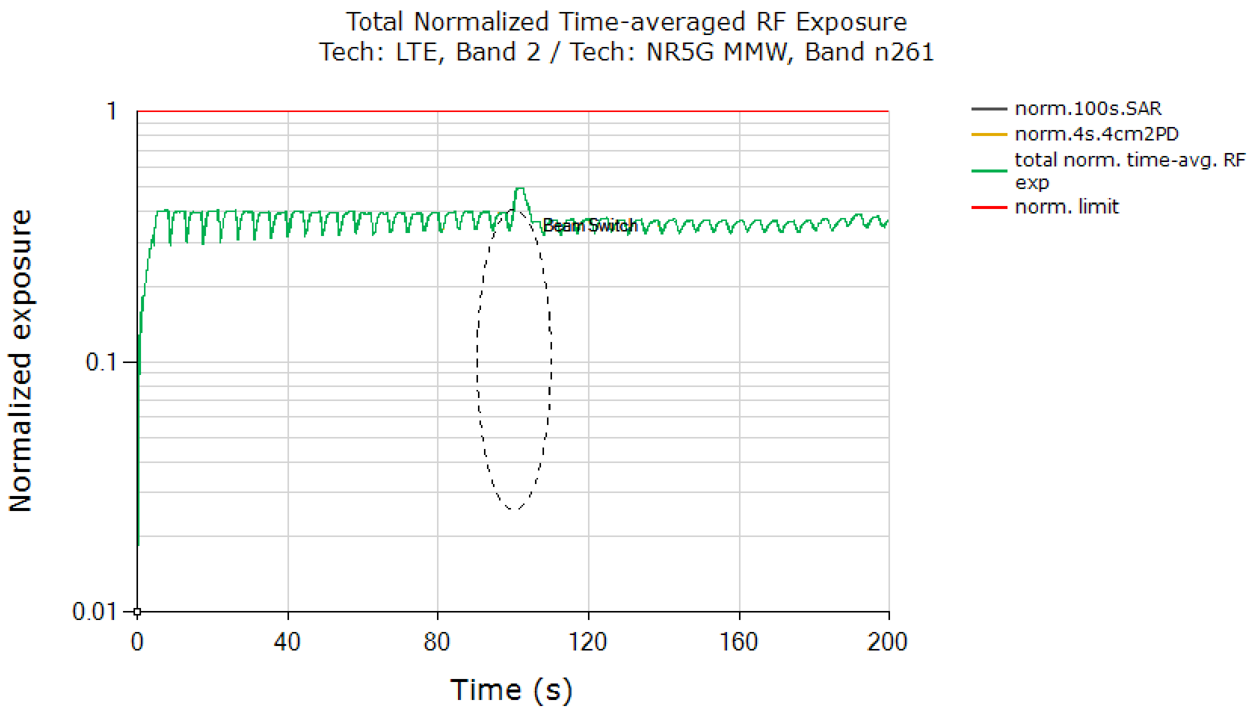
Plot notes: As soon as 5G mmW NR call was established, LTE was placed in all-down bits immediately. Between 0s ~ 120s, mmW exposure is the dominant contributor. Here, Smart Transmit feature allocates a maximum of 100% for mmW. From Table 8-1, this corresponds to a normalized 4cm^{2}PD exposure value for Beam ID 138 of (100% * 5.78 W/m^2)/(10W/m^2) = 57.8% ± 2.1dB device related uncertainty (See orange/green curve between 0s ~ 120s). 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 ~ 200s 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). The calculated maximum RF exposure from LTE corresponds to normalized 1gSAR exposure value of (100% * 0.556 W/kg)/(1.6 W/kg) = 34.8% ± 1.0dB design related uncertainty (note that this level will be achieved by green and black curves if LTE remains in all-up bits for longer time duration which was already demonstrated in maximum Tx power test in Section 8.2.1).

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.

7.2.5 Change in Beam test results for n261

This test was measured with LTE Band 2 and mmW Band n261, with beam switch from Beam ID 140 to Beam ID 12, by following the test procedure is described in Section 4.3.3.

Plot : Normalized time-averaged exposure for mmW (4cm^{2}PD), as well as total normalized time-averaged exposure versus time:



