RF EXPOSURE REPORT

(Part 2: Test Under Dynamic Transmission Condition)

Name of Sample: Mobile Cellular Phone

Model of Sample: XT2429-1

Applicant: Motorola Mobility LLC

Issued Date: Mar. 21, 2024

ACCREDITED
Cert #3680.01

ADR TEST AND CERTIFICATION CENTER

Motorola Mobility LLC, a Lenovo Company

Add: No. 19, Gao Xin 4th Road Wuhan, People's Republic of China 430205

Phone: (86)18702717862

E-mail: lucz1@motorola.com

Name of Client	**Motorola Mobility LLC**		
Address of Client	**222 W, Merchandise Mart Plaza, Chicago IL 60654 USA**		
Trademark	**Motorola**	**FCC ID**	**IHDT56AR4**
Applicant No.	**RF173570**	**Sample No.**	**NGCL2Q0106** **NGCL2N0544**
Delivering Date	**Mar. 01, 2024**	**Test Date(s)**	**Mar. 04, 2024~ Mar. 12, 2024**
Sample Illustration	**None**		
Standard	**FCC 47 CFR Part 2(2.1093)**		
Remarks	**None**		

Editor: Gavin Gao **Auditor: Xingwei Zhang** **Approver: Huangsheng Lin**

Matters Needing Attention

a) The electronic report shall be valid after encryption.
b) The paper report shall be valid after being stamped with the official seal of the company.
c) The report is invalid without the signature of the Editor, Auditor and Approver.
d) The test report is invalid if there is any evidence of erasure and/or falsification.
e) If there is any dissidence for the test report, please file objection to the lab within 15 days from the date of receiving the test report.
f) The test report is only responsible for the tested model/sample.
g) Context of the test report cannot be used partially or in full for publicity and/or promotional purposes without previous written approval of the lab.

Revision History

Report No.	Version	Description	Issued Date
24ADRTCC6003B	Rev.01	Initial issue of report	Mar. 21, 2024

Catalogue

1. Introduction

The equipment under test (EUT) is a Mobile Cellular Phone (FCC ID: IHDT56AR4), it contains the Qualcomm modem supporting 2G/3G/4G technologies and 5G NR bands. Both modems are enabled with Qualcomm Smart Transmit feature to control and manage transmitting power in real time and to always ensure the time-averaged RF exposure is following the FCC requirement.

This purpose of the Part2 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.

The P_{limit} used in this report is determined in Part0 and Part1 report.
Refer to Part 1 SAR report, for product description and terminology used in this report.

Test Lab Information:

Testing LAB	ADR TEST AND CERTIFICATION CENTER
Test Site Location	No. 19, Gao Xin 4th Road Wuhan, People’s Republic of China (430205)
Certificate Number	3680.01
TEL	027-81806505
FAX	027-81806512
E-mail	lucz1@motorola.com

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-varying Tx power transmission: To prove that the Smart Transmit feature accounts for Tx power variations in time accurately.
(2) During a call disconnect and re-establish scenario: To prove that the Smart Transmit feature accounts for history of past Tx power transmissions accurately.
(3) During 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 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 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 1 report, the RF exposure is proportional to the Tx power for a SAR-characterized wireless device. Thus, feature validation in Part 2 can be effectively performed through conducted and radiated 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 6.

To add confidence in the feature validation, the time-averaged SAR measurements are also performed but only performed for transmission scenario1 to avoid the complexity in SAR measurement (such as, for scenario3 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:

(1) Demonstrate the total RF exposure averaged over FCC defined time windows does not exceed FCC's SAR limits, through time-averaged power measurements:
1) Measure conducted Tx power (for f < 6GHz) versus time, and radiated Tx power (EIRP for f > 10GHz) versus time.
2) Convert it into RF exposure and divide by respective FCC limits to get normalized exposure versus time.
3) Perform running time-averaging over FCC defined time windows.
4) Demonstrate that the total normalized time-averaged RF exposure is always less than 1 for all transmission scenarios.
   Mathematical expression (For sub-6 transmission only):

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

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

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 or 10gSAR* values at P_{limit} corresponding to sub-6 transmission.

(2) Demonstrate the total RF exposure averaged over FCC defined time windows does not exceed FCC's SAR limits, through time-averaged SAR measurements. Note as mentioned earlier, this measurement is performed for transmission scenario 1 only:

1) 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.
2) Convert it into RF exposure and divide by respective FCC limits to obtain normalized exposure versus time.
3) Perform time averaging over FCC defined time window.
4) Demonstrate that the total normalized time-averaged RF exposure is always less than 1 for transmission scenario 1.

Mathematical expression (For sub-6 transmission only):

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

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

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.

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

3. SAR Time Averaging Validation Test Procedures

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

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 < 6 GHz) validation:

(1) Test sequence 1: request EUT's Tx power to be at maximum power, measured Pmax, for 80s, then requesting for half of the maximum power, i.e., measured Pmax/2, for the rest of the time.

(2) Test sequence 2: request EUT's Tx power to vary with time. This sequence is generated relative to measured Pmax, measured Plimit and calculated Preserve (=
measured Plimit in dBm - Reserve_power_margin in dB) of EUT based on measured Plimit.

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

Note: For test sequence generation, "measured Plimit" and "measured Pmax" are used instead of the "Plimit" specified in EFS entry and "Pmax" specified for the device, because Smart Transmit feature operates against the actual power level of the "Plimit" that was calibrated for EUT. The "measured Plimit" 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 Plimit.

3.2. Test configuration selection criteria for validating 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 provided.

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

The criteria for the selection are based on the Plimit values determined in Part 1 report. Select the band in each supported technology that corresponds to the Plimit value that is less than Pmax for validating Smart Transmit.

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

3.2.2. Test configuration selection for change in call

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

(1) Select technology/band with least Plimit among all supported technologies/bands, and select the radio configuration in this technology/band that corresponds to the highest measured 1gSAR at Plimit listed in Part 1 report.

(2) In case of multiple bands having same least Plimit, then select the band having the highest measured 1gSAR at Plimit 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., EUT forced to have Tx power at Preserve) for longest duration in one FCC defined time window. The call change (call drop/reestablish) is performed during the Tx power enforcement duration (i.e., during the time when EUT is forced to have Tx power at Preserve). 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:

For a given antenna, to have EUT switch from a technology/band with lowest Plimit within the technology group (in case of multiple bands having the same Plimit, then select the band with highest measured 1gSAR at Plimit) to a technology/band with highest Plimit within the technology group, in case of multiple bands having the same Plimit, then select the band with lowest measured 1gSAR at Plimit 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 Preserve).

3.2.4. 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 Plimit < Pmax within any technology and DSI group, and for the same technology/band having a different Plimit 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 Preserve).

3.2.5. 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 SARradio1 only, SARradio1 + SARradio2, and SARradio2 only scenarios.

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

(1) Select any two < 6GHz technologies/bands that the EUT supports simultaneous transmission (for example, LTE+ Sub6 NR).

(2) Among all supported simultaneous transmission configurations, the selection order is:

1) select one configuration where both Plimit of radio1 and radio2 is less than their corresponding Pmax, preferably, with different Plimits. If this configuration is not available, then,

2) select one configuration that has Plimit less than its Pmax for at least one radio. If this cannot be found, then,

3) select one configuration that has Plimit of radio1 and radio2 greater than Pmax but with least (Plimit – Pmax) delta.

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

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:

(1) Select any technology/band that has operation frequency classified in one time window defined by FCC (such as 100-seconds time window), and its corresponding Plimit is less than Pmax if possible.

(2) 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 Plimit is less than Pmax if possible.

(3) It is preferred both Plimit values of two selected technology/band less than corresponding Pmax, but if not possible, at least one of technologies/bands has its Plimit 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 Exposure Category Switch

When exposure DSI changes from head to body-worn or vice versa, it is obvious that the exposure from an active radio does not expose the same tissues. Therefore, with Qualcomm Smart Transmit EFS version 18 (or higher), the exposure continuity is handled in two categories: Head exposure and non-head exposure.

Head exposure category includes all 4 positions of left cheek, left tilted, right cheek and right titled
Non-head exposure category includes all other exposure scenarios (except head), i.e., body-worn, hotspot, extremity, etc.

The purpose of this test is to demonstrate that Smart Transmit ensures time-averaged RF exposure compliance when the EUT exposure category changes. For this purpose, there are two tests performed: (a) start with head exposure and switch to non-head exposure and switch back to head exposure, and (b) start with non-head exposure and switch to head exposure and switch back to non-head exposure.

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 provided.

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 always exceed the FCC limit.

Test procedure is:

(1) Measure Pmax, measure Plimit and calculate Preserve
(= measured Plimit 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 sequence 2 are created based on measured Pmax and measured Plimit of EUT. Test condition to measure Pmax and Plimit is:

1) Measure Pmax with Smart Transmit disabled and callbox set to request maximum power.
2) Measure Plimit 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 (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 using measured Plimit from above Step1. Perform running time average to determine time-averaged power and 1gSAR or 10gSAR versus time as illustrated in Figure 3-1 where using 100-seconds time window as an example.

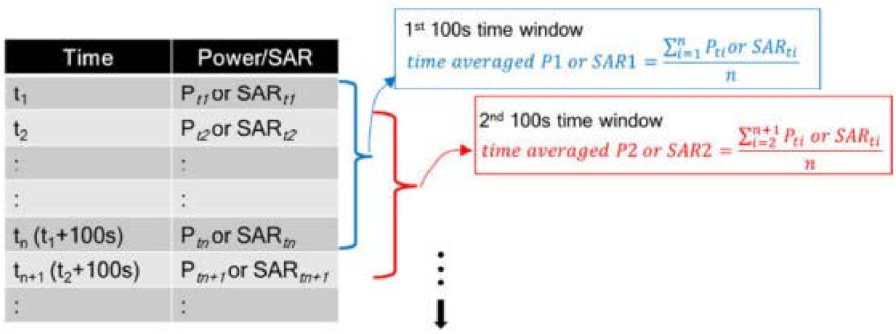


Figure 3-1 100s running average illustration

(3) Make one plot containing:

a. Instantaneous Tx power versus time measured in Step 2,

b. Requested Tx power used in Step 2 (test sequence 1),

c. Computed time-averaged power versus time determined in Step 2,

d. Time-averaged power limit (corresponding to FCC SAR limit of 1.6 W/kg for 1g-SAR or 4.0W/kg for 10g-SAR) given by

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

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

(4) Make another plot containing:

a. Computed time-averaged 1gSAR or 10gSAR versus time determined in Step 2

b. FCC 1gSARlimit of 1.6W/kg or FCC 10gSARlimit of 4.0W/kg.

(5) Repeat Steps 2 ~ 4 for pre-defined test sequence 2 and replace the requested Tx power (test sequence 1) in Step 2 with test sequence 2.

(6) Repeat Steps 2 ~ 5 for all the selected technologies and bands.

The validation criteria are, always, the time-averaged power versus time shown in Step 3 plot shall not exceed the time-averaged power limit, in turn, the time-averaged 1gSAR or 10gSAR versus time shown in Step 4 plot shall not exceed the FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

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

Test procedure:

(1) Measure Plimit for the technology/band selected in Section 3.2.2. Measure Plimit 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 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, reestablish 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. Once the measurement is done, extract instantaneous Tx power versus time, convert the measured conducted Tx power into 1gSAR or 10gSAR value, and then perform the running time average to determine time-averaged power and 1gSAR or 10gSAR versus time.

(5) Make one plot containing: (a) instantaneous Tx power versus time, (b) requested power, (c) computed time-averaged power, (d) time-averaged power limit calculated.

(6) Make another plot containing: (a) computed time-averaged 1gSAR or 10gSAR versus time, and (b) FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

The validation criteria are, always, the time-averaged power versus time shall not exceed the time-averaged power limit, in turn, the time-averaged 1gSAR or 10gSAR versus time shall not exceed the FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

3.3.3. Change in technology and band

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

Similar to the change in call test in Section 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 Preserve level (i.e., during Tx power enforcement) to make sure that the EUT's Tx power from previous Preserve level to the new Preserve level (corresponding to new technology/band). Since the Plimit 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_10gSAR_P_{limit_1}* correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at P_{limit}, and measured *1gSAR* or *10gSAR* value at P_{limit} of technology1/band1; *conducted_Tx_power_2(t)*, *conducted_Tx_power_P_{limit_2}(t)*, and *1g_or_10gSAR_P_{limit_2}* correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at P_{limit}, and measured *1gSAR* or *10gSAR* value at P_{limit} of technology2/band2. Transition from technology1/band1 to the technology2/band2 happens at time-instant 't_1'.

Test procedure:

(1) Measure Plimit for both the technologies and bands selected in Section 3.2.3. Measure Plimit 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 seconds, 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 at 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 Plimit values from Step 1 of this section. Perform the running time average to determine time-averaged power and 1gSAR or 10gSAR versus time.

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

(6) Make one plot containing: (a) instantaneous Tx power versus time, (b) requested power, (c) computed time-averaged power, (d) time-averaged power limit calculated.

(7) Make another plot containing: (a) computed time-averaged 1gSAR or 10gSAR versus time, and (b)

FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

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

3.3.4. Change in antenna

This test is to demonstrate the correct power control by Smart Transmit during antenna switches from one antenna to another. The test procedure is identical to Section 3.3.3, by replacing technology/band switch operation with antenna switch. The validation criteria are, at all times, the time-averaged 1gSAR or 10gSAR versus time shall not exceed FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

Note: If the EUT does not support antenna switch within the same technology/band, but has multiple antennas to support different frequency bands, then the antenna switch test is included as part of change in technology and band (Section 3.3.3) test.

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, by replacing technology/band switch operation with DSI switch. The validation criteria are, at all times, the time-averaged 1gSAR or 10gSAR versus time shall not exceed FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

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 windows of 100s for Tx frequency < 3GHz, and 60s for Tx frequency between 3GHz and 6GHz.

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

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

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

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

where, *conducted_Tx_power_1(t)*, *conducted_Tx_power_P_{limit_1}(t)*, and *1g_ or 10g_SAR_P_{limit_1}* correspond to the instantaneous Tx power, conducted Tx power at P_{limit}, and compliance *1g_ or 10g_SAR* values at P_{limit_1} of band1 with time-averaging window '$T1_{SAR}$'; *conducted_Tx_power_2(t)*, *conducted_Tx_power_P_{limit_2}(t)*, and *1g_ or 10g_SAR_P_{limit_2}* correspond to the instantaneous Tx power, conducted Tx power at P_{limit}, and compliance *1g_ or 10g_SAR* values at P_{limit_2} of band2 with time-averaging window '$T2_{SAR}$'. One of the two bands is less than 3GHz, another is greater than 3GHz. Transition from first band with time-averaging window '$T1_{SAR}$' to the second band with time-averaging window '$T2_{SAR}$' happens at time-instant 't_1'.

Test procedure:

(1) Measure Plimit for both the technologies and bands selected in Section 3.2.6.
Measure Plimit 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:

1) Establish radio link with callbox in the technology/band having 100s time window selected in Section 3.2.6.
2) 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 about ~60s in this second technology/band, and then switch back to the first technology/band. Continue with callbox requesting EUT's Tx power to be at maximum power for at least another 100s. Measure and record Tx power versus time for the entire duration of the test.
3) Once the measurement is done, extract instantaneous Tx power versus time, and convert the conducted Tx power into 1gSAR or 10gSAR value (see Eq. (7a) and (7b)) using corresponding technology/band Step 1 result, and then perform 100s running average to determine time-averaged 1gSAR or 10gSAR versus time. Note that in Eq.(7a) & (7b), instantaneous Tx power is converted into instantaneous 1gSAR or 10gSAR value by applying the worst-case 1gSAR or 10gSAR value tested in Part 1 for the selected technologies/bands at Plimit.
4) Make one plot containing: (a) instantaneous Tx power versus time measured in Step 4.
5) Make another plot containing: (a) instantaneous 1gSAR versus time determined in
Step 5, (b) computed time-averaged 1gSAR versus time determined in Step 5, and (c) corresponding regulatory 1gSARlimit of 1.6W/kg or 10gSARlimit of 4.0W/kg.

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

1) Establish radio link with callbox in the technology/band having 60s time window selected in Section 3.2.6.
2) 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 be at maximum power for about ~100s in this second technology/band, and then switch back to the first technology/band. Continue with callbox requesting EUT's Tx power to be at maximum power for the remaining time for a total test time of 500 seconds. Measure and record Tx power versus time for the entire duration of the test.
3) Repeat above Step 5~7 to generate the plots.

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

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. Here, radio1 represents primary radio and radio2 represents secondary radio.

Test procedure:

(1) Measure conducted Tx power corresponding to Plimit for radio1 and radio2 in selected band. Test condition to measure conducted Plimit is: 1) Establish device in call with the callbox for radio1 technology/band. Measure conducted Tx power corresponding to radio1 Plimit with Smart Transmit enabled and Reserve_power_margin set to 0 dB, callbox set to request maximum power. 2) Repeat above step to measure conducted Tx power corresponding to radio2 Plimit. 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 Plimit (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 these radios into 1gSAR or 10gSAR value (see Eq. (6a) and (6b)) using corresponding technology/band Plimit measured in Step 1, and then perform the running time average to determine time-averaged 1gSAR or 10gSAR versus time.

(4) Make one plot containing: (a) instantaneous Tx power versus time measured in Step 2.

(5) Make another plot containing: (a) instantaneous 1gSAR versus time determined in
Step 3, (b) computed time-averaged 1gSAR versus time determined in Step 3, and (c) corresponding regulatory 1gSARlimit of 1.6W/kg or 10gSARlimit of 4.0W/kg.

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

3.3.8. Change in WIFI/BT back off

The purpose of the test is to demonstrate that Smart Transmit applies back off for the selected sub6 band when Wi-Fi is transmitting. The actual procedure to enable WIFI/BT Transmit should be requested directly from the DUT manufacturer. The validation criteria are, at all times, the time-averaged 1gSAR or 10gSAR versus time shall not exceed FCC limit of 1.6 W/ kg for 1gSAR or 4.0 W/ kg for 10gSAR.

3.3.9. Exposure Category Switch

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

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

1. Measure Plimit for all the technology(s)/band(s)/antenna(s)/DSI(s) selected following the above selection criteria. Measure Plimit with Smart Transmit Peak exposure mode enabled and callbox set to request maximum power.
2. Set EUT to intended Smart Transmit exposure mode.
3. Establish radio link with first DSI and with callbox in the selected technology(s)/band(s)/antenna(s).
4. Request EUT to transmit at 0 dBm for at least 100 seconds, followed by requesting EUT to transmit at maximum Tx power for the active radio(s) for half of the regulatory time window, and then switch to the second DSI for ~10s, and switch back to the first DSI for at least one time window. Throughout this test, when switching between DSls (i.e., switching between exposure categories), continue with callbox requesting EUT to transmit at maximum Tx power for the active radio(s). Measure and record Tx power versus time for the entire duration of the test.
5. Once the measurement is done, extract instantaneous Tx power versus time, and convert the conducted Tx power into 1g_or_10gSAR value (see Eq. (7a) and (7b)) using the corresponding Plimit measured in Step 1 and 1g or 10gSAR value measured in Part 1 report, and then perform 100s running average to determine time-averaged 1g_or_10gSAR versus time as illustrated in Figure 3-1. Note that in Eq.(7a) & (7b), instantaneous Tx power is converted into instantaneous 1g_or_10gSAR value by applying the worst-case 1gSAR value for the selected technologies/bands at Plimit as reported in Part 1 report.
6. Make one plot containing: (a) computed time-averaged normalized 1g_or_10gSAR of the selected technology(s)/band(s)/antenna(s) versus time determined in Step 5 for exposure under first DSI, (b) total time-averaged normalized exposure for exposure under first DSI if simultaneous transmission scenario was tested, and (c) normalized regulatory limit of 1.0.
7. Make another plot containing: (a) computed time-averaged 1g_or_10gSAR of the selected technology(s)/band(s)/antenna(s) versus time determined in Step 5 for exposure under second DSI, (b) total time-averaged normalized exposure for exposure under second DSI if simultaneous transmission scenario was tested, and(c) normalized regulatory limit of 1.0.The validation criteria is, at all times, the time-averaged normalized exposure versus time shall not exceed the normalized limit of 1.0 for both first & second DSls (i.e., both head exposure category and non-head exposure category).

3.4. Test procedure for time-varying SAR measurements

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

To perform the validation through SAR measurement for transmission scenario 1 described in Section 2, the "path loss" between callbox antenna and EUT needs to be calibrated to ensure that the EUT Tx power reacts to the requested power from callbox in a radiated call. It should be noted that when signaling in closed loop mode, protocol-level power control is in play, resulting in EUT not solely following callbox TPC (Tx power control) commands. In other words, EUT response has many dependencies (RSSI quality of signal, path loss variation, fading, etc.,) other than just TPC commands. These dependencies have less impact in conducted setup (as it is a controlled environment and the path loss can be very well calibrated) but have significant impact on radiated testing in an uncontrolled environment, such as SAR test setup. Therefore, the deviation in EUT Tx power from callbox requested power is expected, however the time-averaged SAR should not exceed FCC SAR requirement at all times as Smart Transmit controls Tx power at EUT.

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

(1) "Path Loss" calibration: Place the EUT against the phantom in the worst-case position determined based on Section 3.2.1. For each band selected, prior to SAR measurement, perform path loss calibration between callbox antenna and EUT. Since the SAR test environment is not controlled and well calibrated for OTA test, extreme care needs to be taken to avoid the influence from reflections the test setup is described in Section 6.1.

(2) Time averaging feature validation:

1) For given radio configuration(technology/band) selected in Section 3.2.1, enable Smart Transmit and set Reserve_power_margin to 0 dB, with callbox to request maximum power, perform area scan, conduct pointSAR measurement at peak location of the area scan. This point SAR value, pointSAR Plimit corresponds to point SAR at the measured Plimit.

2) Set Reserve_power_margin to actual(intended) value and reset power on EUT to enable Smart Transmit. Note, if Reserve power margin cannot be set wirelessly, care must be taken to re-position the EUT in the exact same position relative to the SAM phantom as in above Step 2.1) Establish radio link in desired radio configuration, with callbox requesting the TX power at power levels described by test sequence 1 generated in Step 1 of Section 3.3.1, conduct pointSAR measurement versus time at peak location of the area scan determined in Step 2.1) of this section. Once the measurement is done, extract instantaneous point SAR vs time data, pointSAR(t), and convert it into instantaneous 1gSAR or 10g SAR vs. time using Eq. (3a), re-written below:

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

where, pointSAR_Plimit is the value determined in Step 2.1), and pointSAR(t) is the Instantaneous pointSAR measured in Step 2.2), 1g_or_10gSAR_Plimit is the measured 1gSAR or 10gSAR value listed in Part 1 report.

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

4) Make one plot containing: (a) time-averaged 1gSAR or 10gSAR versus time determined in Step 2.3) of this section, (b) FCC limit of 1.6 Wkg for 1gSAR or 4.0 W/ kg for 10g SAR.

5) Repeat 2.2) ~ 2.4) for test sequence 2 generated in Step 1 of Section 3.3.1.

6) Repeat 2.1) ~ 2.5) for all the technologies and bands selected in Section 3.2.1.

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

4. Test Configurations

4.1. WWAN (sub-6) transmission

The Plimit values, corresponding to SAR_design_target, for technologies and bands supported by EUT are derived in Part 1 report. Note all Plimit power levels entered correspond to average power levels after accounting for duty cycle in the case of TDD modulation schemes.

Per Qualcomm's document, embedded file system (EFS) version 20 products are required to be verified for Smart Tx generation for relevant MCC settings. It was confirmed that this DUT contains embedded file system (EFS) version 20 configured for Smart Tx second generation (Gen 2) for Sub6 with MCC settings for the US market and WLAN/BT are the radios outside of Smart Transmit control.

Test case #	Test scenario	Tech	Band	Ant	DSI	Channel	Freq (MHz)	BW	RB size	RB offset	mode	Position	Gap (mm)	Part1, SAR@Plimit 1g or 10g SAR(W/kg)	Plimit EFS setting (dBm)	Target Pmax (dBm)	Measured Plimit (dBm)	Measured Pmax (dBm)
1	Time-Varying	GSM	1900	1	3	661	1880	/	/	/	GRPS(2TX slots)	Back	5	0.677	21.5	21	21.3	21.1
2		WCDMA	2	1	3	9262	1852.4	/	/	/	RMC 12.2Kbps	Back	5	0.992	21	23	21.7	23.8
3		WCDMA	4	1	3	1513	1752.6	/	/	/	RMC 12.2Kbps	Back	5	1.05	21	23	21.11	23.3
4		LTE	25	4	3	26340	1880	20	1	0	QPSK	Back	5	0.644	17.5	23	16.6	23
5		LTE	42	2	7	42590	3500	20	50	0	QPSK	Left Side	5	0.497	12.5	21	13.1	21.1
6		5G NR	2	1	3	376000	1880	20	1	1	DFT-SCS-15KHz	Back	5	1.01	19.5	23	20.1	23.6
7		5G NR	78	2	7	633332	3499.98	100	135	69	DFT-SCS-30KHz	Left Side	5	0.456	12.5	22.5	12.3	22.6
8	Call Drop	LTE	25	4	3	26340	1880	20	1	0	QPSK	Back	5	0.644	17.5	23	16.6	23
9	Tech Switch	LTE	25	1	3	26590	1905	20	50	0	QPSK	Back	5	0.916	20.5	22.5	20.5	22.4
		WCDMA	2	1	3	9262	1852.4	/	/	/	RMC 12.2Kbps	Back	5	0.992	21	23	21.7	23.8
10	100s-60s-100s	LTE	25	4	3	26340	1880	20	1	0	QPSK	Back	5	0.644	17.5	23	16.6	23
		LTE	42	2	3	42590	3500	20	1	0	QPSK	Back	5	0.723	15.5	21	15.2	20.6
11	60s-100s-60s	LTE	42	2	3	42590	3500	20	1	0	QPSK	Back	5	0.723	15.5	21	15.2	20.6
		LTE	25	4	3	26340	1880	20	1	0	QPSK	Back	5	0.644	17.5	23	16.6	23
12	DSI Switch	LTE	25	4	3	26340	1880	20	1	0	QPSK	Back	5	0.644	17.5	23	16.6	23
		LTE	25	4	2	26340	1880	20	1	0	QPSK	Right Cheeek	0	0.641	17	23	16.1	23
13	Exposure Category Switch (Non head→head→Non Head)	LTE	25	4	3	26340	1880	20	1	0	QPSK	Back	5	0.644	17.5	23	16.6	23
		LTE	25	4	2	26340	1880	20	1	0	QPSK	Right Cheeek	0	0.641	17	23	16.1	23
14	Exposure Category Switch (Head→Non head→ Head)	LTE	25	4	2	26340	1880	20	1	0	QPSK	Right Cheeek	0	0.641	17	23	16.1	23
		LTE	25	4	3	26340	1880	20	1	0	QPSK	Back	5	0.644	17.5	23	16.6	23
15	EN-DC SAR vs SAR	LTE	7	4	3	21100	2535	20	1	0	QPSK	Back	5	0.695	19	23	19.35	23.2
		5G NR	78	2	3	633332	3499.98	100	270	0	DFT-SCS-30KHz	Back	5	0.66	17	22.5	16.8	22.2

Note: The EUT has a several DSI states to manage power for different RF exposure conditions, detail DSI states and trigger conditions shown on the following table, the maximum 1gSAR or 10gSAR among all exposure scenarios is used in Smart Transmit feature for time averaging operation.

Trigger Conditions:

Exposure conditions	Measure Distance	Trigger Conditions	DSI	SAR design target
Head	touch&tilt 15deg	Receiver on	DSI2	1g SAR design target
Body Worn	5 mm	Sensor On	DSI3	1g SAR design target
Body Worn / Sensor Off	Sensor Trigger Distance -1mm	Receiver off/Sensor Off	DSI4	1g SAR design target
Hotspot	5 mm	Hotspot On	DSI7	1g SAR design target
Extremity	0mm	Sensor On	DSI6	10g SAR design target
Extremity / Sensor Off	Sensor Trigger Distance -1mm	Receiver off/Sensor Off	DSI4	10g SAR design target

Antenna：

Antenna Group 1	Ant2 & Ant4 & Ant5 & Ant6 & Ant7 & Ant8
Antenna Group 0	Ant0 & Ant1 & Ant11

SAR design Target:

FCC SAR	Measure Distance	SAR Design Target	
		WWAN 2/3/4/5G AG0	WWAN 2/3/4/5G AG1
Body Worn (1g)	5 mm	1.03	0.71
Hotspot (1g)	5 mm	1.03	0.50
Head (1g)	touch&tilt 15deg	1.03	0.71
Extremity (10g)	0 mm	2.55	1.98

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

5.1. Measurement setup

The Rohde & Schwarz CMW500 callbox is used in this test. The test setup schematic are shown in Figures 5-1. For single antenna measurement, one port (RF1 COM) of the callbox is connected to the RF port of the EUT using a directional coupler. For antenna & technology switch measurement, two ports (RF1 COM and RF3 COM) of the callbox used for signaling two different technologies are connected to a combiner, which is in turn connected to a directional coupler. The other end of the directional coupler is connected to a splitter to connect to two RF ports of the EUT corresponding to the two antennas of interest. In both the setups, power meter is used to tap the directional coupler for measuring the conducted output power of the EUT. For time averaging validation test (Section 3.3.1), call drop test (Section 3.3.2), and DSI switch test (Section 3.3.4), only RF1 COM port of the callbox is used to communicate with the EUT. For technology/band switch measurement (Section. 3.3.3), both RF1 COM and RF3 COM port of callbox are used to switch from one technology communicating on RF1 COM port to another technology communicating on RF3 COM port. All the path losses from RF port of EUT to the callbox RF COM port and to the power meter are calibrated and automatically entered as offsets in the callbox and the power meter via test scripts on the PC used to control callbox and power meter.

Sub6 NR test setup: The Anritsu MT8000A/MT8821C callbox is used in this test. The test setup schematic are shown in Figures 5-1. For single antenna measurement, one port (RF1 COM) of the callbox is connected to the RF port of the EUT using a directional coupler.

LTE+5G NR test setup: The Anritsu MT8000A/MT8821C callbox is used in this test. If LTE conducted port and 5G NR conducted port are same on this EUT, therefore, low-high-pass filter are used to separate LTE and 5G NR signals for power meter measurement via directional couplers, as shown in below Figure 5-1. 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.

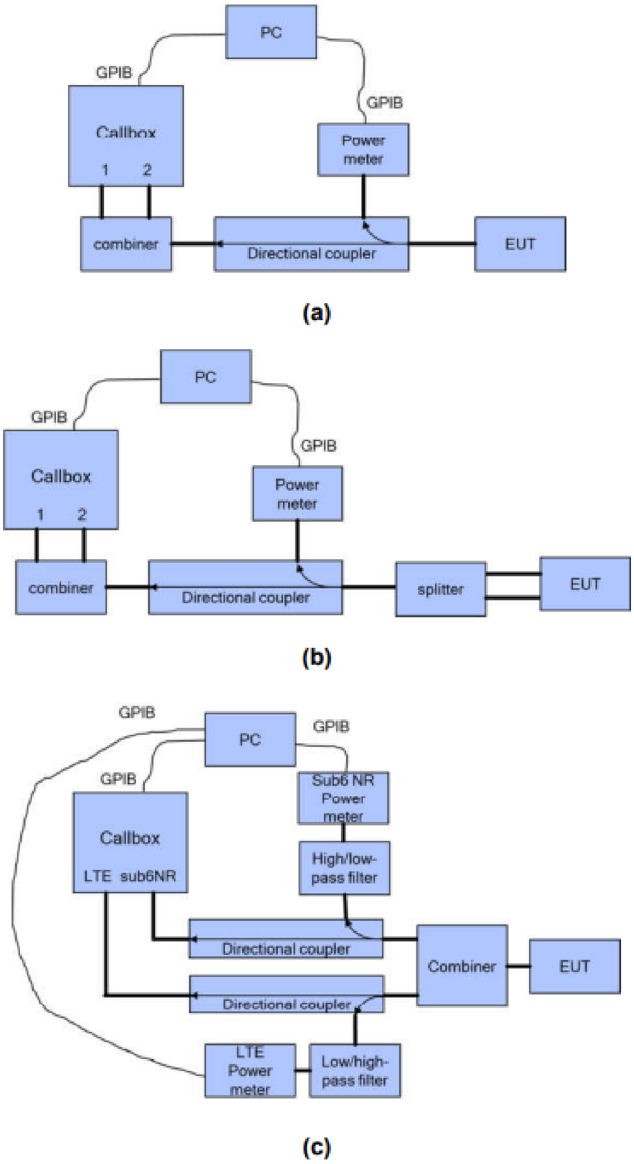


Figure 5-1 Conducted power measurement setup

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

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

- 0dBm for 100 seconds.
- test sequence 1 or test sequence 2 (defined in Section 3.1 and generated in Section 3.2.1), for 360 seconds.
- stay at the last power level of test sequence 1 or test sequence 2 for the remaining time.

Power meter readings are periodically recorded every 100ms. A running average of this measured Tx power over 100 seconds is performed in the post-data processing to determine the 100s-time averaged power. For call drop, technology/band/antenna switch, and DSI switch tests, after the call is established, the callbox is set to request the 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 Preserve level. See Section 3.3 for detailed test procedure of call drop test, technology/band/antenna switch test and DSI switch test.

5.2. Plimit and Pmax measurement results

The measured Plimit for all the selected radio configurations given in Table 4-2 are listed in below Table 5-1. 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.

5.3. Time-varying Tx power measurement results

The measurement setup is shown in Figures 5-1(a) and 5-1(c). The purpose of the timevarying 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:

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

(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_Plimit and 1g_or_10gSAR_Plimit correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at Plimit, and measured 1gSAR and 10gSAR values at Plimit reported in Part 1 test (listed in Table 4-2 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.

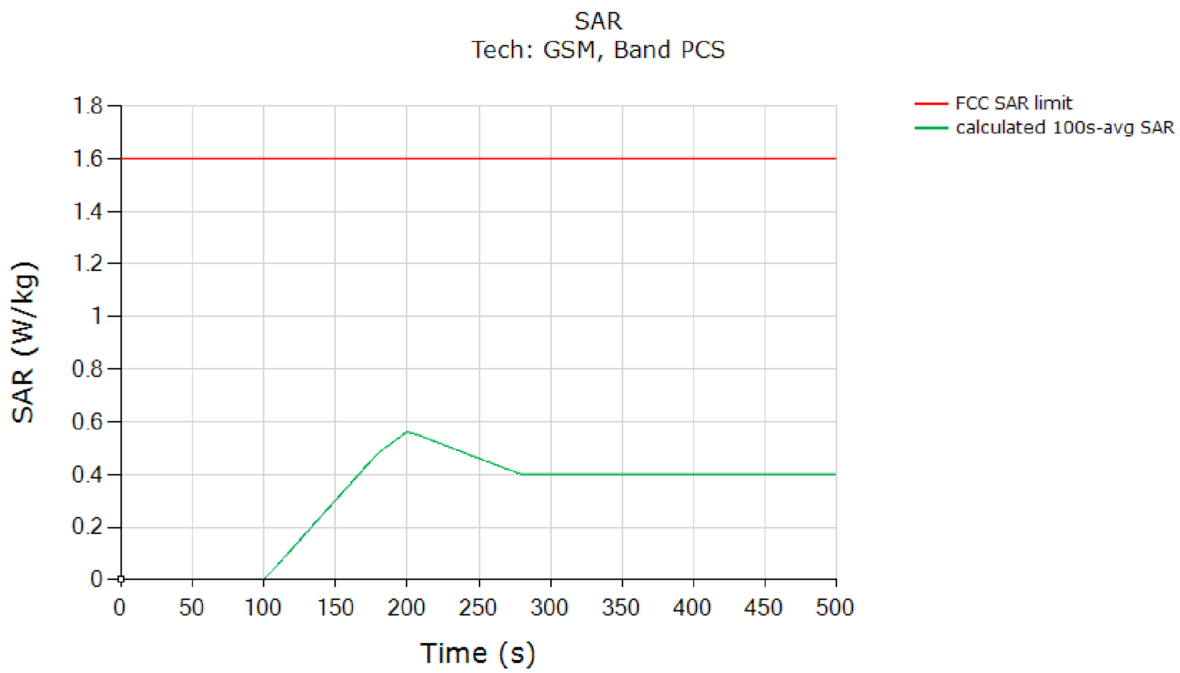
Similarly, in all the 1g or 10gSAR plots (when converted using Eq. (1a)), the green curve represents the 100s/60s-time averaged 1gSAR or 10gSAR value calculated based on instantaneous 1gSAR or 10gSAR; and the red line limit represents the FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

The power limiting enforcement is effective in all the tests, and the time-averaged 1gSAR does not exceed the SAR design target + device uncertainty for all the tested technologies/bands. Therefore, Qualcomm Smart Transmit time averaging feature is validated.