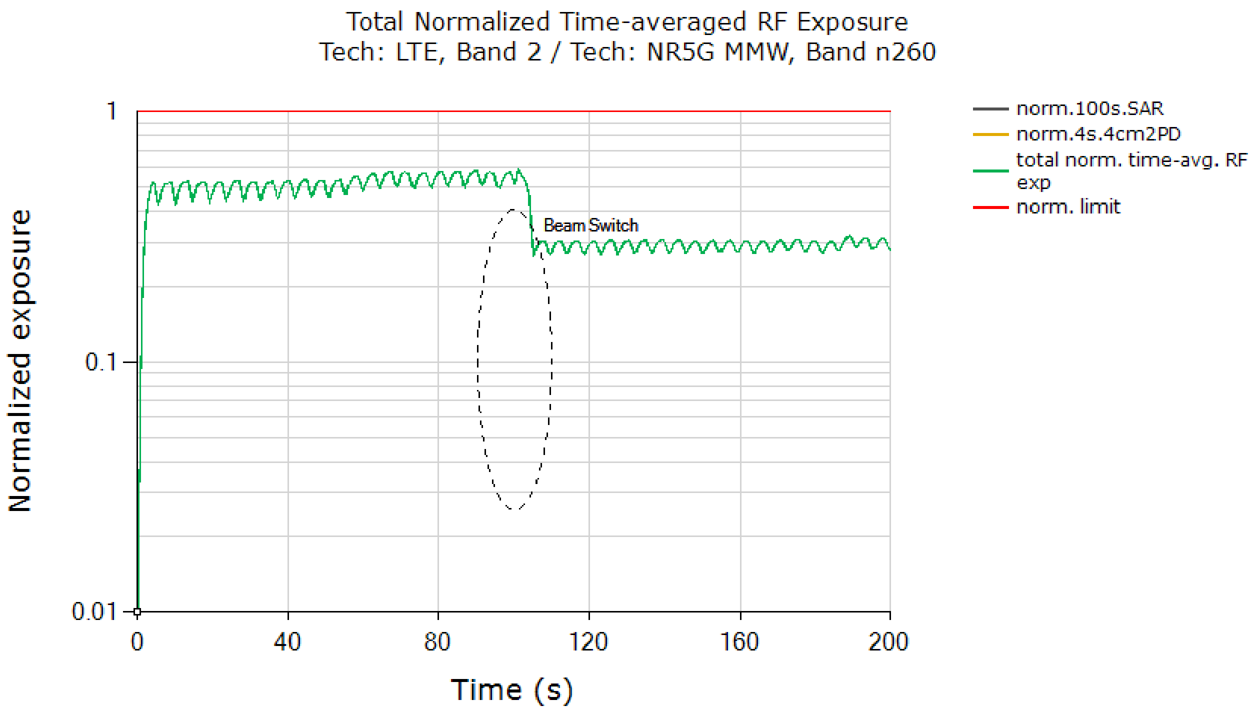
FCC requirement for total RF exposure (normalized)	1.0
Max total normalized time-averaged RF exposure (green curve)	0.495
Validated	

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 100% for mmW. From Table 8-1, exposure between 1s ~ 100s corresponds to a normalized 4cm^{2}PD exposure value for Beam ID 140 of (100%* 5.20 W/m^2)/ (10W/m^2) = 52.0% ± 2.1dB device related uncertainty. At ~100s time mark (shown in black dotted ellipse), the normalized 4cm^{2}PD exposure value for n261 Beam ID 12 = (100%* 5.20 W/m2)/(10 W/m2) = 52.0% ± 2.1dB device related uncertainty. Additionally, during the switch, the radio between the averaged radiated powers of the two beams (yellow curve) should correspond to the difference in EIRPs measured at each corresponding *input.power.limit* for these beams listed in Table 8-1.

7.2.6 Change in Beam test results for n260

This test was measured with LTE Band 2 and mmW Band n260, with beam switch from Beam ID 138 to Beam ID 10, by following the test procedure is described in Section 4.3.3.

Plot : Normalized time-averaged exposure for 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)	0.590
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 100% for mmW. From Table 8-1, exposure between 1s ~ 100s corresponds to a normalized 4cm^{2}PD exposure value for Beam ID 138 of (100%* 5.78 W/m^2)/ (10W/m^2) = 57.8% ± 2.1dB device related uncertainty. At ~100s time mark (shown in black dotted ellipse), the normalized 4cm^{2}PD exposure value for n261 Beam ID 10 = (100%* 4.28 W/m2)/(10 W/m2) = 42.8% ± 2.1dB device related uncertainty. Additionally, during the switch, the radio between the averaged radiated powers of the two beams (yellow curve) should correspond to the difference in EIRPs measured at each corresponding *input.power.limit* for these beams listed in Table 8-1.

8. PD Test Results for mmW Smart Transmit Feature Validation.

8.1. Power density measurement system

The power density measurement system is constructed based on the DASY6 platform by SPEAG. The DASY6 with EummWV2 and 5G software module can measure the RF exposure (power density) up to 110GHz as close as 2mm from any transmitter.

8.2. Power density probe

The EummWV2 probe is used in the power density measurement. It is designed for precise near-field measurements in the mm-wave range by Schmid & Partner Engineering AG of Zurich, Switzerland. The specifications are:

- Frequency range: 0.75 ~ 110 GHz
- Dynamic range: <50 – 3000 V/m (up to 10000 V/m with additional PRE-10 voltage divider)
- Linearity: <± 0.2 dB
- Supports sensor model calibration (SMC)
- ISO17025 accredited calibration

8.3. Power density measurement system verification

The power density system verification is performed using the SPEAG verification device. It consists of a ka-band horn antenna with a corresponding gun oscillator packaged within a cube-shaped housing.

The specification of the verification device is:

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

Below Table shows the verification test results. The measured power density (PD) value is within 0.4dB of target level target level. Note that the uncertainty of 5G verification source is 1.4 dB (K=2).