5.3.1. GSM 1900

Test result for test sequence 1:

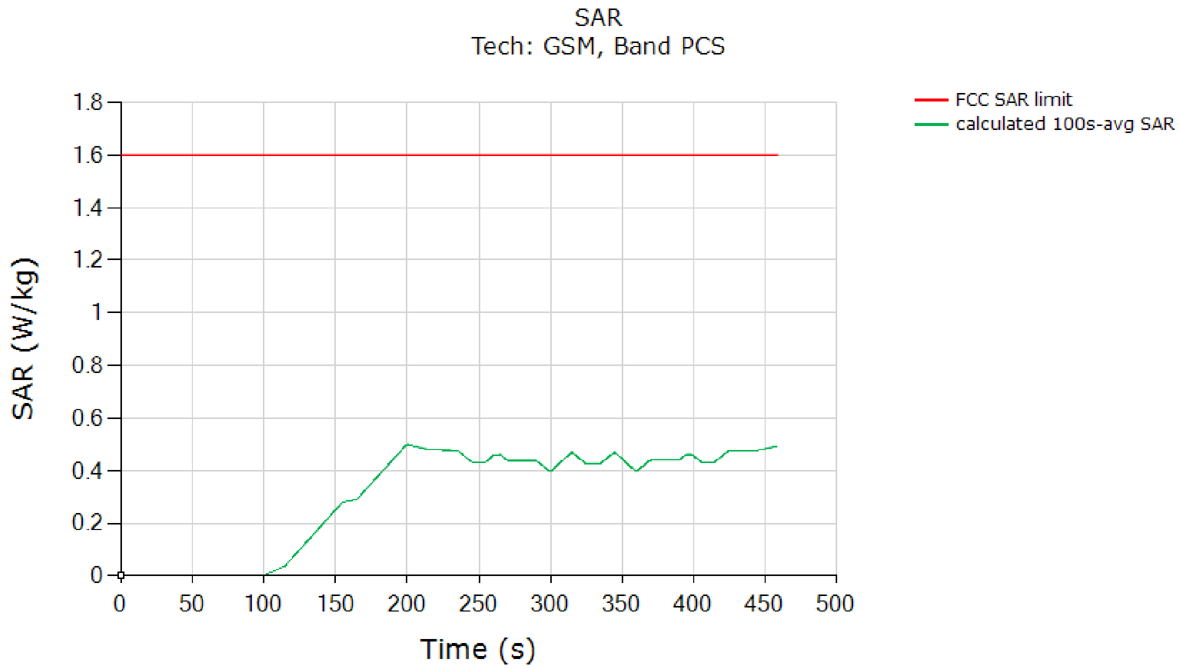
Above time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.56
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

Test result for test sequence 2:

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

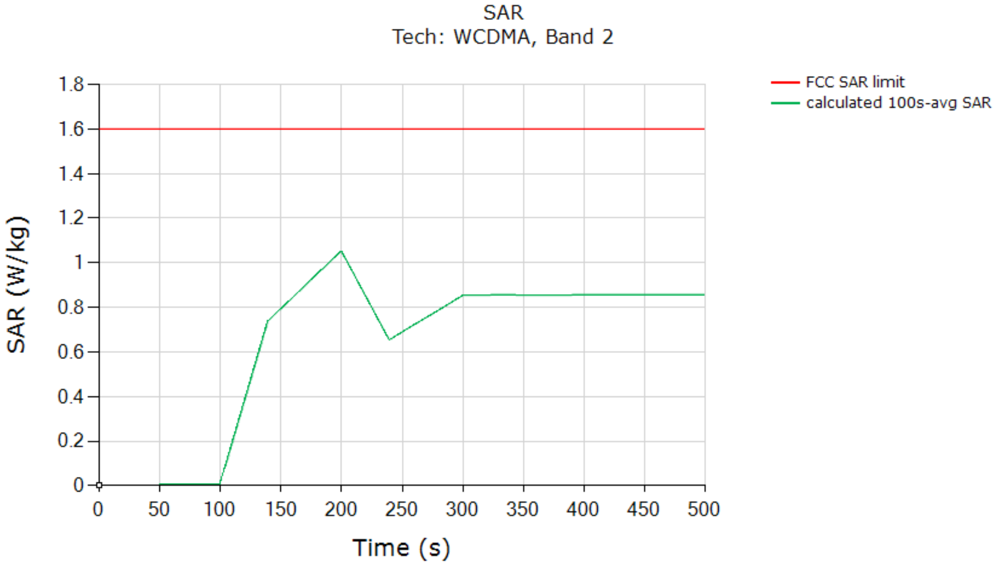


	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.499
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

5.3.2. WCDMA Band II

Test result for test sequence 1:

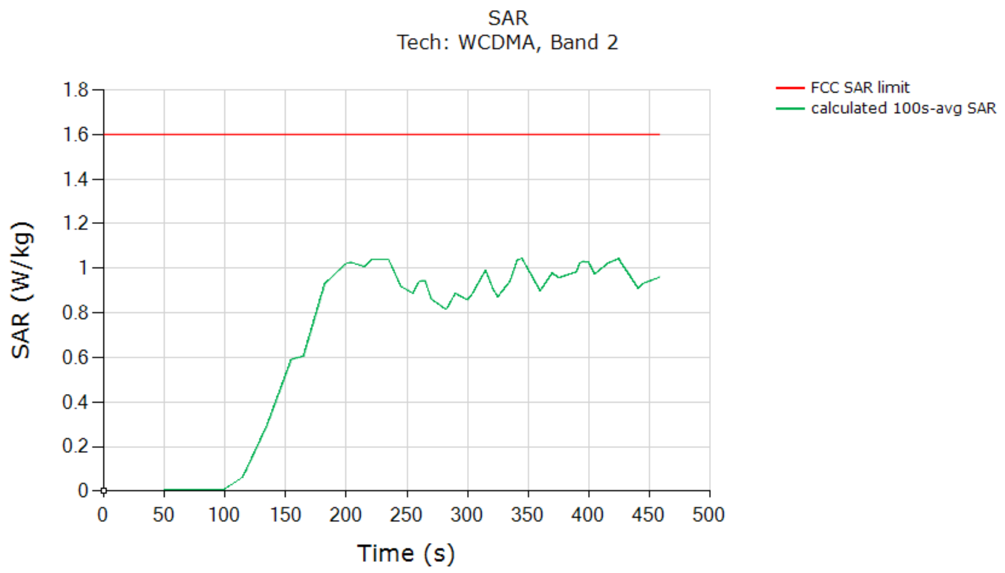
Above time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	1.052
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

Test result for test sequence 2:

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

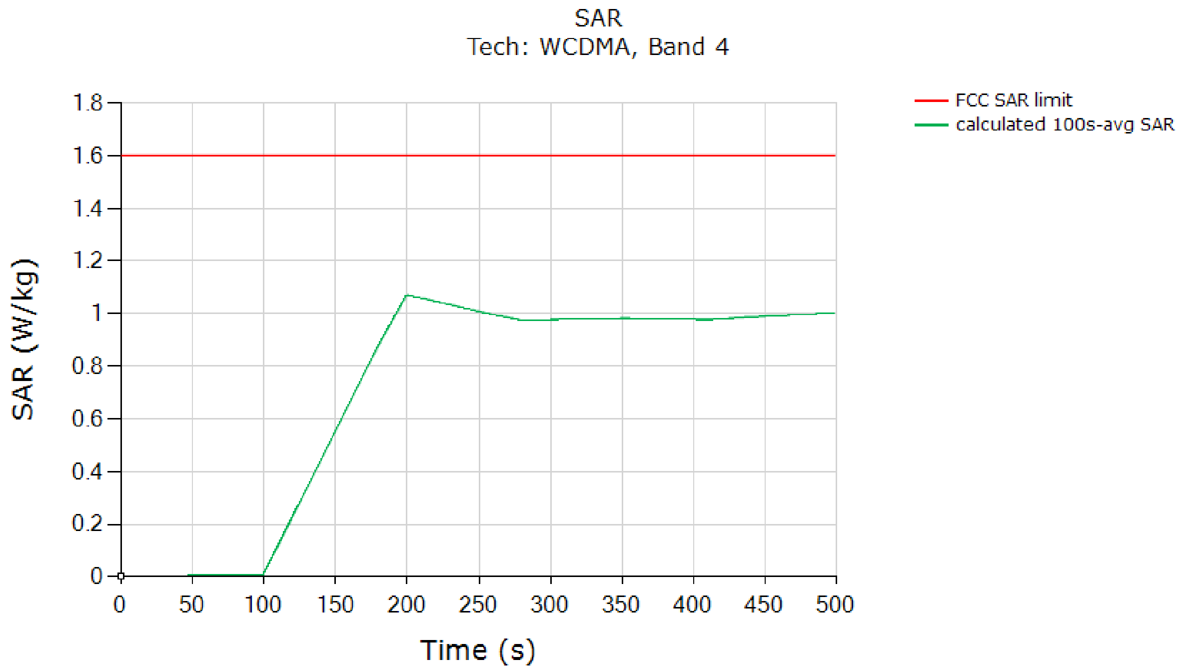


	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	1.044
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

5.3.3. WCDMA Band IV

Test result for test sequence 1:

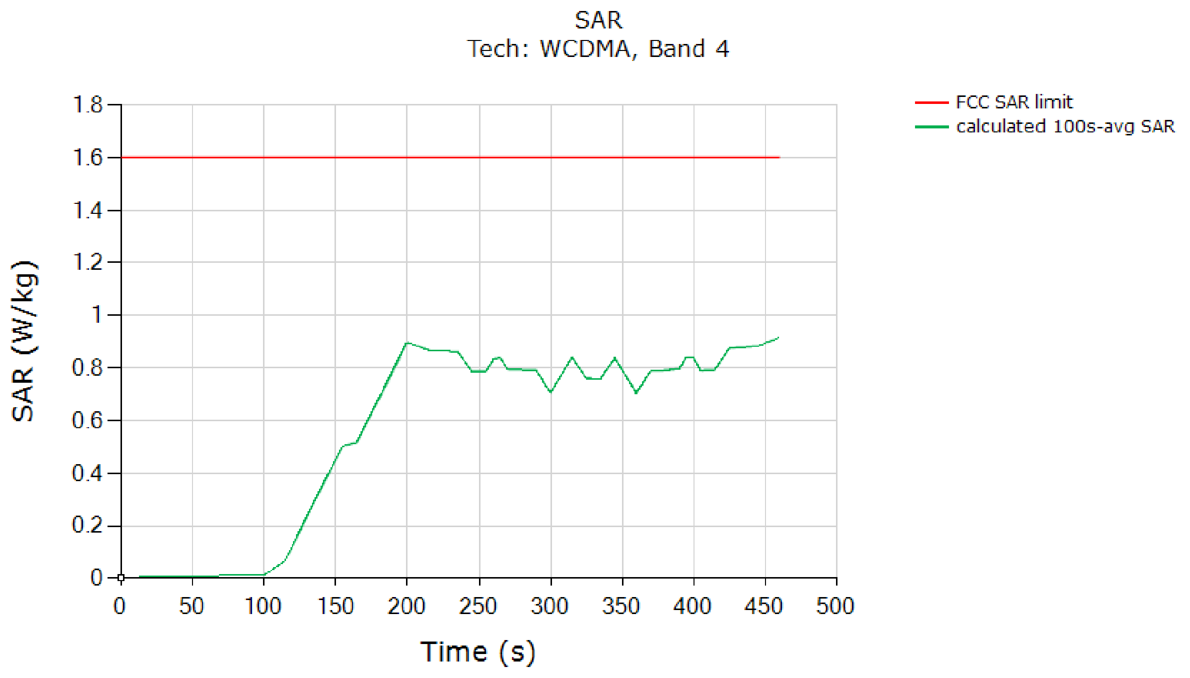
Above time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	1.069
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

Test result for test sequence 2:

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

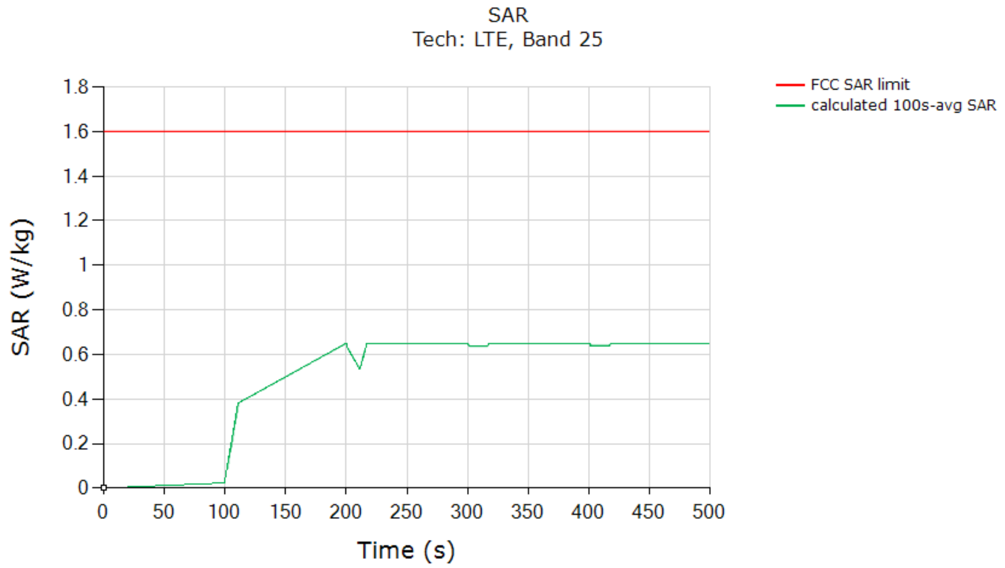


	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.913
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

5.3.4. LTE Band 25

Test result for test sequence 1:

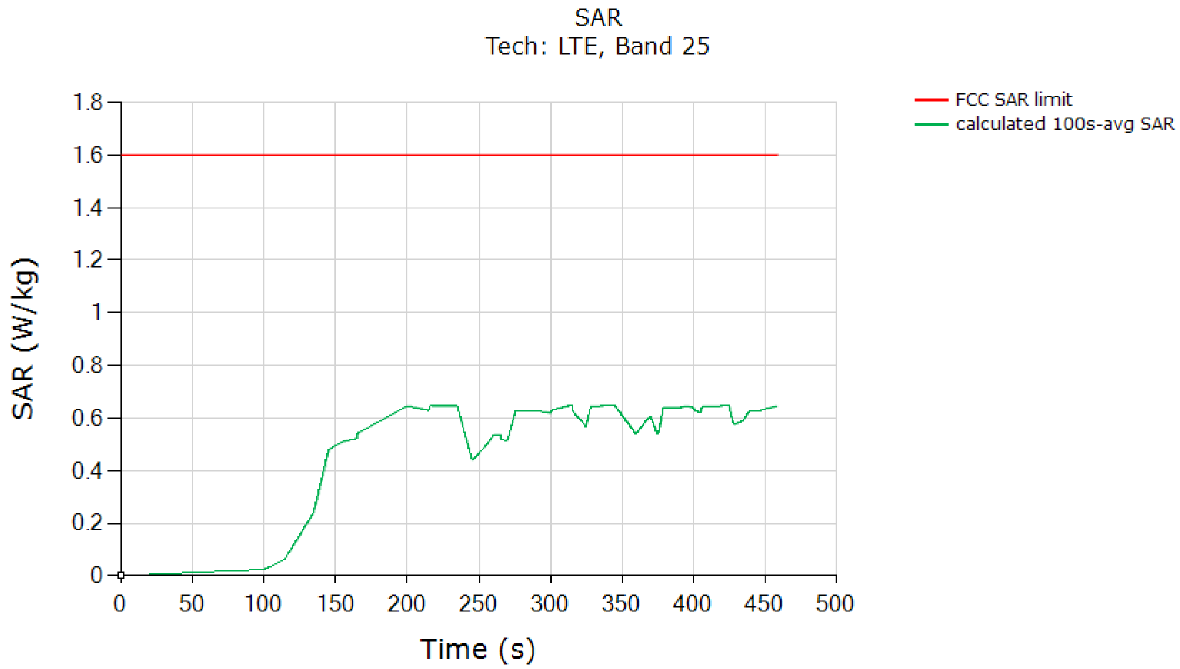
Above time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.65
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

Test result for test sequence 2:

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

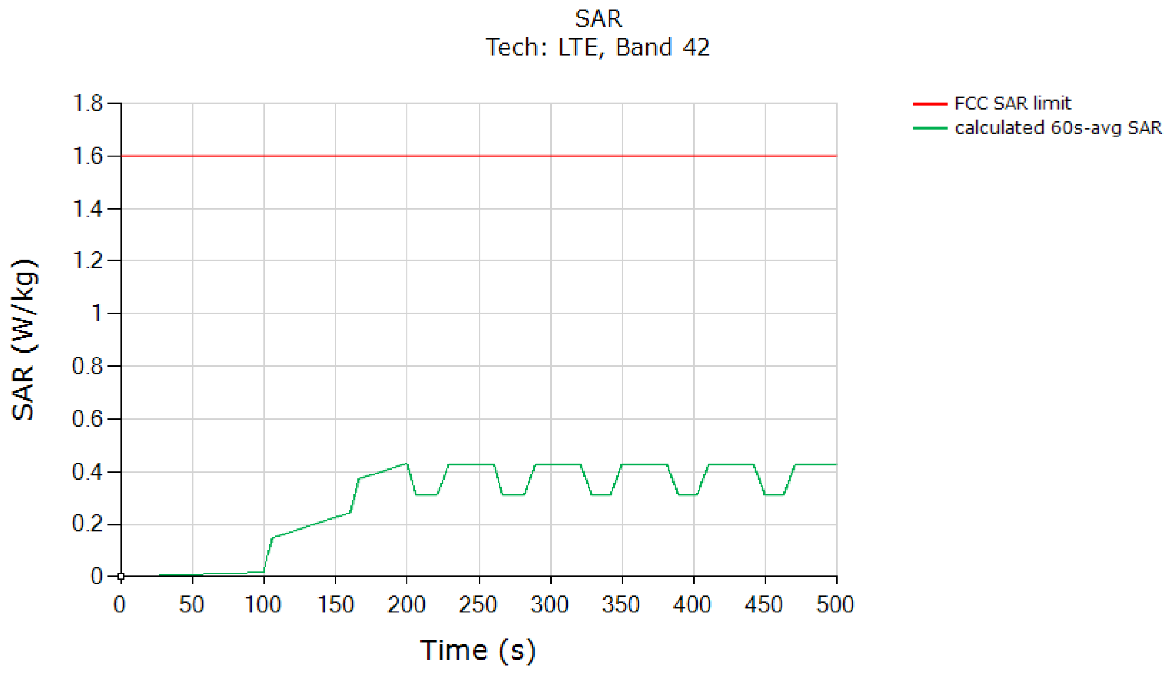


	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.648
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

5.3.5. LTE Band 42

Test result for test sequence 1:

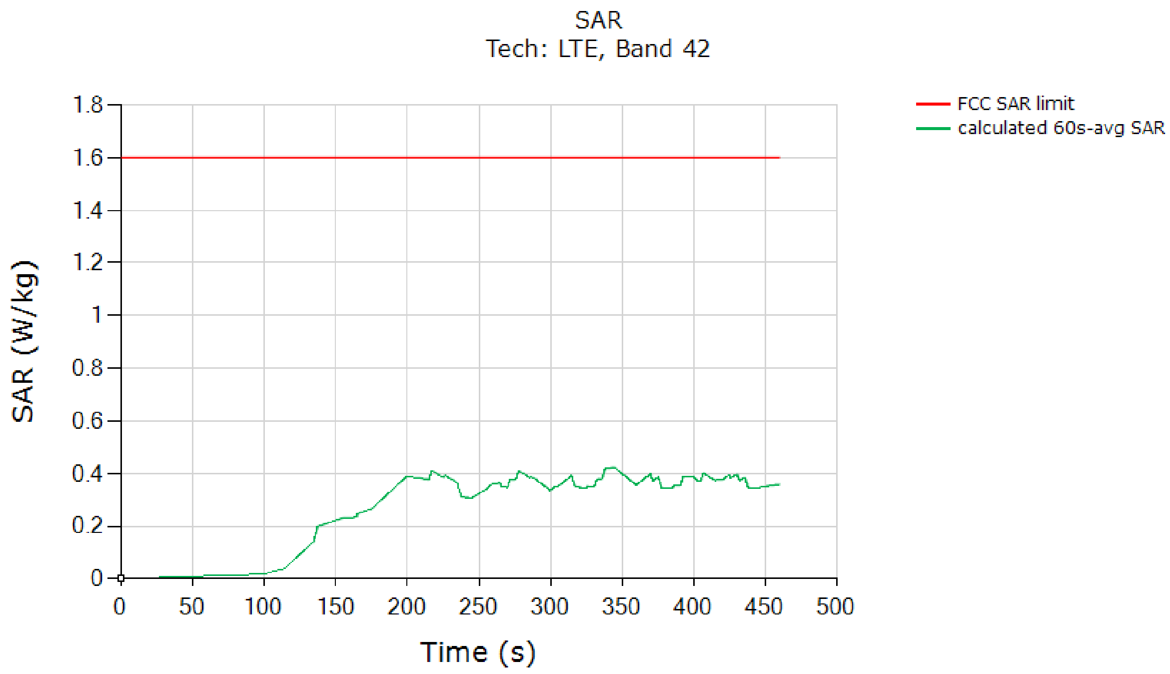
Above time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:



	(W/kg)
FCC 1gSAR limit	1.6
Max 60s-time averaged 1gSAR (green curve)	0.43
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

Test result for test sequence 2:

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

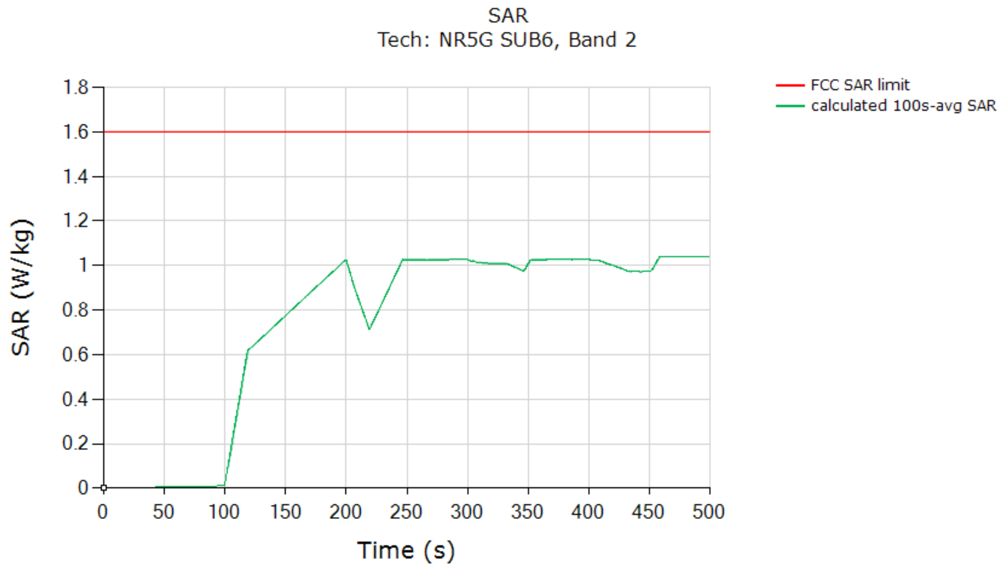


	(W/kg)
FCC 1gSAR limit	1.6
Max 60s-time averaged 1gSAR (green curve)	0.422
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