SAR 8 Room

Date Tested	Source		Total psPD (W/m^2 over 4cm^2)		Deviation (dB)	Plot No.
	Serial #	Cal. Due date	Target	Measured		
11-17-2022	1082	3-1-2023	44.40	44.20	-0.02	1
11-21-2022	1082	3-1-2023	44.40	44.30	-0.01	2

8.4. Measurement setup

This measurement setup is similar to normal PD measurements, the EUT is positioned in 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 NRP50S 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 4.4.

Worst-surface of EUT (for the mmW beam being tested) is positioned facing up for PD measurement with cDASY6 mmW probe as shown in Figure C-4 (see A.5 in Appendix A). Figure C-5 shows the schematic of this measurement setup.

See A.5 in Appendix A

Figure C-4 Worst-surface of EUT positioned facing up for the mmW beam being tested

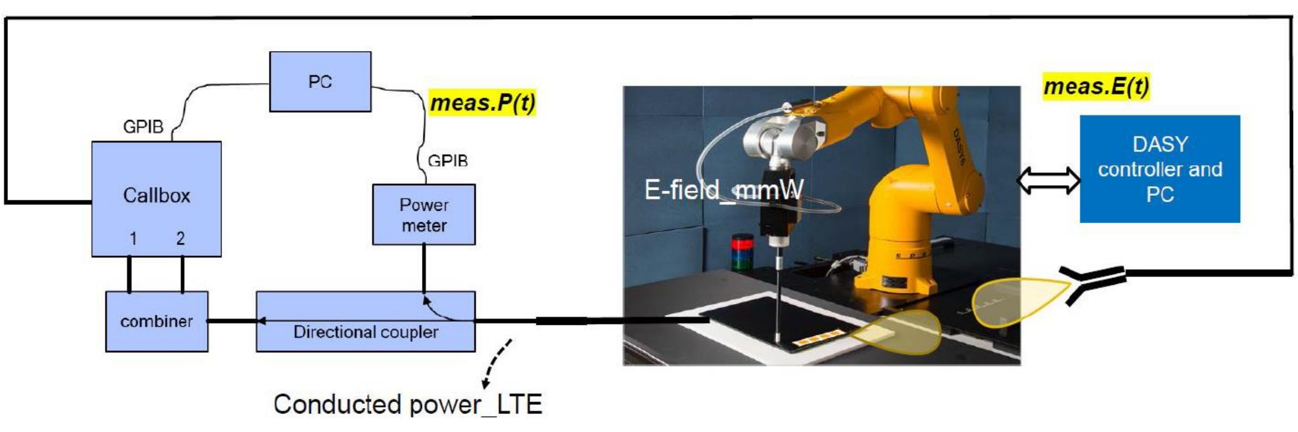


Figure C-5 PD measurement setup

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 reading are periodically recorded every 10ms on NRP50S power sensor for LTE conducted Tx power. Time-averaged E-field measurements are performed using EUmmWV2 mmW probe at peak location of fast area scan. The distance between EummWV2 mmW probe tip to EUT surface is ~0.5 mm, and the distance between EummWV2 probe sensor to probe tip is 1.5 mm. cDASY6 records relative point E-field (i.e., radio $[pointE(t)]^2$ / $[pointE\_input.power.limit]^2$ versus time for mmW NR transmission.

8.5. PD measurement results for maximum power transmission scenario

cDASY6 system validation for PD measurement is provided in Section 9.3, and the associated SPEAG certificates are attached in Appendix D(Probes) & E(Verification sources) in PD part 1 report. The following configurations were measured by following the detailed test procedure is described in Section 4.4:

1. LTE Band 2 (DSI = 3) and mmW Band n261 Beam ID 145
2. LTE Band 2 (DSI = 3) and mmW Band n260 Beam ID 138

The measured conducted Tx power of LTE and ratio of $[pointE(t)]^2$ / $[pointE\_input.power.limit]^2$ of mmW is convert into 1gSAR and $4cm^2$PD 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 *4cm²PD@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.

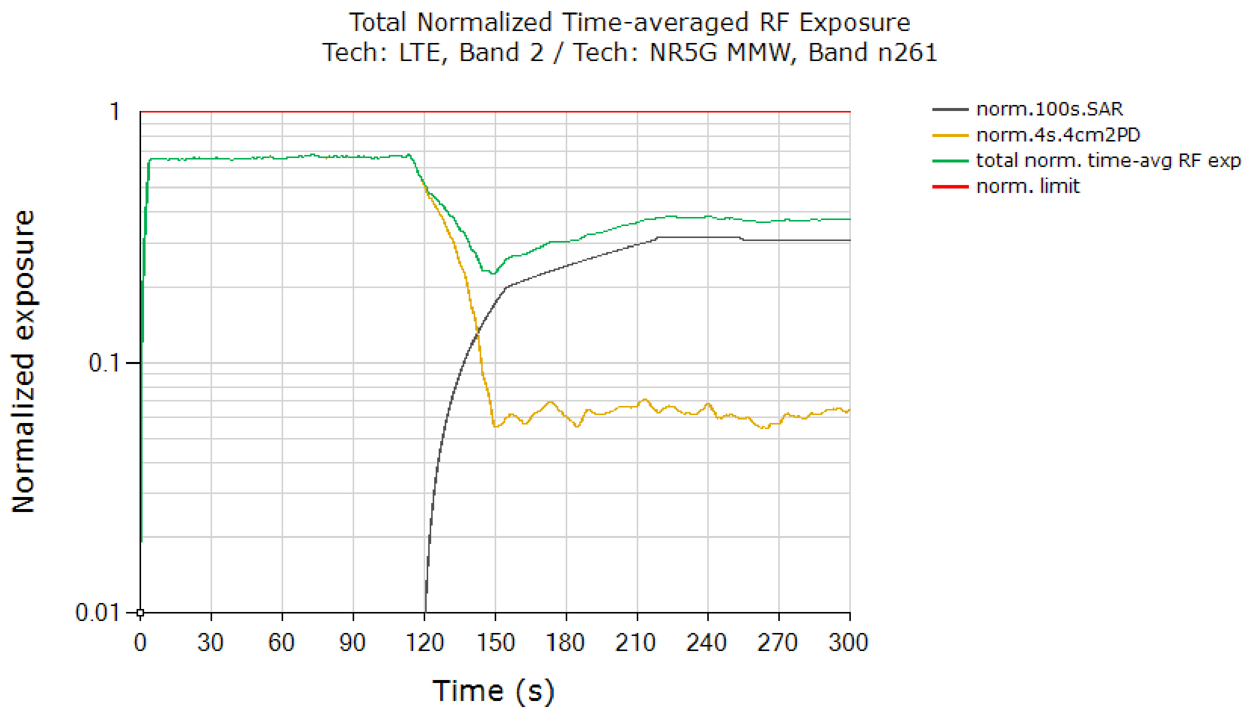
Note: cDASY6 system measures relative E-field, and provides ratio of $[pointE(t)]^2$ / $[pointE\_input.power.limit]^2$

Versus time.

The radio configurations tested are described in Table 5-3 and 5-4. The 1gSAR at P_{limit} for LTE Band 2 DSI =3, the measured $4cm^2$PD at *input.power.limit* of mmW n261 beam 145 and n260 beam 138, are all listed in Table 8-1.

8.5.1 PD test results for n261

Step 2.e plot (in Section 4.4) for normalized instantaneous and time-averaged exposure for LTE band 2 and mmW n261 beam 145:



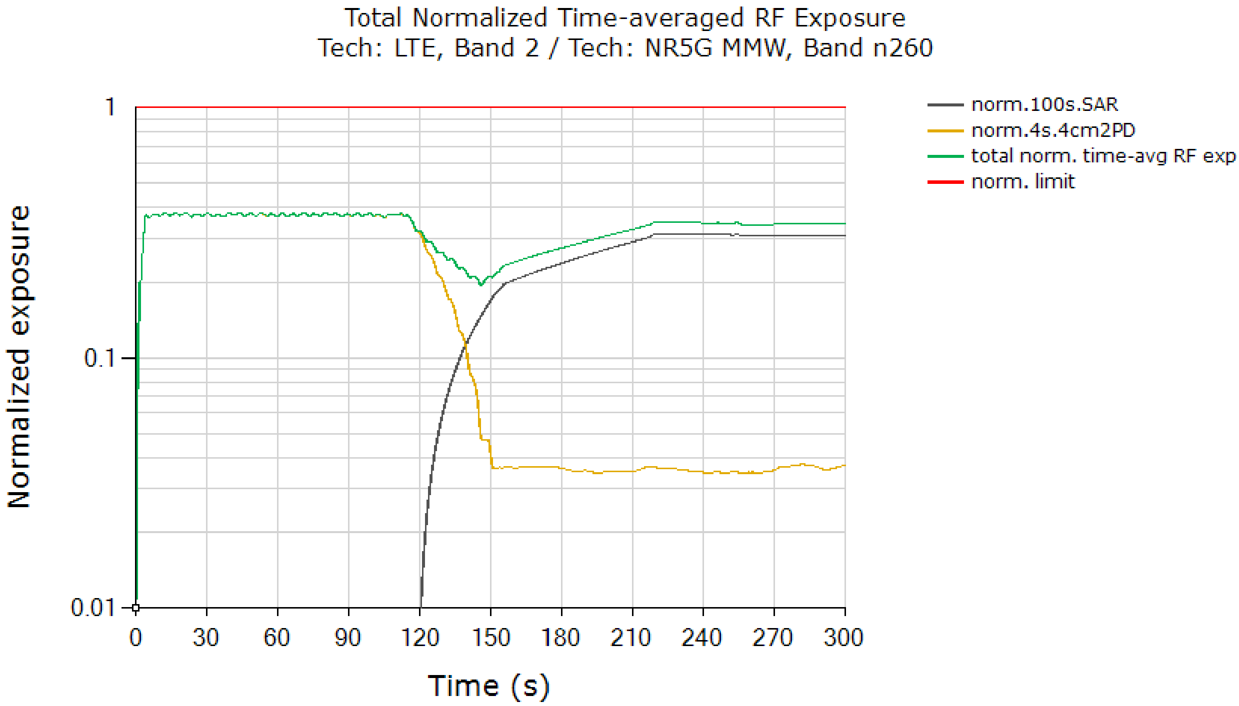
FCC limit for total RF exposure (normalized)	1.0
Max total normalized time-averaged RF exposure (green curve)	0.677
Validated	