5.3.6. 5G NR n2

Test result for test sequence 1:

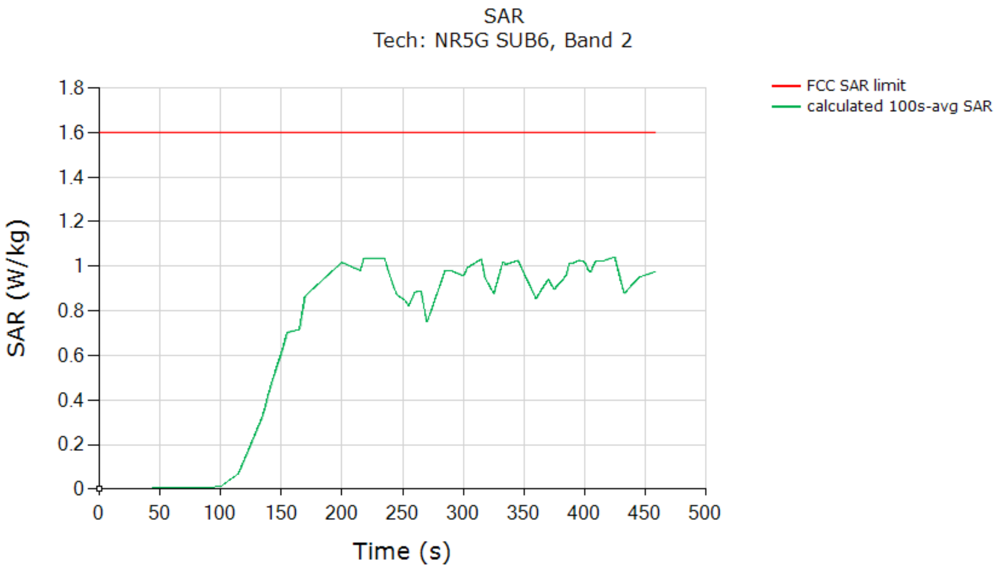
Above time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	1.039
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

Test result for test sequence 2:

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

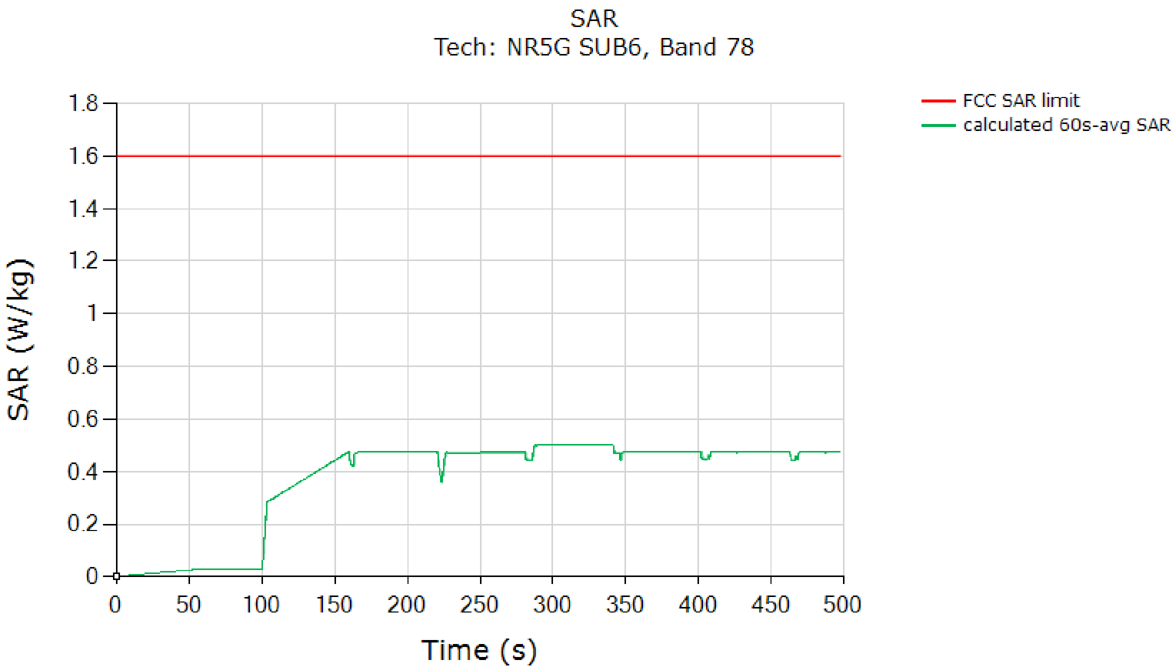


	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	1.041
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

5.3.7. 5G NR n78

Test result for test sequence 1:

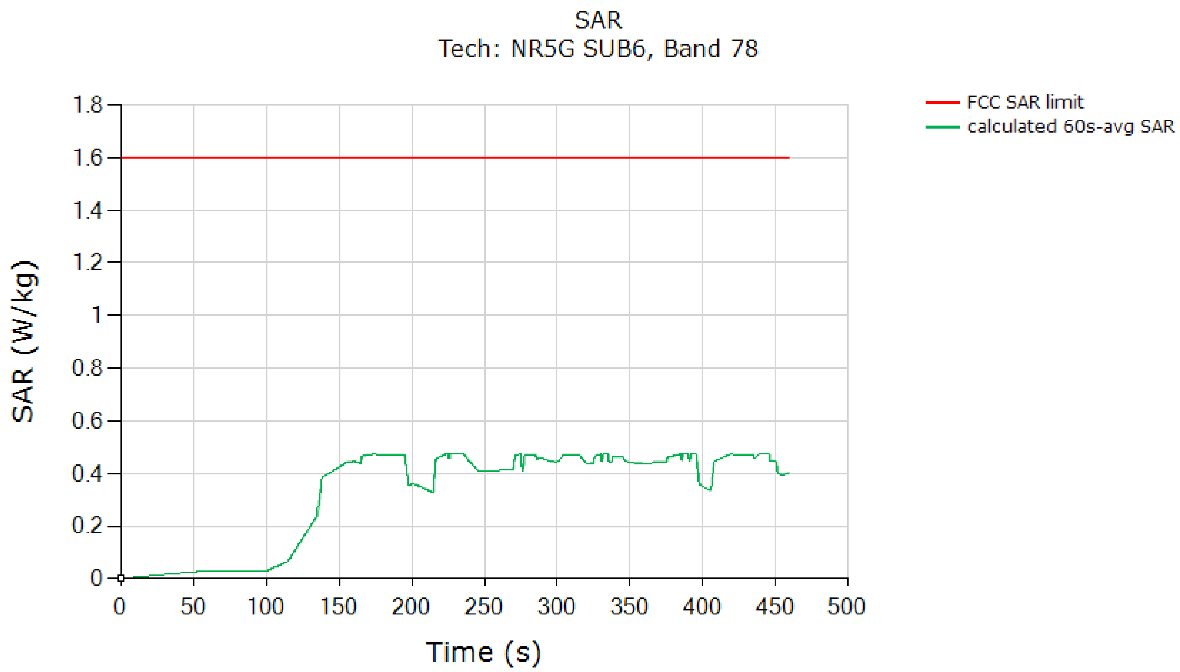
Above time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:



	(W/kg)
FCC 1gSAR limit	1.6
Max 60s-time averaged 1gSAR (green curve)	0.499
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

Test result for test sequence 2:

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



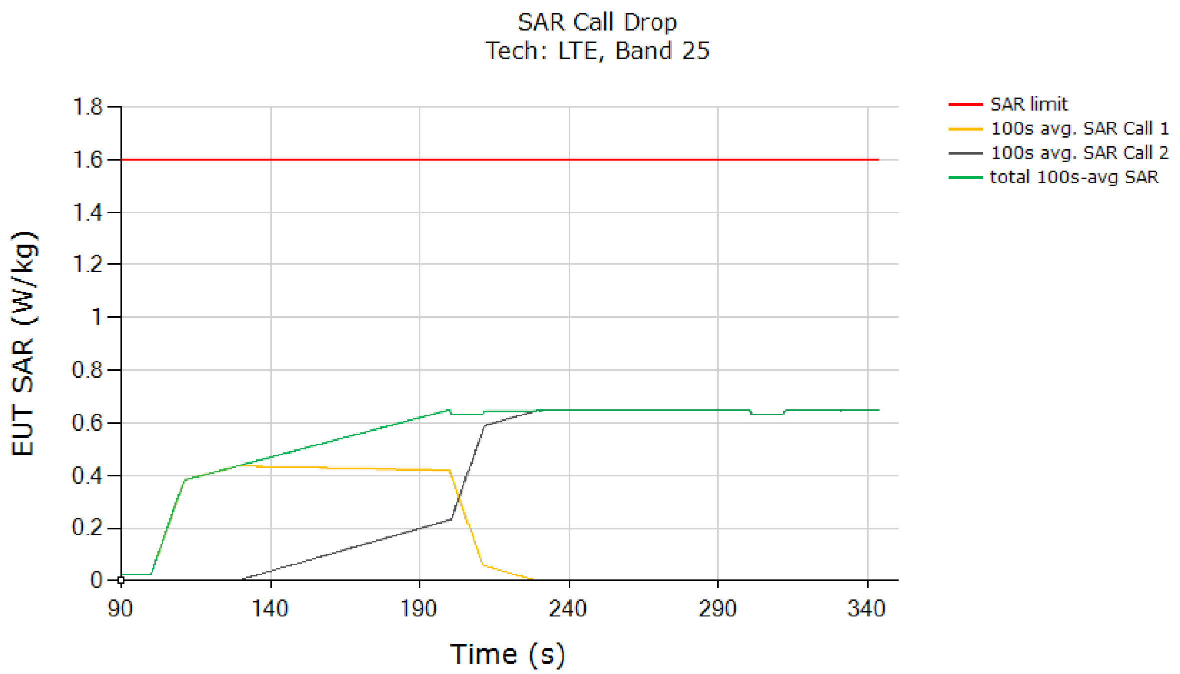
	(W/kg)
FCC 1gSAR limit	1.6
Max 60s-time averaged 1gSAR (green curve)	0.478
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

5.4. Change in call test results

This test was measured with LTE Band 25, DSI=3, and with callbox requesting maximum power. The call drop was manually performed when the EUT is transmitting at Preserve level as shown in the plot below (dotted black region). The measurement setup is shown in Figure 5-1. The detailed test procedure is described in Section 3.3.2.

Call drop test result:

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



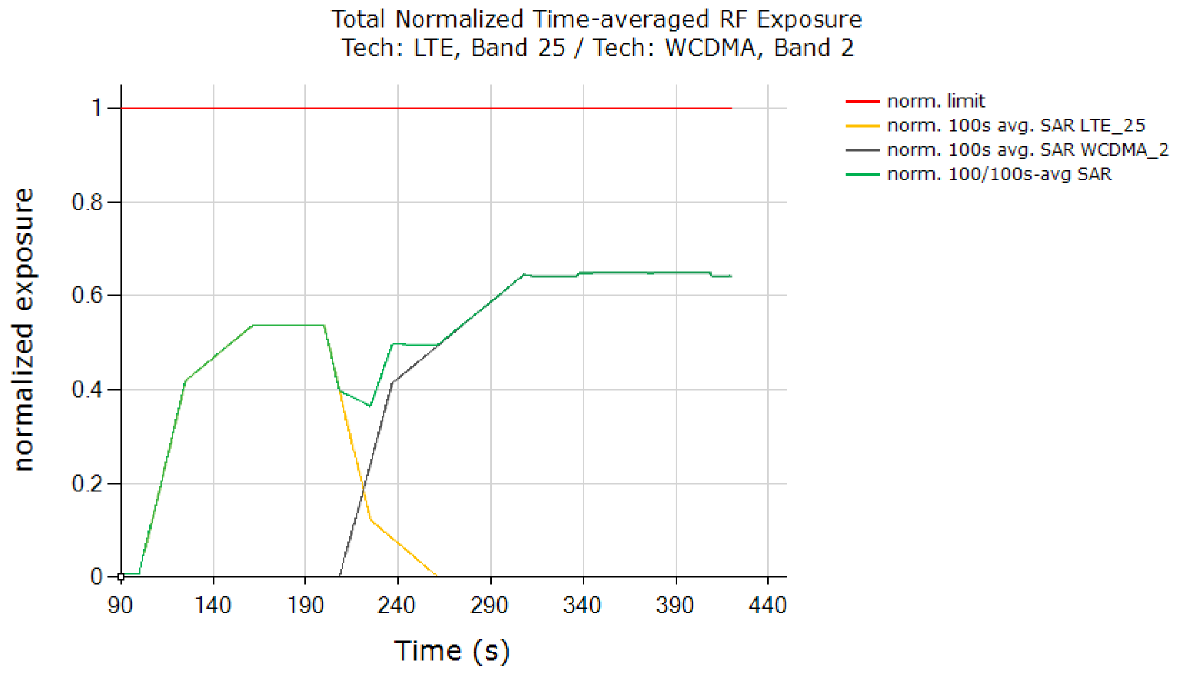
	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.648
Validated	

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

5.5. Change in technology/band test results

This test was conducted with callbox requesting maximum power, and with antenna & technology switch from LTE Band 25, DSI = 3 to WCDMA Band 2, DSI = 3. Following procedure detailed in Section 3.3.3, and using the measurement setup shown in Figure 5-1(a) and (c), the technology/band switch was performed when the EUT is transmitting at Preserve level as shown in the plot below.

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 normalized time-averaged RF exposure does not exceed the FCC limit of 1.0:



	Exposure Ratio
FCC normalized Exposure Ratio limit	1.0
Max 100s-time averaged 1gSAR (green curve)	0.65
Validated	

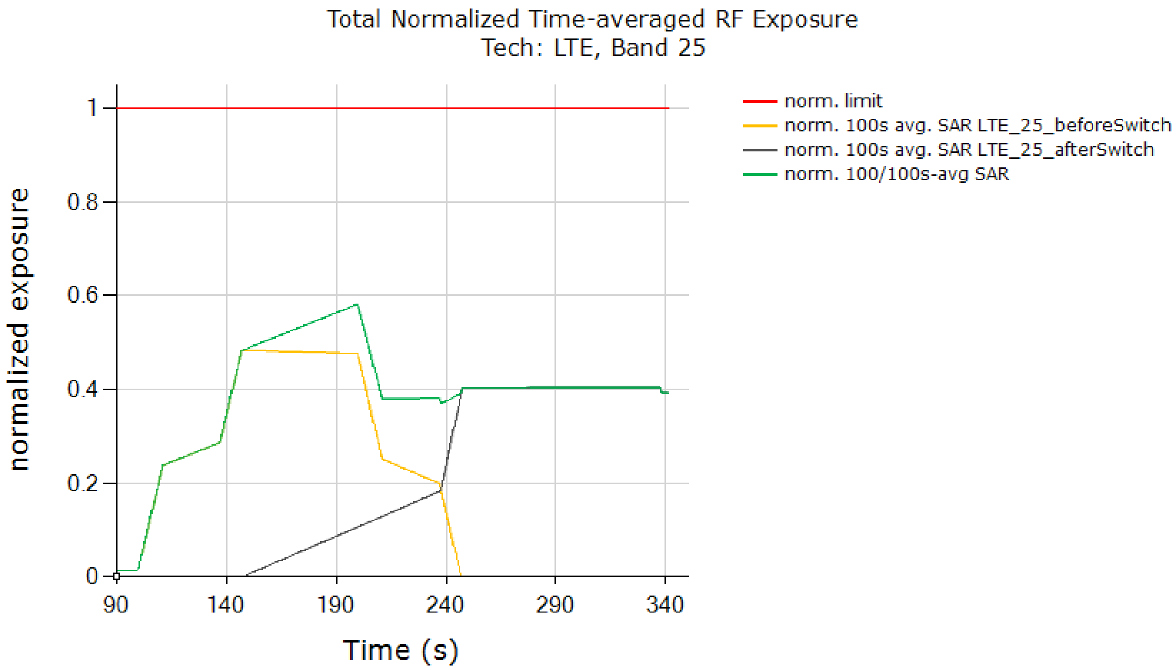
The test result validated the continuity of power limiting in Change in technology/band test results.

5.6. Change in DSI test results

This test was conducted with callbox requesting maximum power, and with DSI switch from LTE Band 25 DSI=3 to DSI = 2. Following procedure detailed in Section 3.3.5 using the measurement setup shown in Figure 5-1(a) and (c), the DSI switch was performed when the EUT is transmitting at Preserve level as shown in the plot below.

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 normalized time-averaged RF exposure does not exceed the FCC limit of 1.0:



	Exposure Ratio
FCC normalized Exposure Ratio limit	1.0
Max 100s-time averaged normalized Exposure Ratio (green curve)	0.582
Validated	

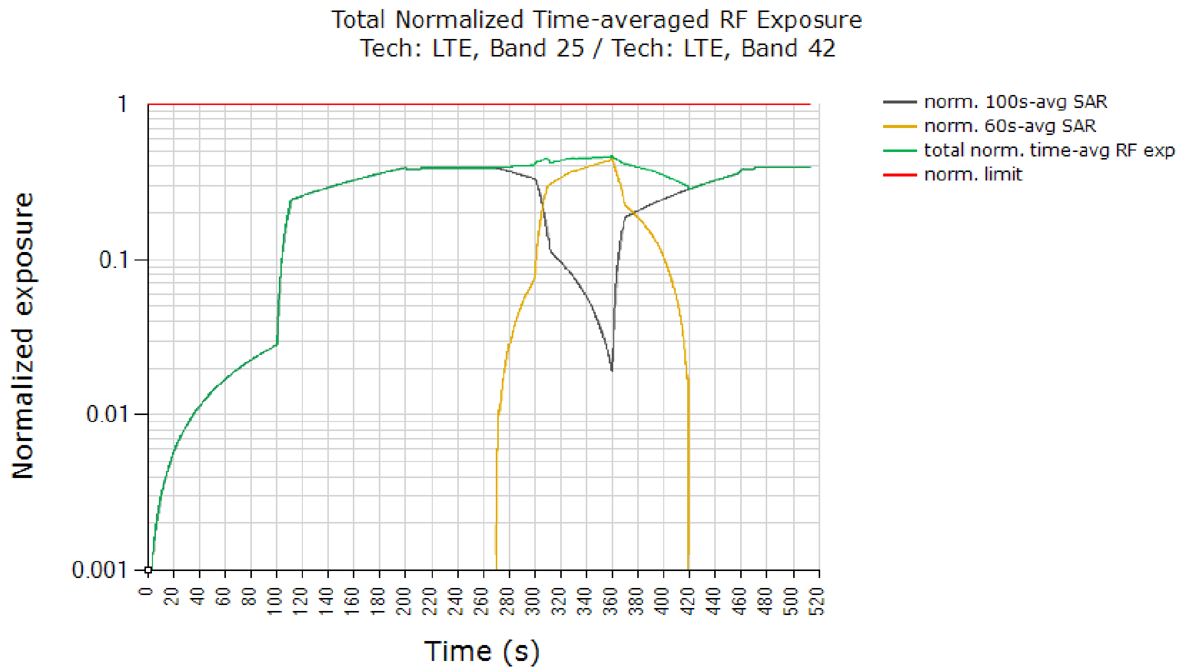
The test result validated the continuity of power limiting in Change in DSI results.

5.7. Change in time window/antenna switch test results

Test case 1: transition from LTE Band 25 to LTE Band 42 (i.e., 100s to 60s), then back to LTE Band 25

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

All the conducted Tx power measurement results were converted into time-averaged normalized SAR values using Equation (7a), (7b) and (7c), and plotted below to demonstrate that the normalized time-averaged RF exposure does not exceed the FCC limit of 1.0. Equation (7a) is used to convert the Tx power of device to obtain 100s-averaged normalized SAR in LTE Band 25 as shown in purple curve. Similarly, equation (7b) is used to obtain 60s-averaged normalized SAR in LTE Band 42 as shown in yellow curve. Equation (7c) is used to obtain total time-averaged normalized SAR as shown in green curve.



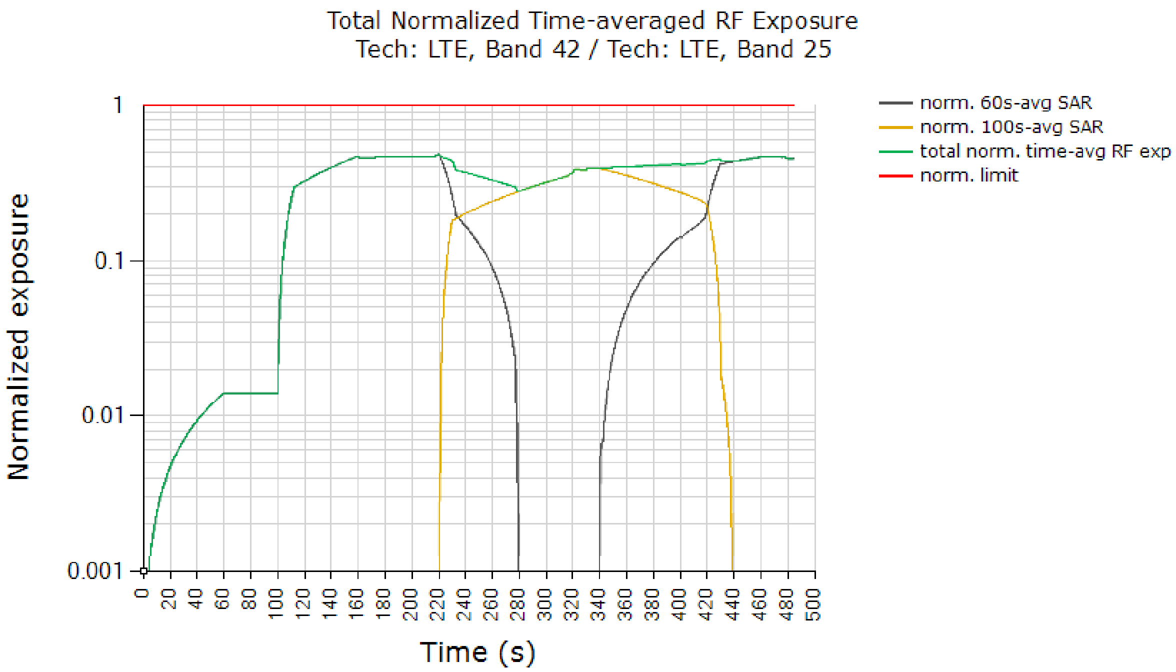
	Exposure Ratio
FCC normalized Exposure Ratio limit	1.0
Max time averaged normalized Exposure Ratio (green curve)	0.465
Validated	

Note: Maximum power is requested by callbox for the entire duration of the test, with tech/band switches from 100s-to-60s window at ~270s time stamp, and from 60s-to-100s window at ~360s time stamp. Smart Transmit controls the Tx power during these time window switches to ensure total time-averaged RF exposure, i.e., sum of yellow and purple curves given by equation (7c), is always compliant. In time-window switch test, at all times the total time averaged normalized RF exposure (green curve) should not exceed normalized SAR_design_target +1dB device uncertainty. In this test, with a maximum normalized SAR of 0.465 being ≤ 0.56 (=0.71/1.6+1dB device uncertainty), the above test result validated the continuity of power limiting in time-window switch scenario.

Test case 2: transition from LTE Band 42 to LTE Band 25 (i.e., 60s to 100s), then back to LTE Band 42

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 normalized time-averaged RF exposure does not exceed the FCC limit of 1.0. Equation (7a) is used to convert the Tx power of device to obtain 60s-averaged normalized SAR in LTE Band 42 as shown in purple curve. Similarly, equation (7b) is used to obtain 100s-averaged normalized SAR in LTE Band 25 as shown in yellow curve. Equation (7c) is used to obtain total time-averaged normalized SAR as shown in green curve.

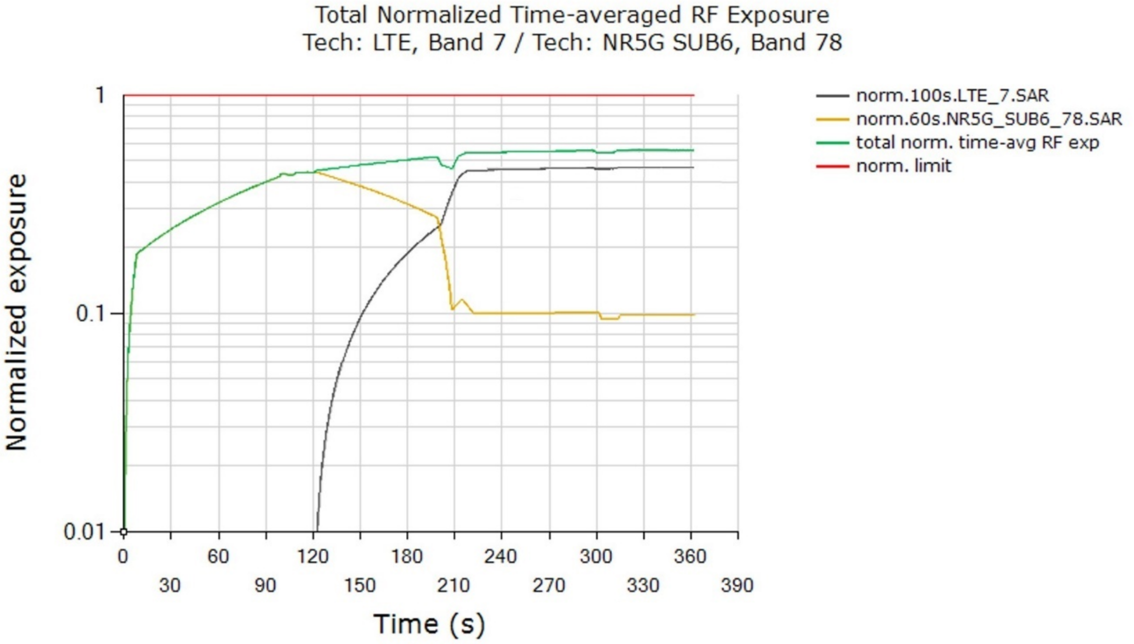


	Exposure Ratio
FCC normalized Exposure Ratio limit	1.0
Max time averaged normalized Exposure Ratio (green curve)	0.48
Validated	

Note: Maximum power is requested by callbox for the entire duration of the test, with tech/band switches from 60s-to-100s window at ~220s time stamp, and from 100s-to-60s window at ~340s time stamp. Smart Transmit controls the Tx power during these time-window switches to ensure total time-averaged RF exposure, i.e., sum of yellow and purple curves given by equation (7c), is always compliant. In time-window switch test, at all times the total time averaged normalized RF exposure (green curve) should not exceed normalized SAR_design_target +1dB device uncertainty. In this test, with a maximum normalized SAR of 0.48 being ≤ 0.56 (=0.71/1.6+1dB device uncertainty), the above test result validated the continuity of power limiting in time-window switch scenario.

5.8. Switch in SAR exposure test results (EN-DC combination)

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 normalized time-averaged RF exposure does not exceed the FCC limit of 1.0. Equation (7a) is used to convert the LTE Tx power of device to obtain 100s-averaged normalized SAR in LTE Band 7 as shown in purple curve. Similarly, equation (7b) is used to obtain 100s-averaged normalized SAR in 5G NR n66 as shown in yellow curve. Equation (7c) is used to obtain total time-averaged normalized SAR as shown in green curve.



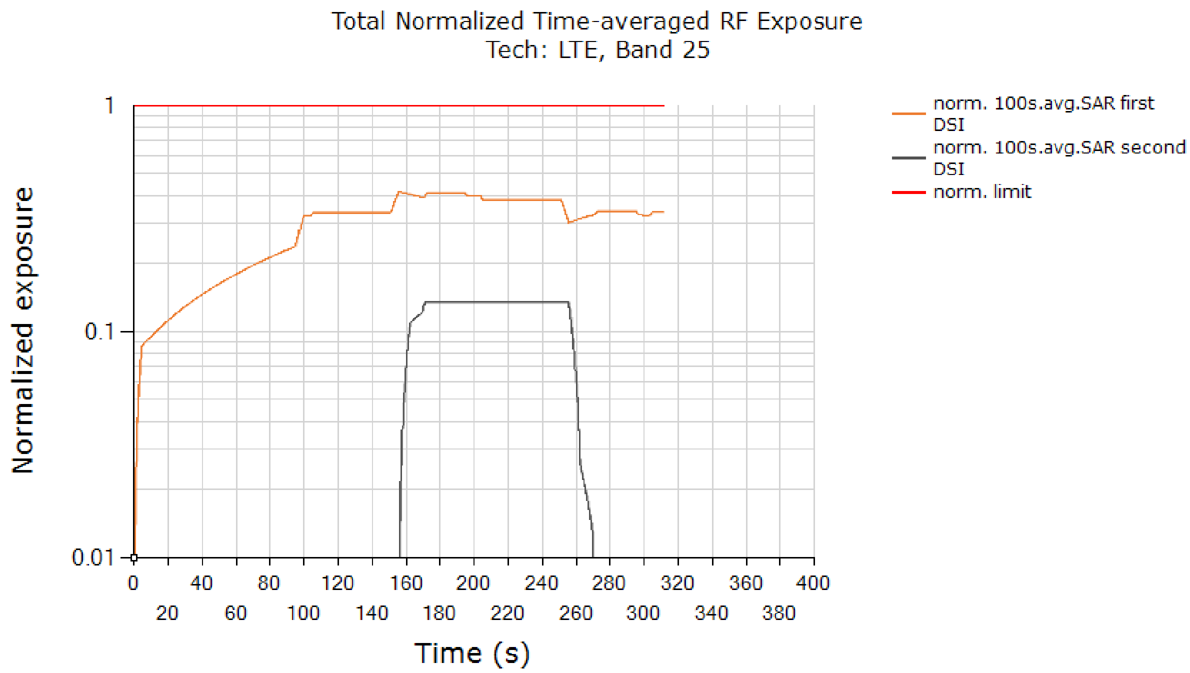
	Exposure Ratio
FCC normalized Exposure Ratio limit	1.0
Max time averaged normalized Exposure Ratio (green curve)	0.541
Validated	

Note: Device starts predominantly in 5G NR SAR exposure scenario between 0s and 120s, and in LTE SAR + 5G NR SAR exposure scenario between 120s and 240s, and in predominantly in LTE SAR exposure scenario after t=240s. Here, Smart Transmit allocates a maximum of 100% of exposure margin (based on 3dB reserve margin setting) for 5G NR. This corresponds to a normalized 1gSAR exposure value=0.66W/kg measured SAR at 5G NR Plimit /1.6W/kg limit = 0.41+ "+1dB --1dB" device related uncertainty (see orange curve between Os~120s). For predominantly LTE SAR exposure scenario, maximum normalized 1gSAR exposure should correspond to 100% exposure margin = 0.695W/kg measured SAR at LTE Plimit /1.6W/kg limit = 0.434+ "+1dB ~-1dB" device related uncertainty (see black curve after t = 240s). Additionally, in SAR exposure switch test, at all times the total time-averaged normalized RF exposure (green curve) should not exceed normalized SAR_design_target +1dB device uncertainty. In this test, with a maximum normalized SAR of 0.541 being <0.56 (=0.71/1.6+1dB device uncertainty), the above test result validated the continuity of power limiting in SAR exposure switch scenario.

5.9. Exposure Category Switch test results

In case of head to non-head to head exposure switch test for LTE Band 25, 'first DSI' in section3.3.9 test procedure refers to head DSI and 'second DSI' refers to non-head DSI. Similarly, in case of non-head to head to non-head exposure switch test, 'first DSI' in section 3.3.9 test procedure refers to non-head DSI and 'second DSI' refers to head DSI. The validation criteria is, at all times, the time-averaged normalized exposure versus time shall not exceed the normalized limit of 1.0 for both first & second DSIs (i.e., both head exposure category and non-head exposure category).

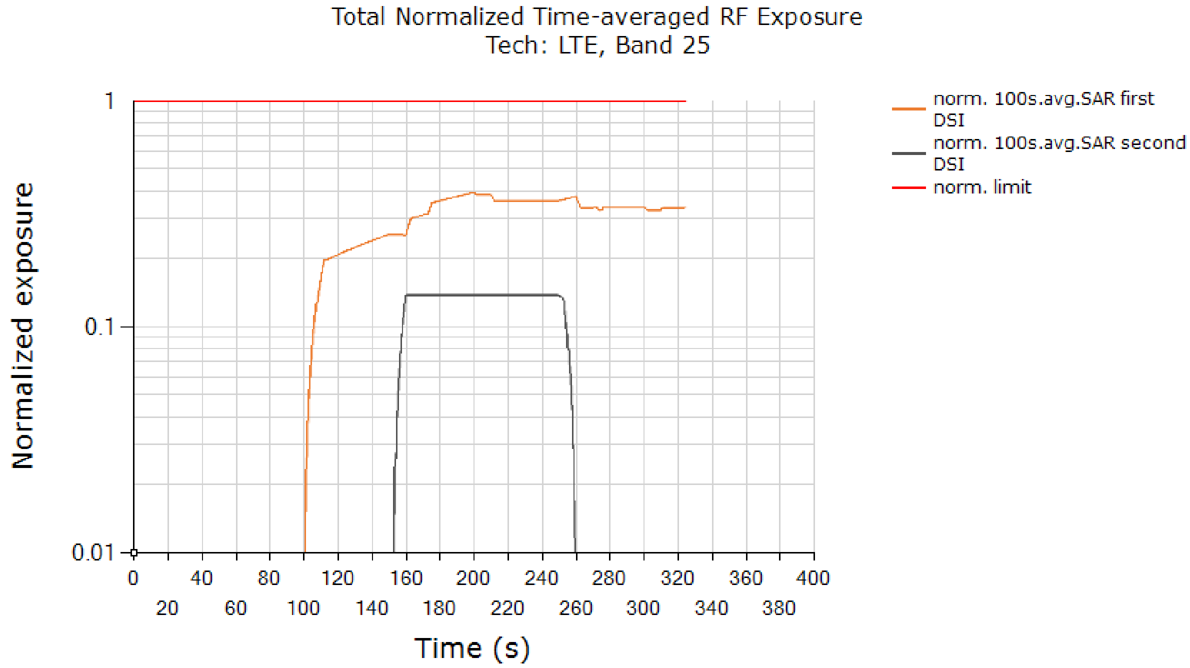
Test case 1: For head to non-head to head exposure switch test, the time-averaged normalized RF exposure in head exposure DSI (orange curve) did not exceed normalized limit of 1.0 at all times.



	Exposure Ratio
FCC normalized Exposure Ratio limit	1.0
Max 100s-time averaged normalized Exposure Ratio (green curve)	0.416
Validated	

Note: Maximum Tx power is requested at t-100s, time-averaged exposure in head DSI gradually increases until t-150s where the device is switched from head exposure DSI (first DSI, orange curve) to non-head exposure DSI (second DSI, black curve) as evident from increase in exposure of black curve and no change in orange curve between t-150s and t-160s. At t-150s, device is switched back from non-head exposure to head exposure as evident from increase in exposure of orange curve and no change in black curve. In this test, the time-averaged normalized RF exposure in head exposure DSI (orange curve) did not exceed normalized limit of 1.0 at all times, and is less than normalized measured 1g SAR of 0.416 being≤0.56 (=0.71/1.6 +1dB device uncertainty), validating the exposure continuity when switching between head exposure and non-head exposure categories.

Test case 2: For non-head to head to non-head exposure switch test, the time-averaged normalized RF exposure in non-head exposure DSI (orange curve) did not exceed normalized limit of 1.0 at all times.



	Exposure Ratio
FCC normalized Exposure Ratio limit	1.0
Max 100s-time averaged normalized Exposure Ratio (green curve)	0.394
Validated	

Note: Maximum Tx power is requested at t-100s, time-averaged exposure in non-head DSI gradually increases until t-150s where the device is switched from non-head exposure DSI (first DSI, orange curve) to head exposure DSI (second DSI, black curve) as evident from increase in exposure of black curve and no change in orange curve between t-150s and t-160s. At t-150s, device is switched back from head exposure to non-head exposure as evident from increase in exposure of orange curve and no change in black curve. In this test, the time-averaged normalized RF exposure in non-head exposure DSI (orange curve) did not exceed normalized limit of 1.0 at all times, and is less than normalized measured 1gSAR of 0.394 being⩽0.56 (=0.71/1.6 +1dB device uncertainty), validating the exposure continuity when switching between non-head exposure and head exposure categories.

6. SAR Test Results for Sub-6 Smart Transmit Feature Validation

6.1. Measurement setup

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

As mentioned in Section 3.4, for EUT to follow TPC command sent from the callbox wirelessly, the "path loss" between callbox antenna and the EUT needs to be very well calibrated. Since the SAR chamber is in uncontrolled environment, precautions must be taken to minimize the environmental influences on "path loss". Similarly, in the case of time-varying SAR measurements in 5G NR (with LTE as anchor), "path loss" between callbox antenna and the EUT needs to be carefully calibrated for both LTE link as well as for 5G NR link.

The EUT is placed in worst-case position according to Table 4-2.

6.2. SAR measurement results for time-varying Tx power transmission scenario

Following Section 3.4 procedure, time-averaged SAR measurements are conducted using EX3DV4 probe at peak location of area scan over 500 seconds. cDASY6 system verification for SAR measurement is provided in Appendix C, and the associated SPEAG certificates are attached in Appendix D.

SAR probe integration times depend on the communication signal being tested. Integration times used by SPEAG for their probe calibrations can be downloaded from here (integration time is listed on the bottom of the first page for each tech):
https://www.speag.com/assets/downloads/services/cs/UIDSummary171205.pdf

Since the sampling rate used by cDASY6 for pointSAR measurements is not in user control, the number of points in 100s or 60s interval is determined from the scan duration setting in cDASY6 time-average pointSAR measurement by (100s or 60s / cDASY6_scan_duration * total number of pointSAR values recorded). Running average is performed over these number of points in excel spreadsheet to obtain 100s-/60s-averaged pointSAR.

Following Section 3.4, for each of selected technology/band:

(1) With Reserve_power_margin set to 0 dB, area scan is performed at Plimit, and timeaveraged pointSAR measurements are conducted to determine the pointSAR at Plimit at peak location, denoted as pointSARPlimit.
(2) With Reserve_power_margin set to actual (intended) value, two more time-averaged pointSAR measurements are performed at the same peak location for test sequences 1 and 2.