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). From Table 8-1, this corresponds to a normalized 4cm^{2}PD exposure value for Beam ID 145 of (100% * 6.36 W/m2)/(10W/m2) = 63.4% ± 2.1dB device related uncertainty (See orange/green curve between 0s ~ 120s). Around 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, i.e., corresponding normalized 1gSAR exposure value of (100% * 0.556 W/kg)/(1.6 W/kg) = 34.8% ± 1.0dB design related uncertainty (See black curves approaching this level towards end of the test).

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.

8.5.2 PD test results for n260

Step 2.e plot (in Section 4.4) for normalized instantaneous and time-averaged exposure for LTE Band 2 and mmW n260 beam 138:



FCC limit for total RF exposure (normalized)	1.0
Max total normalized time-averaged RF exposure (green curve)	0.380
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). From Table 8-1, this corresponds to a normalized $4cm^2$PD exposure value for Beam ID 138 of (100% * 5.78 W/m2)/(10W/m2) = 57.8% ± 2.1dB device related uncertainty (See orange/green curve between 0s ~ 120s). Around 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, i.e., corresponding normalized 1gSAR exposure value of (100% * 0.556 W/kg)/(1.6 W/kg) = 34.8% ± 1.0dB design related uncertainty (See black curves approaching this level towards end of the test).

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.

9. Test Equipment

The measuring equipment used to perform the tests documented in this report has been calibrated in accordance with the manufacturers' recommendations, and is traceable to recognized national standards.

Conducted/Radiated test

Conducted for Sub6 test

Test equipments

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
Pow er Sensor	R & S	NRP8S	104520	8-3-2023
Pow er Sensor	R & S	NRP8S	104521	8-3-2023
Pow er Divider	Weinschel	WA1575-1313	N/A	8-2-2023
Directional Coupler	NARDA	4216-10	02835	8-3-2023
Directional Coupler	NARDA	ZUDC20-183+	N/A	8-2-2023
Directional Coupler	NARDA	ZUDC20-183+	N/A	8-3-2023

Others

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
Base Station Simulator	R & S	CMW500	150314	8-2-2023
UXM 5G Wireless Test Platform	Keysight	E7515B	MY59150850	12-13-2022

Radiated for mmW test

Test equipments

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
Pow er Sensor	R & S	NRP8S	104520	8-3-2023
Pow er Sensor	R & S	NRP50S	102284	8-3-2023
Directional Coupler	Krytal	1850	164429	8-1-2023
Directional Coupler	Krytal	110067006	205759	8-2-2023

Others

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
mmW Chamber	BOJAY	BJ-8827-UL2	ZHBJ2008-BU1-F253779	N/A
UXM 5G Wireless Test Platform	Keysight	E7515B	MY58010202	1-7-2023

Power density test

System Check

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
5G Probe	SPEAG	EUmmWV4	9536	2-28-2023
Dta Acquisition Electronics	SPEAG	DAE4	1670	6-7-2023
Verification kit	SPEAG	5G Verification Source 30GHz	1082	3-1-2023

Others

Name of Equipment	Manufacturer	Type/Model	Serial No.	Cal. Due Date
UXM 5G Wireless Test Platform	Keysight	E7515B	MY57510596	8-5-2023

Note(s):

For calibration reports of PD's probe reference dipole and reference source, Please refer to Part.1 appendix.