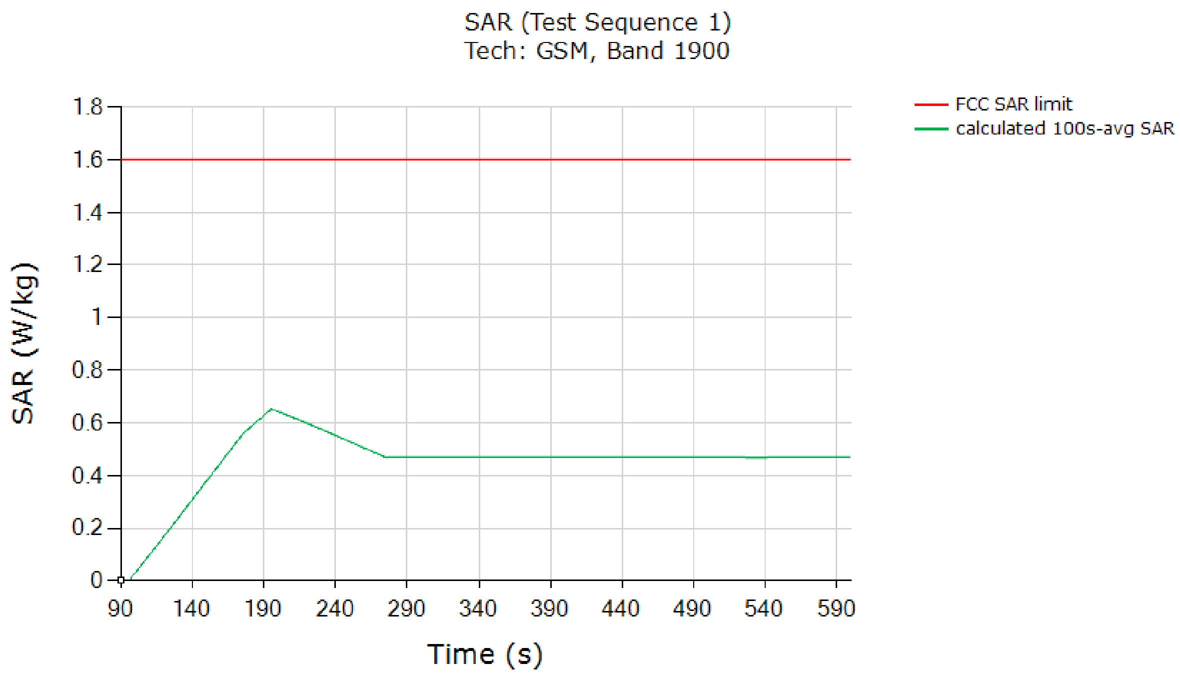
To demonstrate compliance, all the pointSAR measurement results were converted into 1gSAR or 10gSAR values by using Equation (3a), rewritten below:

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

Where, pointSAR(t), pointSAR_Plimit, and 1g_or_10gSAR_Plimit correspond to the measured instantaneous point SAR, measured point SAR at Plimit from above step 1 and 2, and measured 1gSAR or 10gSAR values at Plimit obtained from Part 1 report and listed in Table 4-2 in Section 5.1 of this report. The power limiting enforcement is effective in all the tests, and the time-averaged 1gSAR does not exceed the SAR design target + device uncertainty for all the tested technologies/bands. Therefore, Qualcomm Smart Transmit time averaging feature is validated.

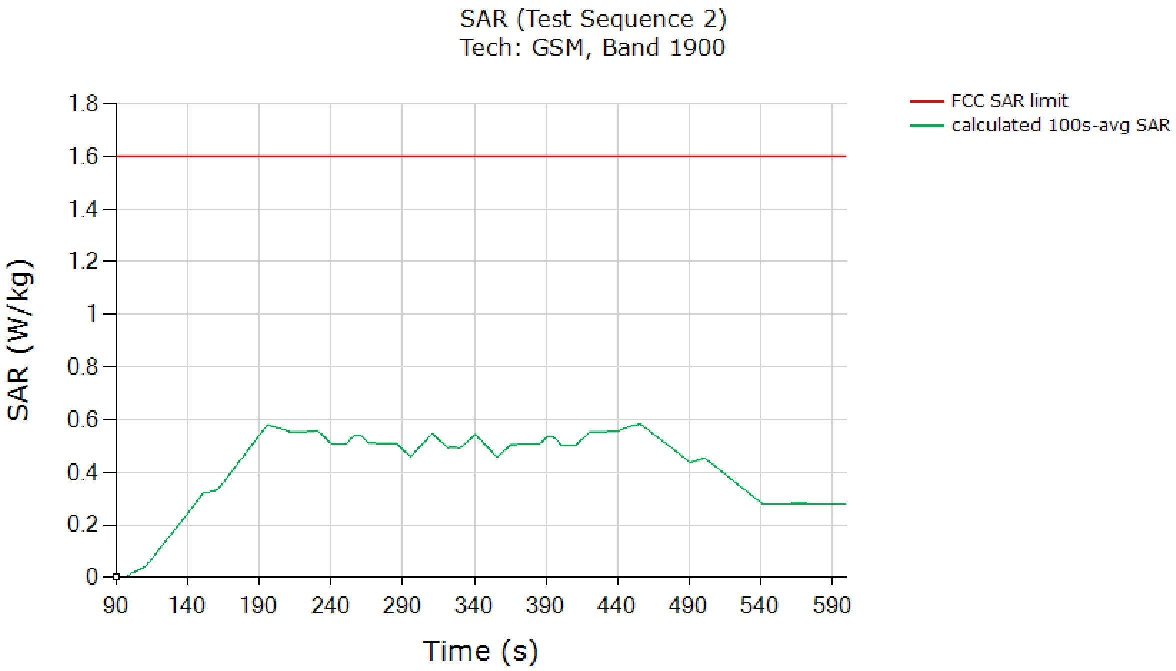
6.2.1. GSM1900 SAR test results

SAR test results for test sequence 1:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.651
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

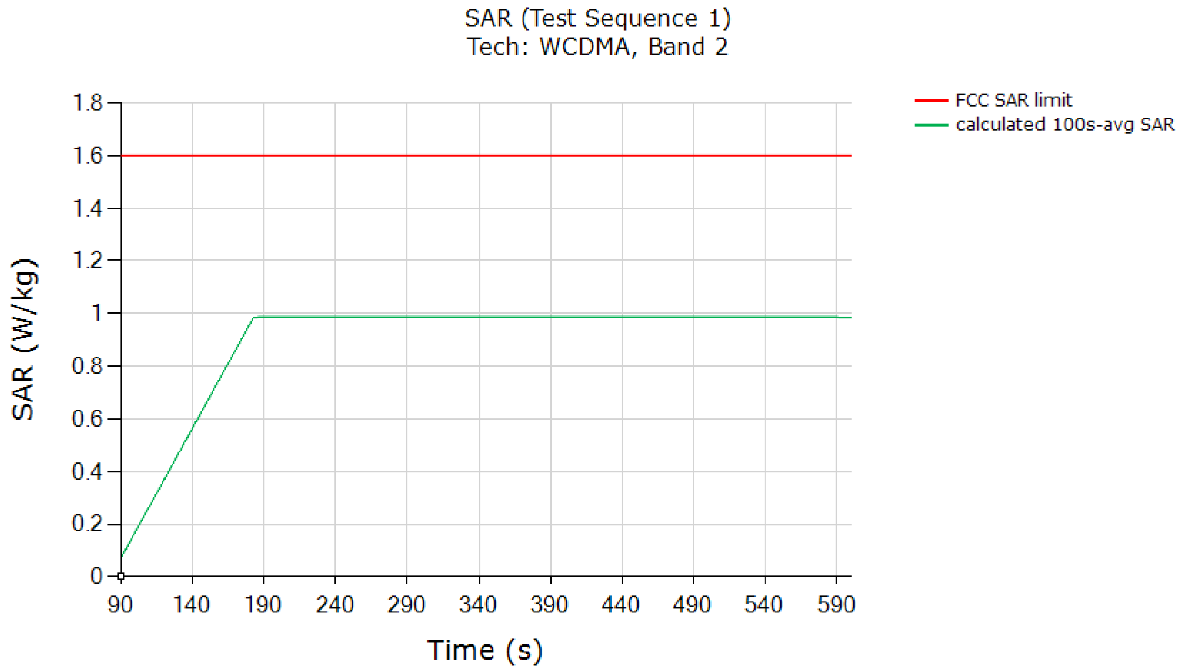
SAR test results for test sequence 2:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.582
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

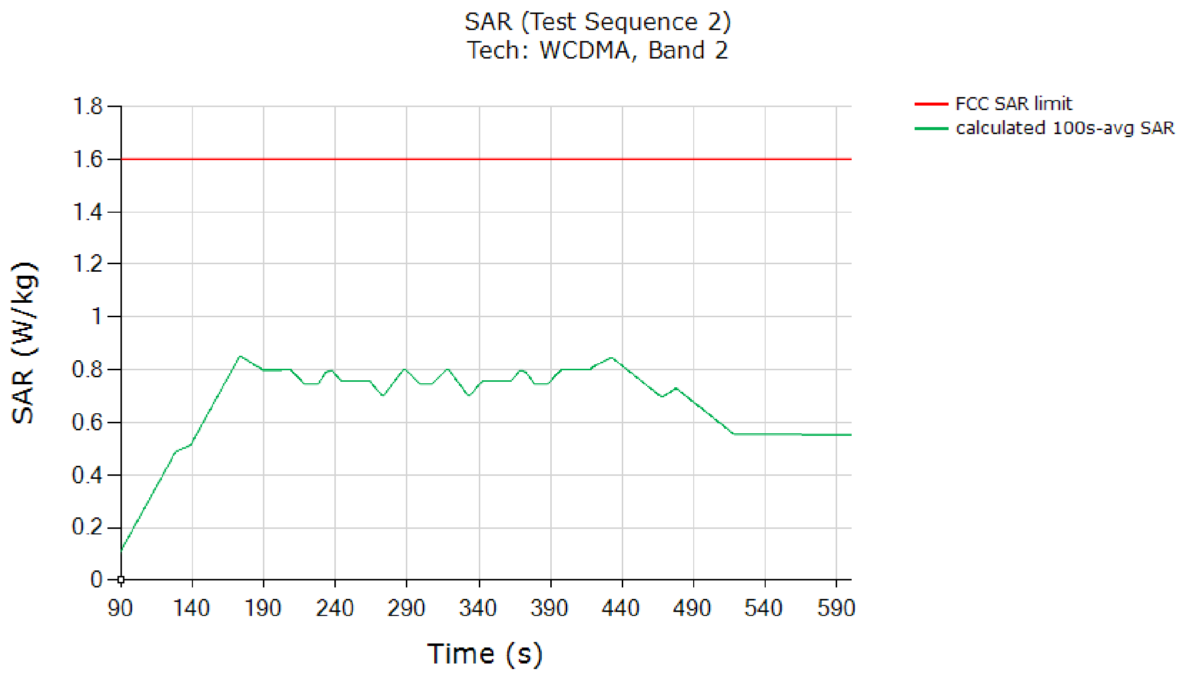
6.2.2. WCDMA Band II SAR test results

SAR test results for test sequence 1:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.987
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

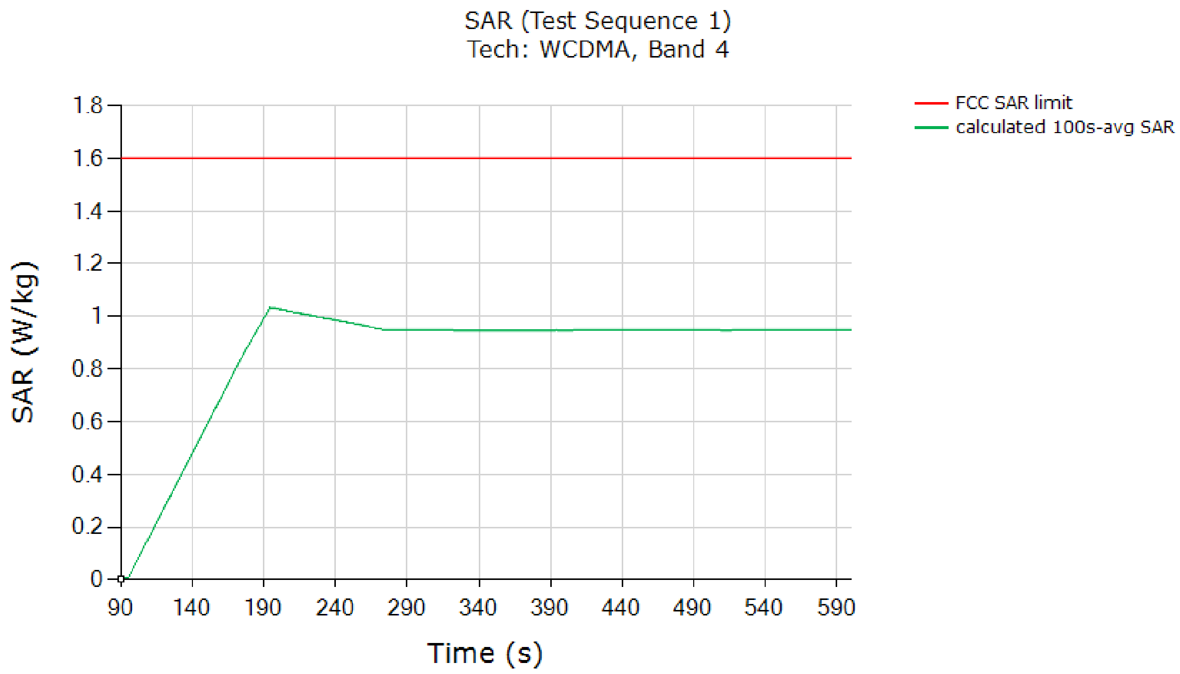
SAR test results for test sequence 2:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.85
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

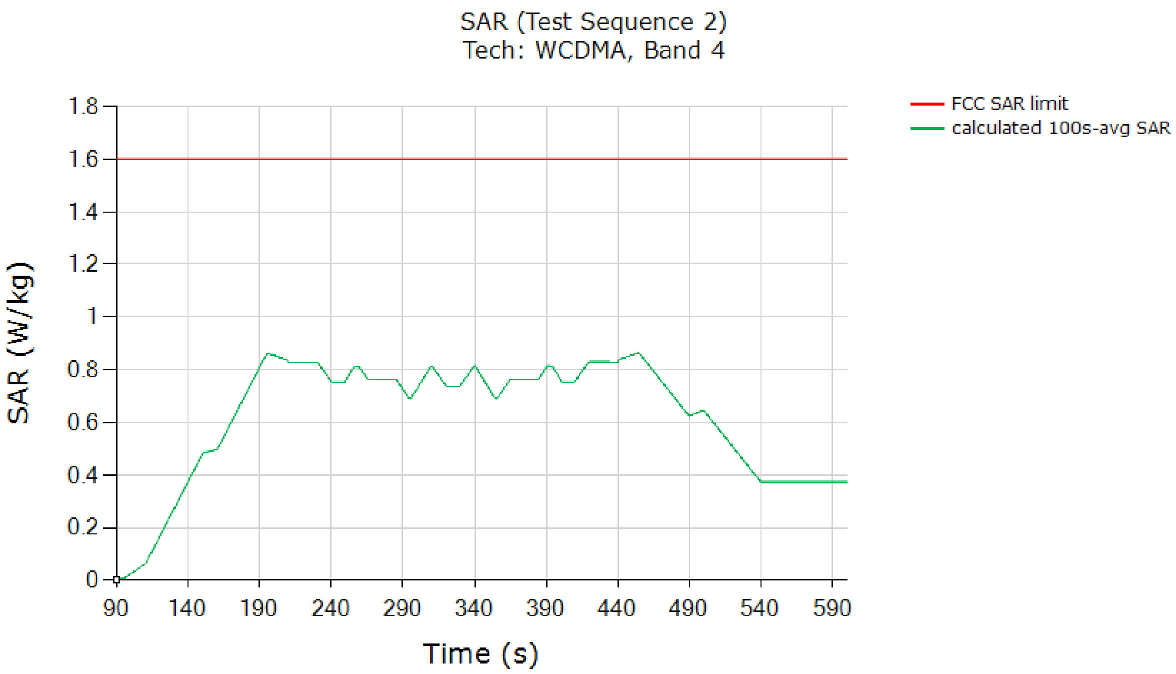
6.2.3. WCDMA Band IV SAR test results

SAR test results for test sequence 1:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	1.032
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

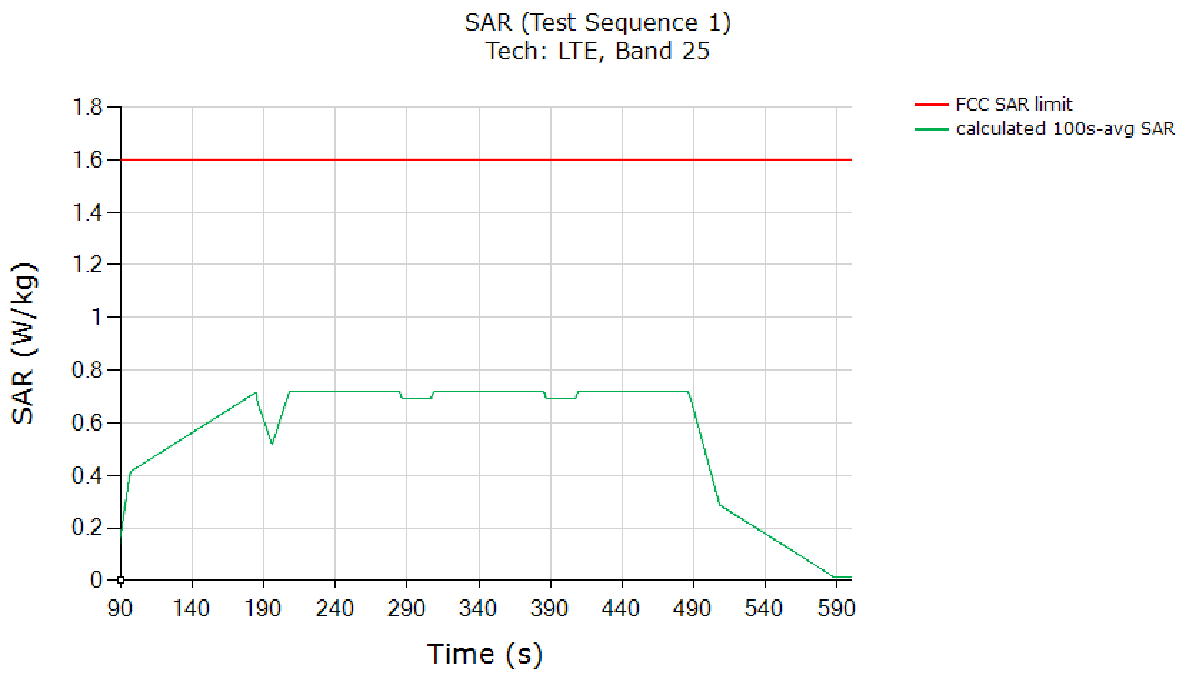
SAR test results for test sequence 2:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.863
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

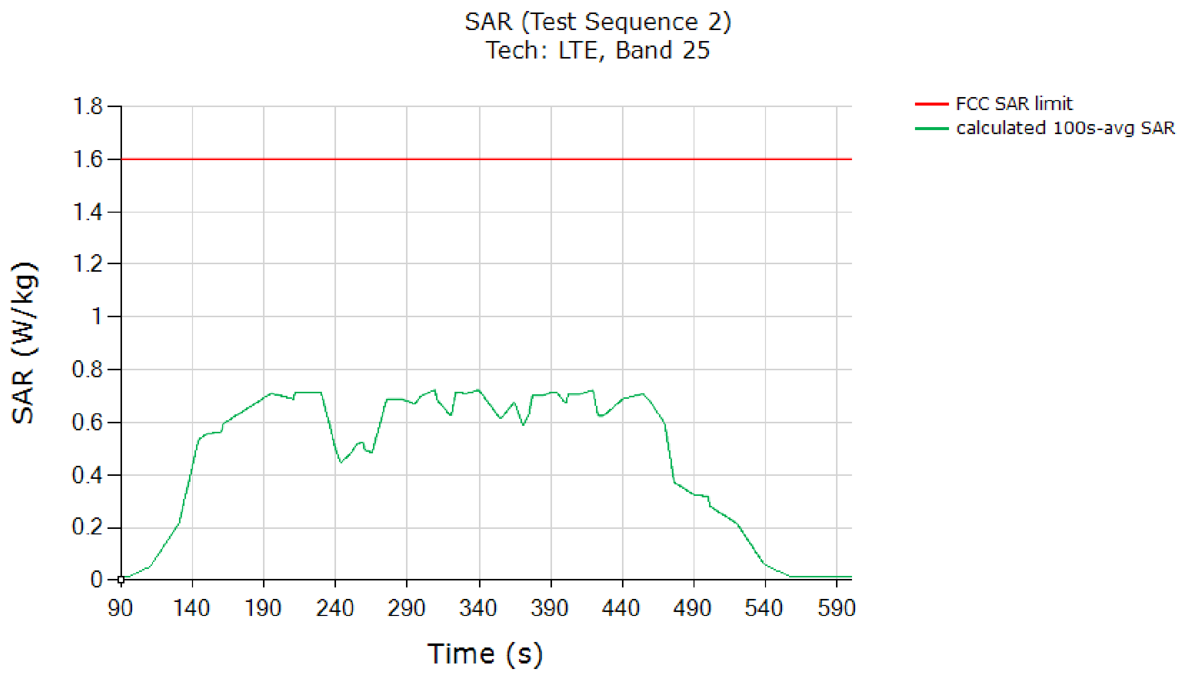
6.2.4. LTE Band 25 SAR test results

SAR test results for test sequence 1:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.718
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

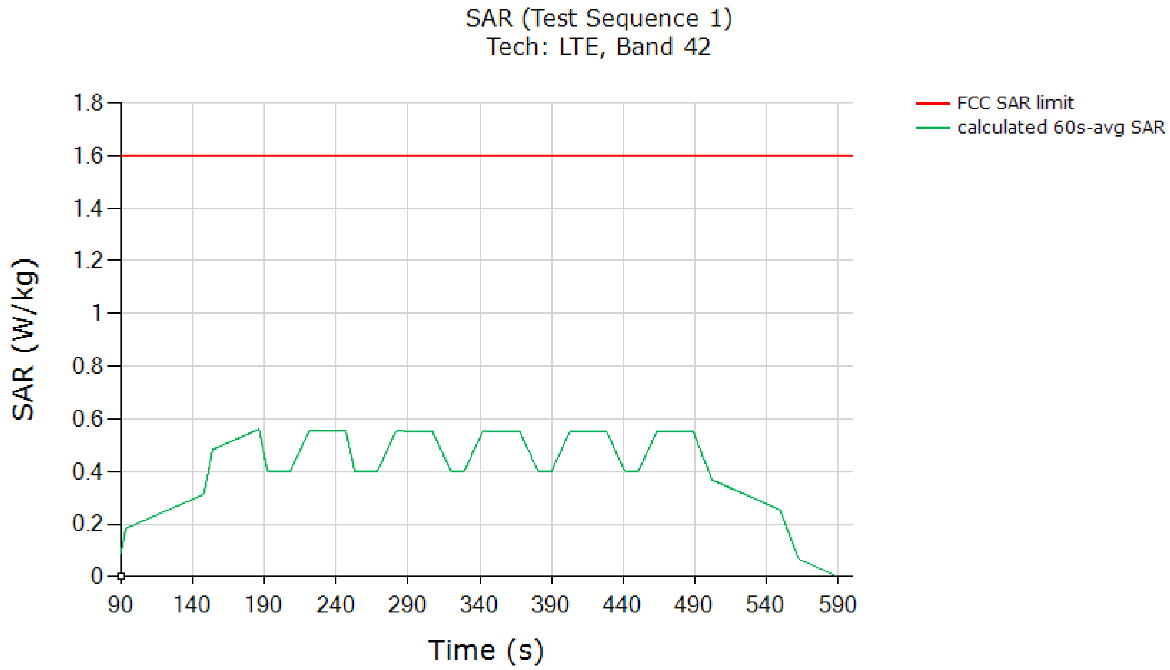
SAR test results for test sequence 2:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.722
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

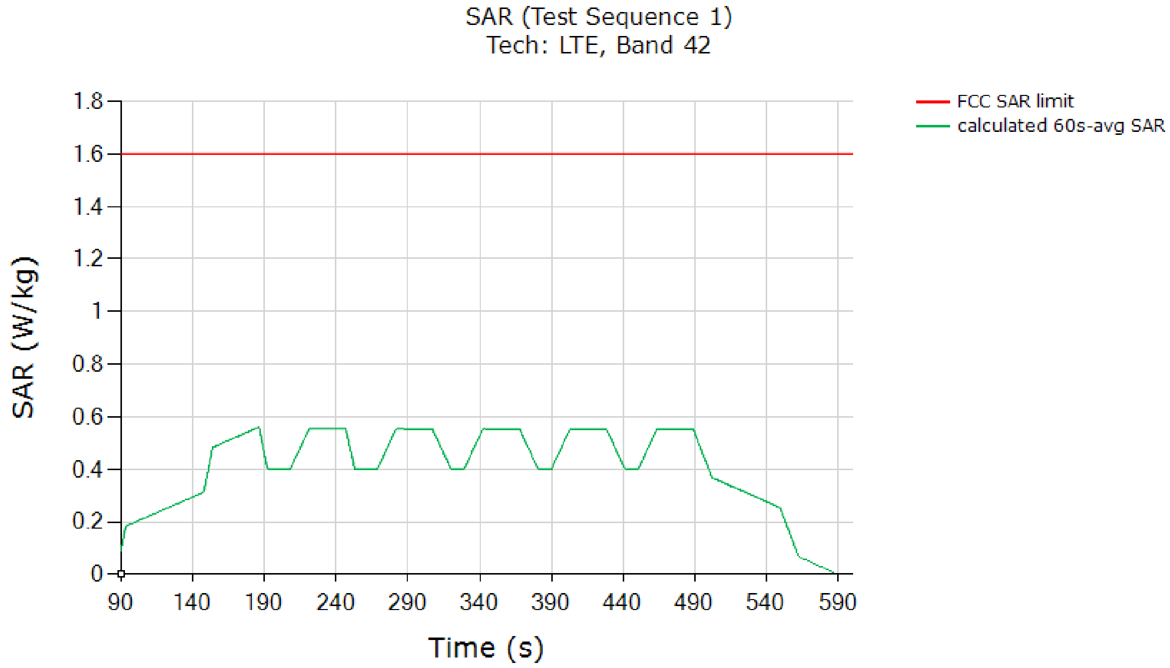
6.2.5. LTE Band 42 SAR test results

SAR test results for test sequence 1:



	(W/kg)
FCC 1gSAR limit	1.6
Max 60s-time averaged 1gSAR (green curve)	0.559
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

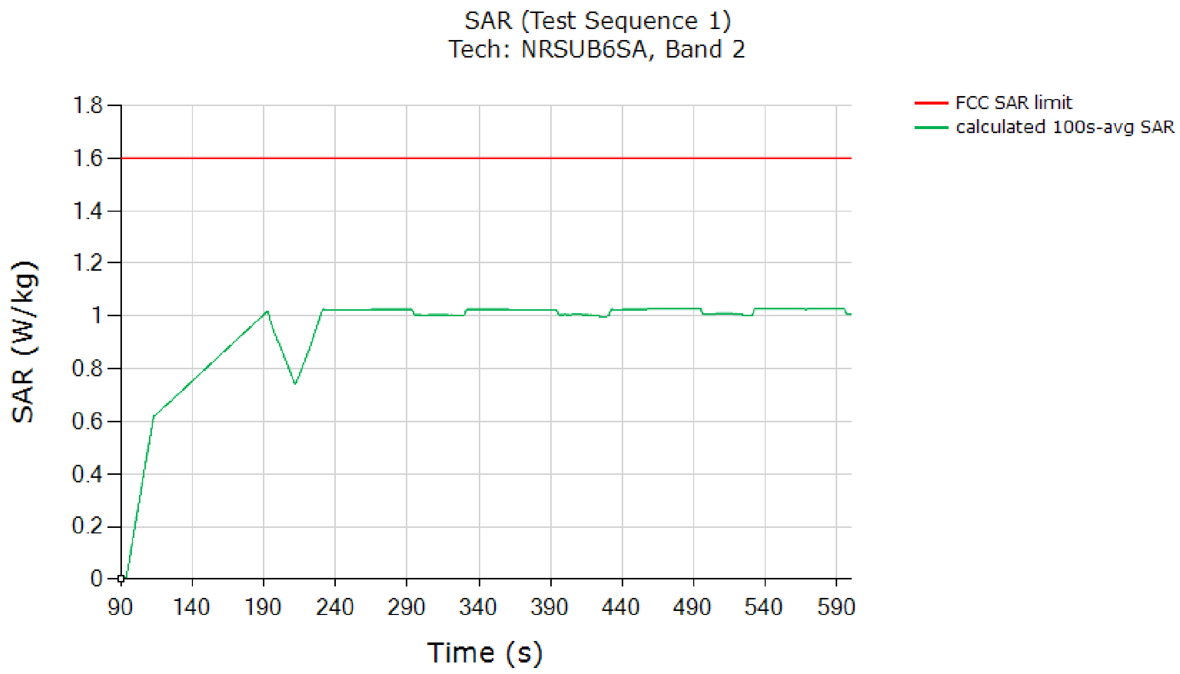
SAR test results for test sequence 2:



	(W/kg)
FCC 1gSAR limit	1.6
Max 60s-time averaged 1gSAR (green curve)	0.544
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

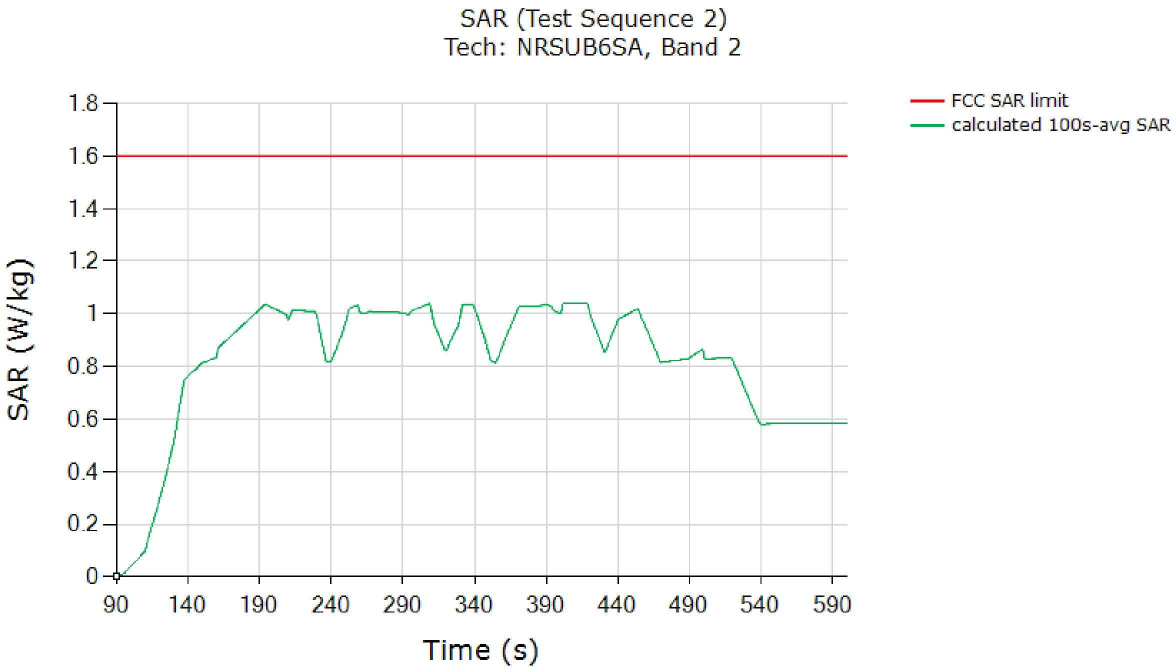
6.2.6. 5G NR n2 SAR test results

SAR test results for test sequence 1:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	1.028
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

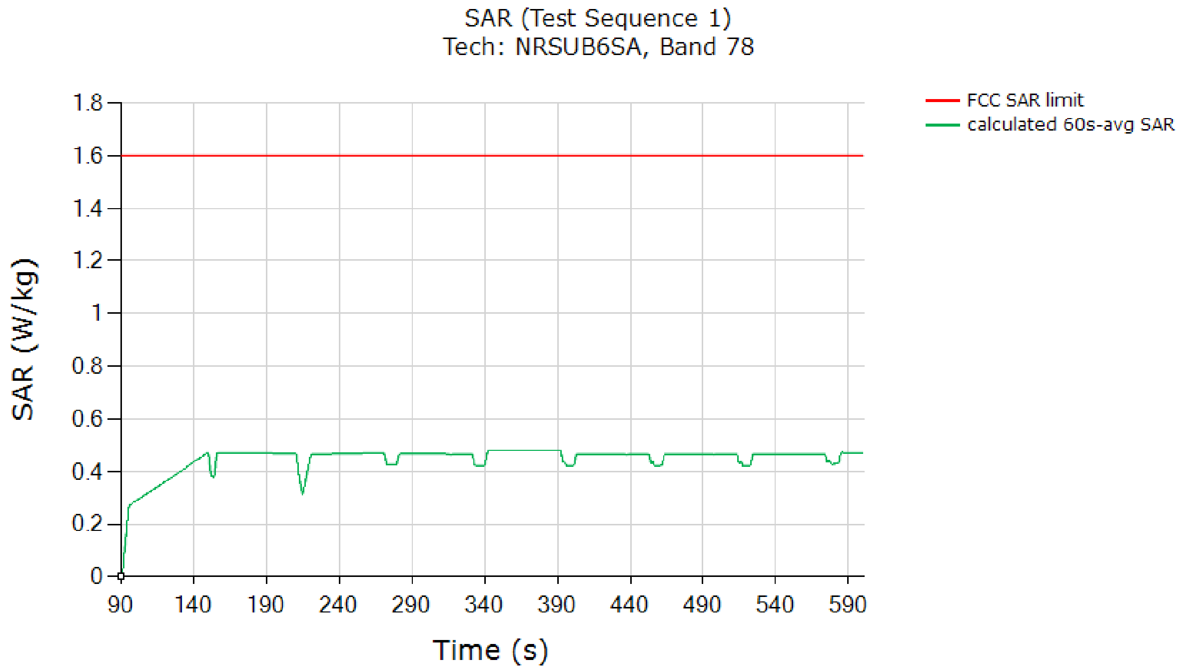
SAR test results for test sequence 2:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	1.039
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

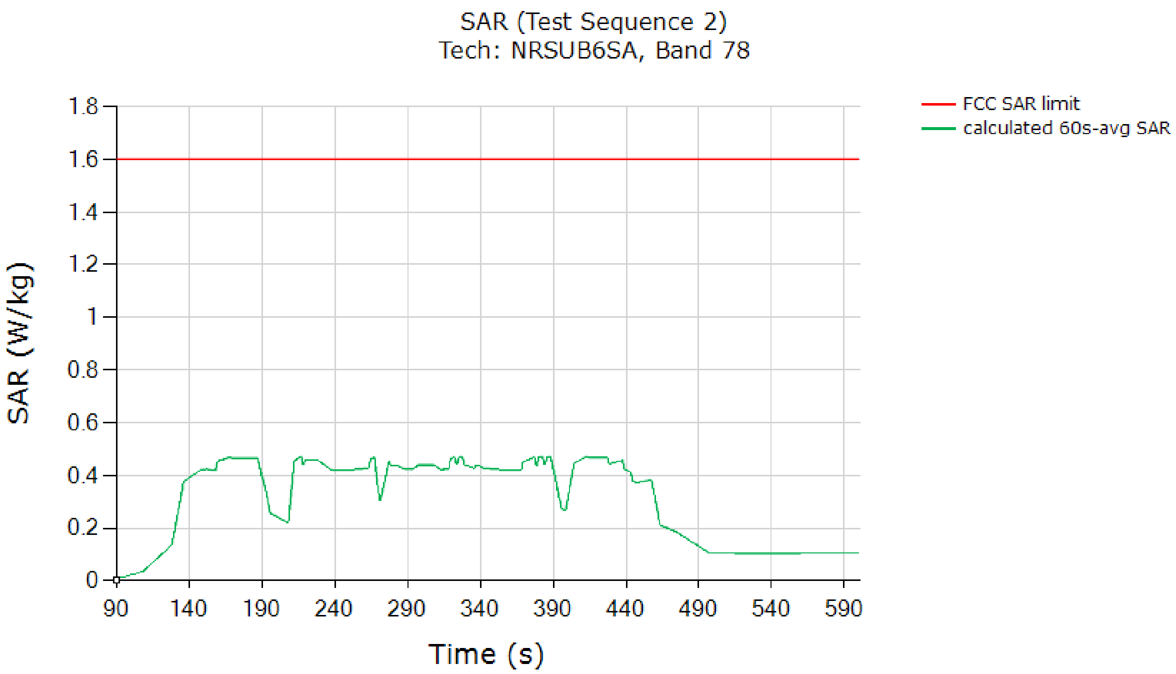
6.2.7. 5G NR n78 SAR test results

SAR test results for test sequence 1:



	(W/kg)
FCC 1gSAR limit	1.6
Max 60s-time averaged 1gSAR (green curve)	0.48
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

SAR test results for test sequence 2:



	(W/kg)
FCC 1gSAR limit	1.6
Max 60s-time averaged 1gSAR (green curve)	0.472
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit +1.0dB device uncertainty	

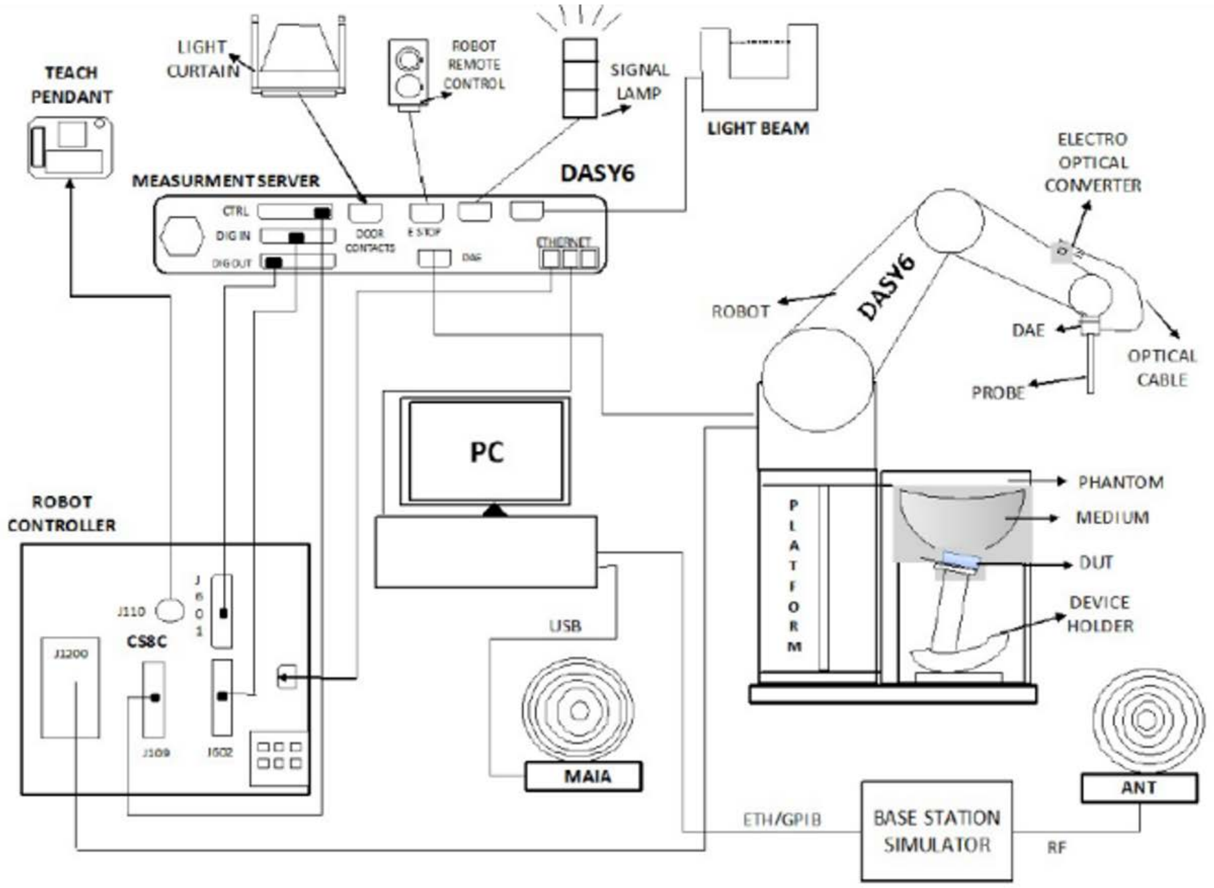
7. Conclusions

Qualcomm Smart Transmit feature employed has been validated through the conducted/radiated power measurement, as well as SAR measurement.
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.