10. Measurement Uncertainty

10.1. Power density

Measurement Uncertainty for cDASY6 Module mmWave

Error Description	Uncertainty value (±dB)	Probe Dist.	Divisor	(Ci)	Std. Unc. (±dB)	(Vi)
Uncertainty terms dependent on the measurement system						
Calibration	**0.49**	Normal	1	1	0.49	Infinity
Probe correction	**0.00**	Rectangular	1.73	1	0.00	Infinity
Frequency response (BW =< 1 GHz)	**0.20**	Rectangular	1.73	1	0.12	Infinity
Sensor cross coupling	**0.00**	Rectangular	1.73	1	0.00	Infinity
Isotropy	**0.50**	Rectangular	1.73	1	0.29	Infinity
Linearity	**0.20**	Rectangular	1.73	1	0.12	Infinity
Probe scattering	**0.00**	Rectangular	1.73	1	0.00	Infinity
Probe positioning offset	**0.30**	Rectangular	1.73	1	0.17	Infinity
Probe positioning repeatability	**0.04**	Rectangular	1.73	1	0.02	Infinity
Sensor mechanical offset	**0.00**	Rectangular	1.73	1	0.00	Infinity
Probe spatial resolution	**0.00**	Rectangular	1.73	1	0.00	Infinity
Field impedance dependance	**0.00**	Rectangular	1.73	1	0.00	Infinity
Amplitude and phase drift	**0.00**	Rectangular	1.73	1	0.00	Infinity
Amplitude and phase noise	**0.04**	Rectangular	1.73	1	0.02	Infinity
Measurement area truncation	**0.10**	Rectangular	1.73	1	0.06	Infinity
Data acquisition	**0.03**	Normal	1.00	1	0.03	Infinity
Sampling	**0.00**	Rectangular	1.73	1	0.00	Infinity
Field reconstruction	**0.60**	Rectangular	1.73	1	0.35	Infinity
Forward transformation	**0.00**	Rectangular	1.73	1	0.00	Infinity
Power density scaling	**-**	Rectangular	1.73	1	-	Infinity
Spatial averaging	**0.10**	Rectangular	1.73	1	0.06	Infinity
System detection limit	**0.04**	Rectangular	1.73	1	0.02	Infinity
Uncertainty terms dependent on the DUT and environmental factors						
Probe coupling with DUT	**0.00**	Rectangular	1.73	1	0.00	Infinity
Modulation response	**0.40**	Rectangular	1.73	1	0.23	Infinity
Integration time	**0.00**	Rectangular	1.73	1	0.00	Infinity
Response time	**0.00**	Rectangular	1.73	1	0.00	Infinity
Device holder influence	**0.10**	Rectangular	1.73	1	0.06	Infinity
DUT alignment	**0.00**	Rectangular	1.73	1	0.00	Infinity
RF ambient conditions	**0.04**	Rectangular	1.73	1	0.02	Infinity
Ambient reflections	**0.04**	Rectangular	1.73	1	0.02	Infinity
Immunity / secondary reception	**0.00**	Rectangular	1.73	1	0.00	Infinity
Drift of the DUT	**0.22**	Rectangular	1.73	1	0.13	Infinity
Combined Std. Uncertainty					0.76	Infinity
Expanded Standard Uncertainty (95%)					**1.53**	

11. Conclusions

Qualcomm Smart Transmit feature employed in Samsung device (FCC ID: A3LSA236V) has been validated through the conducted/radiated power measurement (as demonstrated in Section 6 & 7), PD measurement (as demonstrated in Section 8).

As demonstrated in this report, the power limiting enforcement is effective and the total normalized time-averaged RF exposure does not exceed 1.0 for all the transmission scenarios described in Section 2. Therefore, the EUT complies with FCC RF exposure requirement.

Section A. Test Sequences

1. Test sequence is generated based on below parameters of the EUT:
   a. Measured maximum power (P_{max})
   b. Measured Tx_power_at_SAR_design_target (P_{limit})
   c. Reserve_power_margin (dB)
      - $P_{reserve}$ (dBm) = measured P_{limit} (dBm) – *Reserve_power_margin* (dB)
   d. SAR_time_window (100s for FCC)

2. **Test Sequence 1** Waveform:

   Based on the parameter above, the Test Sequence 1 is generated with one transmission between high and low Tx powers. Here, high power = P_{max}; low power = P_{max}/2, and the transition occurs after 80 seconds at high power P_{max}. As long as the power enforcement is taking into effective during one 100s/60s time window, the validation test with this defined test sequence 1 is valid, otherwise, select other radio configuration (band/DSI within the same technology group) having lower P_{limit} for this test. The test sequence 1 waveform is shown below:

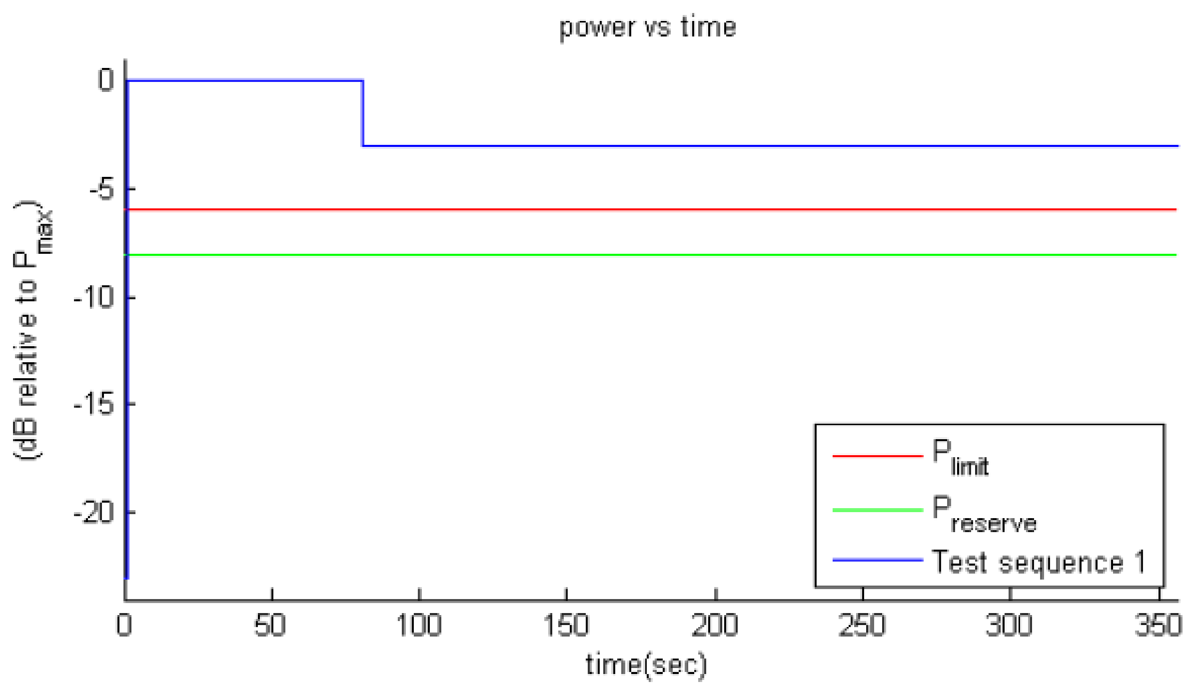


Figure A-1: Test sequence 1 waveform

3. **<u>Test Sequence 2</u>** Waveform:

Based on the parameters in Figure A-1, the Test Sequence 2 is generated as described in Table A-1, which contains two 170 second-long sequences (yellow and green highlighted rows) that are mirrored around the center row of 20s, resulting in a total duration of 360 seconds:

Table A-1: Test sequence 2

Time duration (seconds)	dB relative to P_{limit} or $P_{reserve}$
15	$P_{reserve}$ – 2
20	P_{limit}
20	(P_{limit} + P_{max})/2 averaged in mW and rounded to nearest 0.1 dB step
10	$P_{reserve}$ – 6
20	P_{max}
15	P_{limit}
15	$P_{reserve}$ – 5
20	P_{max}
10	$P_{reserve}$ – 3
15	P_{limit}
10	$P_{reserve}$ – 4
20	(P_{limit} + P_{max})/2 averaged in mW and rounded to nearest 0.1 dB step
10	$P_{reserve}$ – 4
15	P_{limit}
10	$P_{reserve}$ – 3
20	P_{max}
15	$P_{reserve}$ – 5
15	P_{limit}
20	P_{max}
10	$P_{reserve}$ – 6
20	(P_{limit} + P_{max})/2 averaged in mW and rounded to nearest 0.1 dB step
20	P_{limit}
15	$P_{reserve}$ – 2

The test Sequence 2 waveform is shown in Figure A-2.

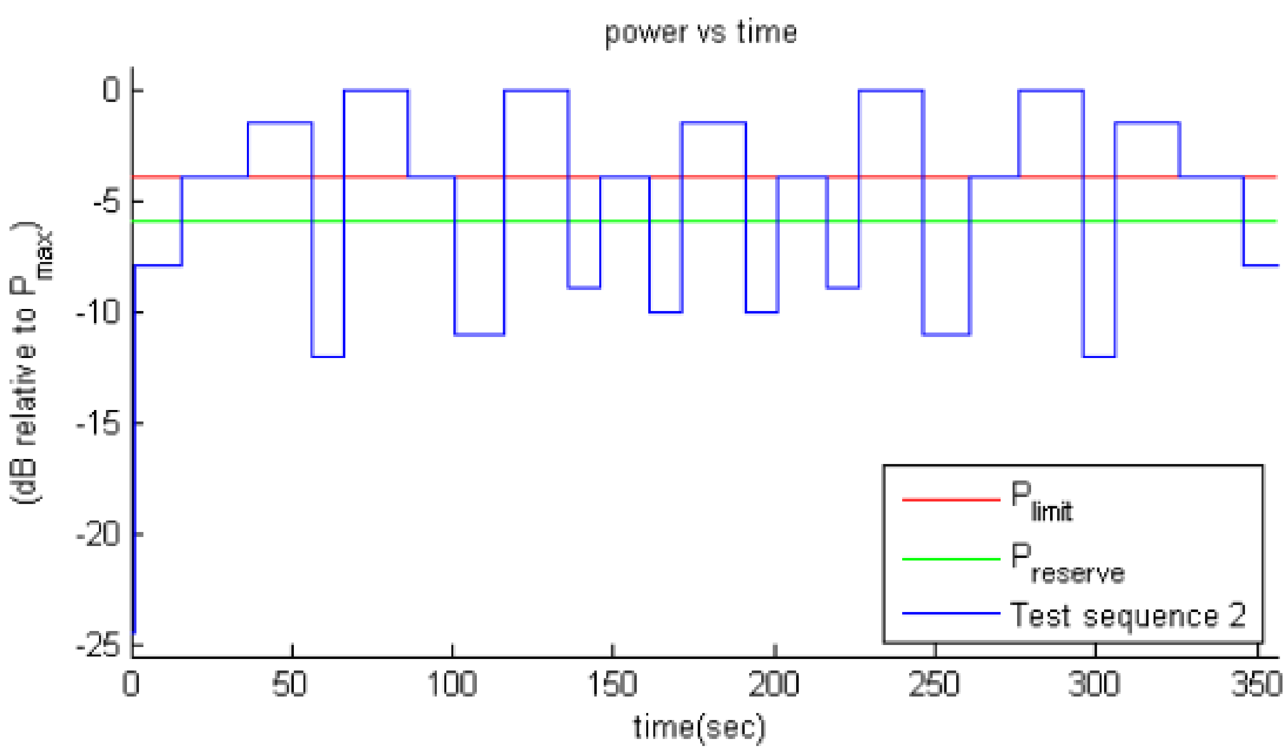


Figure A-2: Test sequence 2 waveform

Section B. Test Procedures for LTE + Sub6 NR

Section B provides the test procedures for validating Qualcomm Smart Transmit feature for LTE + Sub6 NR non-standalone (NSA) mode transmission scenario, where sub-6GHz LTE link acts as an anchor, and Sub6 NR standalone mode (SA) transmission scenario.

B.1 Time-varying Tx power test for sub6 NR in NSA mode and SA mode

Follows Section 3.2.1 to select test configurations for time-varying test. This test in performed with two pre-defined test sequences (described in Section 3.1) applied to Sub6 NR (with LTE on all-down bits or low power for the entire test after establishing the LTE + Sub6 NR call with the callbox). Follow the test procedures described in Section 3.3.1 to demonstrate the effectiveness of power limiting enforcement and that the time averaged Tx power of Sub6 NR when converted into 1g or 10gSAR values does not exceed the regulatory limit at all times (See Eq. (1a) and (1b)). Sub6 NR response to test sequence 1 and test sequence 2 will be similar to other technologies (say, LTE), and are shown in Sections 6.3.7 and 6.3.8.

B.2 Switch in SAR exposure between LTE vs. Sub6 NR during transmission

This test is to demonstrate that Smart Transmit feature accurately accounts for switching in exposures among SAR for LTE radio only, SAR from both LTE radio and sub6 NR, and SAR from sub6 NR only scenarios, and ensures total time-averaged RF exposure compliance with FCC limit.

Test procedure:

1. Measure conducted Tx power corresponding to P_{limit} for LTE and sub6 NR in selected band. Test condition to measure conducted P_{limit} is:

   - Establish device in call with the callbox for LTE in desired band. Measure conducted Tx power corresponding to LTE P_{limit} with Smart Transmit enable and *Reserve_power_margin* set to 0 dB, callbox set to request maximum power.
   - Repeat above step to measure conducted Tx power corresponding to Sub6 NR P_{limit}. If testing LTE + Sub6 NR in non-standalone mode, then establish LTE + Sub6 NR call with callbox and request all down bits for radio1 LTE. In this scenario, with callbox requesting maximum power from Sub6 NR, measured conducted Tx power corresponds to radio2 P_{limit} (as radio1 LTE is at all-down bits).

2. Set *Reserve_power_margin* to actual (intended) value with EUT setup for LTE _Sub6 NR call. First, establish LTE connection in all-up bits with the callbox, and then Sub6 NR connection is added with callbox requesting UE to transmit at maximum power in Sub6 NR. As soon as the Sub6 NR connection is established, request all-down bits on LTE link (otherwise, Sub6 NR will not have sufficient RF exposure margin to sustain the call with LTE in all-up bits). Continue LTE(all-down bits) + Sub6 NR transmission for more than one time-window duration to test predominantly Sub6 NR SAR exposure scenario (as SAR exposure is negligible from all-down bits in LTE). After at least one time-window, request LTE to go all-up bits to test LTE SAR and Sub6 NR SAR exposure scenario. After as least one more time-window, drop (or request all-down bits) Sub6 NR transmission to test predominantly LTE SAR exposure scenario. Continue the test for at least one more time-window. Record the conducted Tx powers for both LTE and Sub6 NR for the entire duration of this test.

3. Once the measurement is done, extract instantaneous Tx power versus time for both LTE and Sub6 NR links. Similar to technology/band switch test in Section 3.3.3, convert the conducted Tx power for both these radios into 1g or 10gSAR value (see Eq. (6a) and (6b)) using corresponding technology/band P_{limit} measured in Step 1, and then perform 100s running average to determine time-averaged 1g or 10gSAR versus time as illustrated in Figure A-1. Note that here it is assumed both radios have Tx frequencies < 3GHz, otherwise, 60s running average should be performed for radios having Tx frequency between 3GHz and 6GHz.

4. Make one plot containing: (a) instantaneous 1g or 10gSAR versus time determined in Step 3, (b) computed time-averaged 1g or 10gSAR versus time determined in Step 3, and (c) corresponding regulatory *1g or 10gSAR*$_{limit}$ of 1.6 W/kg or 4.0 W/kg, and (d) corresponding normalized regulatory *1g or 10gSAR*$_{limit}$ 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 10gSAR*$_{limit}$ limit.

Appendixes

Refer to separated files for the following appendixes.

4790558569-S1 FCC Report RF exposure Part2_App A_Test setup photos

4790558569-S1 FCC Report RF exposure Part2_App B_System Check plots

End OF REPORT