Appendix A．cDASY6 System Verification

1.SAR Test System Configuration

The DASY6 system used for performing compliance tests consists of the following items:



1) A standard high precision 6-axis robot with controller, teach pendant and software. An arm extension for accommodating the data acquisition electronics (DAE).
2) An isotropic Field probe optimized and calibrated for the targeted measurement.
3) A data acquisition electronics (DAE) which performs the signal amplification, signal multiplexing, AD-conversion, offset measurements, mechanical surface detection, collision detection, etc. The unit is battery powered with standard or rechargeable batteries. The signal is optically transmitted to the EOC.
4) The Electro-optical converter (EOC) performs the conversion from optical to electrical signals for the digital communication to the DAE. To use optical surface detection, a special version of the EOC is required. The EOC signal is transmitted to the measurement server.
5) The function of the measurement server is to perform the time critical tasks such as signal filtering, control of the robot operation and fast movement interrupts.
6) The Light Beam used is for probe alignment. This improves the accuracy of the probe positioning.
7) A computer running WinXP or Win10 and the cDASY6 software.
8) Remote control and teach pendant as well as additional circuitry for robot safety such as warning lamps, etc.
9) The phantom, the device holder and other accessories according to the targeted measurement.

2.General Information

2.1.Details of Client

Applicant	Motorola Mobility LLC
Address	222 W,Merchandise Mart Plaza, Chicago IL 60654 USA
Manufacturer	Motorola Mobility LLC
Address	222Merchandise Mart Plaza, Chicago IL 60654 USA

2.2.Testing Laboratory

Testing LAB	ADR TEST AND CERTIFICATION CENTER
Test Site Location	No. 19, Gao Xin 4th Road Wuhan, People's Republic of China (430205)
TEL	027-81806505
FAX	027-81806512
E-mail	lucz1@motorola.com

2.3.Laboratory Qualification

・A2LA (Certificate No. 3680.01)

ADR TEST AND CERTIFICATION CENTER is accredited to ISO/IEC 17025:2017 by American Association for Laboratory Accreditation with Certificate Number 3680.01.

3. SAR E-Field Probe

The SAR measurement is conducted with the dosimetric probe (manufactured by SPEAG).The probe is specially designed and calibrated for use in liquid with high permittivity. The dosimetric probe has special calibration in liquid at different frequency. This probe has a built in optical surface detection system to prevent from collision with phantom.

EX3DV4 Probe		
Construction	Symmetric design with triangular core Built-in shielding against static charges PEEK enclosure material (resistant to organic solvents, e.g., DGBE)	
Frequency	10 MHz – >6 GHz Linearity: ±0.2 dB (30 MHz – 6 GHz)	
Directivity	±0.3 dB in TSL (rotation around probe axis) ±0.5 dB in TSL (rotation normal to probe axis)	
Dynamic Range	10 µW/g – >100 mW/g Linearity: ±0.2 dB (noise: typically <1 µW/g)	
Dimensions	Overall length: 337 mm (tip: 20 mm) Tip diameter: 2.5 mm (body: 12 mm) Typical distance from probe tip to dipole centers: 1 mm	

4.Data Acquisition Electronics (DAE)

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

Photo of DAE

5.Test Equipment List

Test Platform	SPEAG DASY6 Professional				
Description	SAR Test System (Frequency Range 600MHz~6GHz)				
Software Reference	cDASY6 Module SAR V16.0.0.116; SEMCAD X V14.6.14(7483)				
Hardware Reference					
Name of Equipment	Manufacturer	Model/Type	Serial Number	Calibration Date	Due Date of Calibration
SAM Twin Phantom	SPEAG	SAM	1860	NCR	NCR
ELI Phantom	SPEAG	ELI	2007	NCR	NCR
Mounting Device	SPEAG	N/A	141408-5	NCR	NCR
Data Acquisition Electronics	SPEAG	DAE4	1806	2023-10-06	2024-10-05
Data Acquisition Electronics	SPEAG	DAE4	719	2023-04-10	2024-04-09
E-Field Probe	SPEAG	EX3DV4	7846	2023-10-03	2024-10-02
E-Field Probe	SPEAG	EX3DV4	7746	2023-08-22	2024-08-21
System Validation Kit	SPEAG	D1750V2	1128	2021-09-02	2024-09-01
System Validation Kit	SPEAG	D1900V2	5d192	2021-09-01	2024-08-31
System Validation Kit	SPEAG	D3500V2	1143	2022-07-05	2025-07-04
Radio Communication Tester	R&S	CMW500	171831	2023-12-07	2024-12-06
Radio Communication Analyzer	Anritsu	MT8821C	6272374608	2023-12-06	2024-12-05
Radio Communication Test Station	Anritsu	MT8000A	6272398170	2023-12-07	2024-12-06
Dielectric Probe Kit	SPEAG	DAKS-3.5	1140	2023-12-05	2024-12-04
RF Cable	SPEAG	SF404	3028	NCR	NCR
Power Amplifier	Mini-Circuits	ZHL-42W+	15542	NCR	NCR
Power Amplifier	Mini-Circuits	ZVE-8G+	945501433	NCR	NCR
Coupler	Agilent	778D	MY52180451	NCR	NCR
Coupler	Agilent	772D	MY52180200	NCR	NCR
Coupler	WOKEN	0110A05801M-20	CCMCB8W5G1	NCR	NCR
Coupler	WOKEN	0110A05801M-20	CCMCB8W5G2	NCR	NCR
Attenuator	Keysight	8491A	MY52461278	NCR	NCR
Signal Generator	Keysight	N5173B	MY62220848	2023-08-06	2024-08-05
Power Sensor	R&S	NRP18S	102984	2023-12-09	2024-12-08
Power Sensor	R&S	NRP18S	102985	2023-12-09	2024-12-08
Thermometer	SPEAG	DTM3000	3915	2023-03-20	2024-03-19
Temperature and Humidity Meter	testo	608-H1	1845168354	2023-12-15	2024-12-14

Note:

1) Prior to system verification and validation, the path loss from the signal generator to the system check source and the power meter, which includes the amplifier, cable, attenuator and directional coupler, was measured by the network analyzer. The reading of the power meter was offset by the path loss difference between the path to the power meter and the path to the system check source to monitor the actual power level fed to the system check.

2) Justification for Extended Dipole Calibrations

Referring to KDB865664 D01 requirements for dipole calibration, instead of the typical annual calibration recommended by measurement standards, longer calibration intervals of up to three years may be considered when it is demonstrated that the SAR target, impedance and return loss of a dipole have remain stable according to the following requirements. Each measured dipole is expected to evaluate with the following criteria at least on annual interva.

a) There is no physical damage on the dipole.

b) System check with specific dipole is within 10% of calibrated value.

c) Return-loss is within 20% of calibrated measurement.

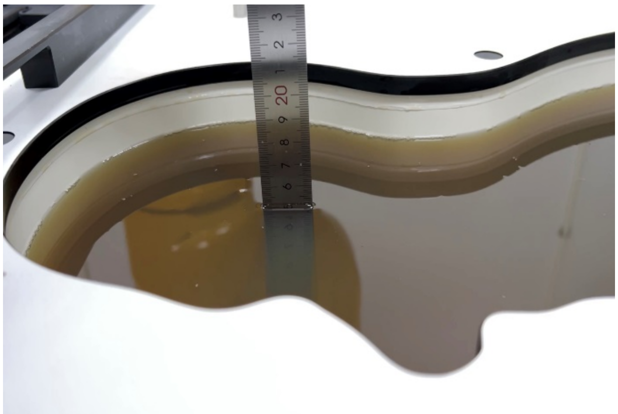
d) Impedance is within 5Ω from the previous measurement.

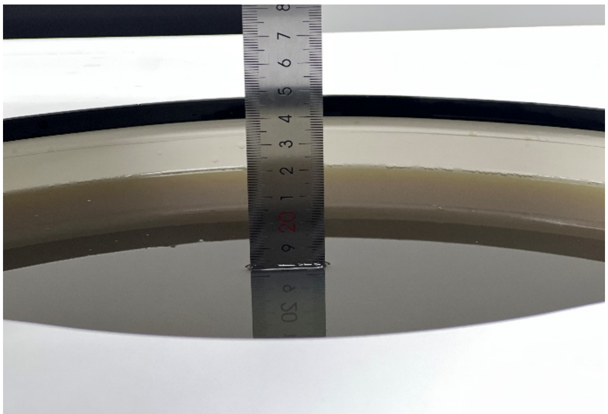
Network analyzer probe calibration against air, distilled water and a shorting block performed before measuring liquid parameters.

6.System Verification

6.1.Tissue Simulating Liquids

For the measurement of the field distribution inside the SAM phantom with DASY, the phantom must be filled with around 25 liters of homogeneous body tissue simulating liquid. According to KDB 865664 D01, the depth of tissue-equivalent liquid in a phantom must be ≥ 15.0 cm with ≤ ± 0.5 cm variation for SAR measurements ≤ 3 GHz and ≥ 10.0 cm with ≤ ± 0.5 cm variation for measurements > 3 GHz. These depths should ensure the SAR probe is immersed sufficiently in the tissue medium while scanning along the curved surfaces of the SAM phantom at various probe angles, with an acceptable separation between the top of the zoom scan volume and the liquid-air boundary above.





6.2.Tissue Verification

The following tissue formulations are provided for reference only as some of the parameters have not been thoroughly verified. The composition of ingredients may be modified accordingly to achieve the desired target tissue parameters required for routine SAR evaluation.

(For Head)

Frequency (MHz)	Water (%)	Sugar (%)	Cellulose (%)	Salt (%)	Preventol (%)	DGBE (%)	Conductivity (σ)	Permittivity (εr)
750	41.10	57.00	0.20	1.40	0.20	0.00	0.89	41.90
835	40.30	57.90	0.20	1.40	0.20	0.00	0.90	41.50
1750~2000	55.20	0.00	0.00	0.30	0.00	44.50	1.40	40.00
2300~2450	55.00	0.00	0.00	0.20	0.00	45.00	1.80	39.20
2600	54.80	0.00	0.00	0.10	0.00	45.10	1.96	39.00

For 5GHz Head, Manufactured by SPEAG:

Ingredients	(% by weight)
Water	64%~78%
Mineral oil	11%~18%
Emulsifiers	9%~15%
Additives and Salt	2%~3%

The temperature of the tissue-equivalent medium used during measurement must also be within 18°C

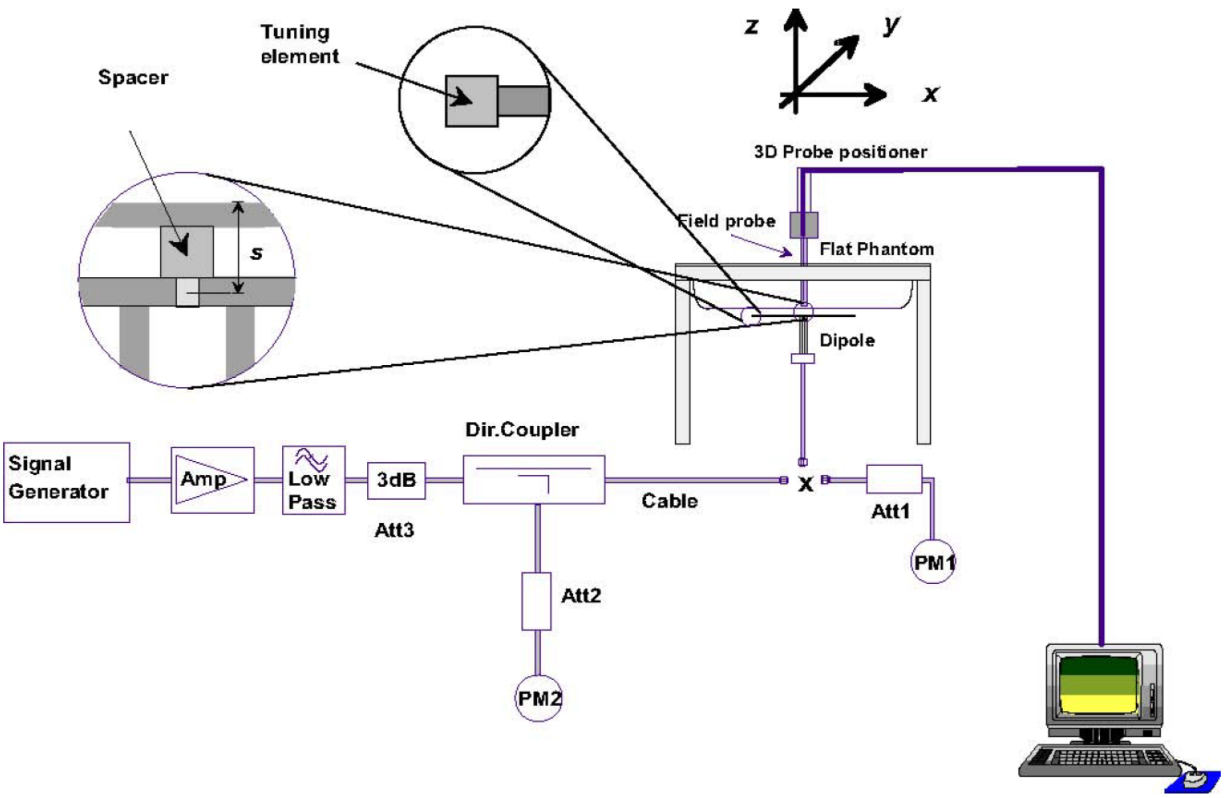
to 25°C and within ± 2°C of the temperature when the tissue parameters are characterized.
The dielectric parameters must be measured before the tissue-equivalent medium is used in a series of SAR measurements. The parameters should be re-measured after each 3~4 days of use; or earlier if the dielectric parameters can become out of tolerance; for example, when the parameters are marginal at the beginning of the measurement series.
Tissue dielectric parameters were measured at the low, middle and high frequency of each operating frequency range of the test device.
The dielectric constant (εr) and conductivity (σ) of typical tissue-equivalent media recipes are expected to be within ± 5% of the required target values; but for SAR measurement systems that have implemented the SAR error compensation algorithms documented in IEEE Std 1528-2013, to automatically compensate the measured SAR results for deviations between the measured and required tissue dielectric parameters, the tolerance for εr and σ may be relaxed to ± 10%. This is limited to frequencies ≤ 3 GHz.

<Measurement Results of Tissue electric parameters>

Date	Tissue Type	Frequency (MHz)	Liquid Temp. (℃)	Measured Conductivity (σ)	Measured Permittivity (εr)	Targeted Conductivity (σ)	Targeted Permittivity (εr)	Deviation Conductivity (%)	Deviation Permittivity (%)
2024-3-5	Head	1750	22.30	1.330	41.01	1.37	40.10	-2.92	2.26
2024-3-6	Head	1900	22.10	1.434	40.21	1.40	40.00	2.43	0.53
2024-3-9	Head	3500	22.10	2.810	39.40	2.91	37.90	-3.44	3.96

6.3.System Performance Check

The microwave circuit arrangement for system Check is sketched as follows. The daily system accuracy verification occurs within the flat section of the SAM phantom. A SAR measurement was performed to see if the measured SAR was within +/- 10% from the target SAR values. The tests were conducted on the same days as the measurement of the EUT. The obtained results from the system accuracy verification are displayed in the following table (a power level of 250mW (below 3GHz) or 100mW (3-6GHz) was input to the dipole antenna). During the tests, the ambient temperature of the laboratory was in the range 22±2°C, the relative humidity was in the range 60% and the liquid depth above the ear reference points was above 15±0.5 cm in all the cases. It is seen that the system is operating within its specification, as the results are within acceptable tolerance of the reference values.



Comparing to the original SAR value provided by SPEAG, the verification data should be within its specification of 10 %. Below table shows the target SAR and measured SAR after normalized to 1W input power. The table below indicates the system performance check can meet the variation criterion and the plots can be referred to Appendix A of this report.

<System Performance Check Results>

1g:

Date	Tissue Type	Frequency (MHz)	Dipole S/N	Probe S/N	DAE S/N	Input Power (mW)	Targeted 1g SAR (W/kg)	Measured 1g SAR (W/kg)	Normalized 1g SAR (W/kg)	Deviation (%)
2024-3-5	Head	1750	1128	7846	1806	250	35.70	8.31	33.24	-6.89
2024-3-6	Head	1900	5d192	7846	1806	250	39.50	10.40	41.60	5.32
2024-3-9	Head	3500	1143	7746	719	100	64.80	6.44	64.40	-0.62

Test Laboratory: ADR TCC SAR LAB

System check_head_1750MHz

Device under Test Properties

Model	Dimensions [mm]	
D1700V2-SN：1128	80.0 x 30.0 x 8.0	Phone

Ambient Temperature: 22.7℃; Liquid Temperature: 22.3℃

Exposure Conditions

Phantom Section, TSL	Position, Test Distance [mm]	Band	Group, UID	Frequency [MHz], Channel Number	Conversion Factor	TSL Conductivity [S/m]	TSL Permittivity
Flat,	FRONT, 0.00	D1750	CW, 0--	1750.000, 50	8.86	1.33	41.01

Hardware Setup

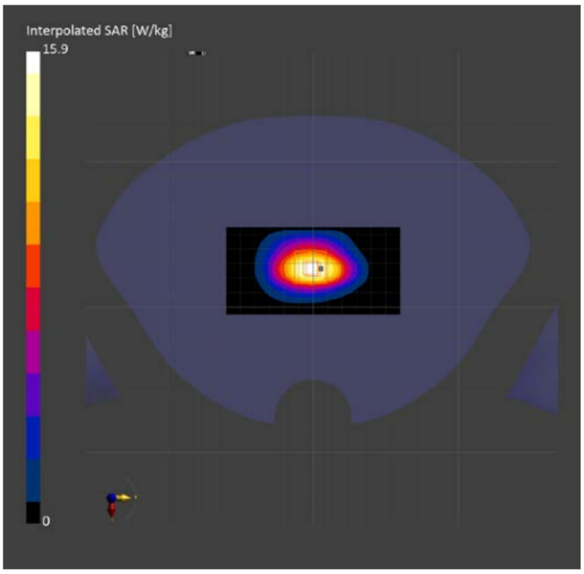
Phantom	TSL	Probe, Calibration Date	DAE, Calibration Date
Twin-SAM V8.0 (30deg probe tilt) - 2157	HSL1750 --	EX3DV4 - SN7846, 2023-10-03	DAE4 Sn1806, 2023-10-06

Scan Setup

	Area Scan	Zoom Scan
Grid Extents [mm]	60.0 x 120.0	30.0 x 30.0 x 30.0
Grid Steps [mm]	15.0 x 15.0	6.0 x 6.0 x 1.5
Sensor Surface [mm]	3.0	1.4
Graded Grid	N/A	Yes
Grading Ratio	N/A	1.5
MAIA	N/A	N/A
Surface Detection	All points	All points
Scan Method	Measured	Measured

Measurement Results

	Area Scan	Zoom Scan
Date	2024-03-05, 09:35	2024-03-05, 09:48
psSAR**1g** [W/kg]	8.62	**8.31**
psSAR**10g** [W/kg]	4.58	**4.42**
Power Drift [dB]	-0.21	0.03
Power Scaling	Disabled	Disabled
Scaling Factor [dB]		
TSL Correction	No correction	No correction
M2/M1 [%]		81.1
Dist 3dB Peak [mm]		10.8



Test Laboratory: ADR TCC SAR LAB

System check_head_1900MHz

Device under Test Properties

Model	Dimensions [mm]	
D1900V2-SN：5d192	80.0 x 30.0 x 8.0	Phone

Ambient Temperature: 22.7℃; Liquid Temperature: 22.1℃

Exposure Conditions

Phantom Section, TSL	Position, Test Distance [mm]	Band	Group, UID	Frequency [MHz], Channel Number	Conversion Factor	TSL Conductivity [S/m]	TSL Permittivity
Flat,	FRONT, 10.00	D1900	CW, 0--	1900.000, 50	8.46	1.434	40.21

Hardware Setup

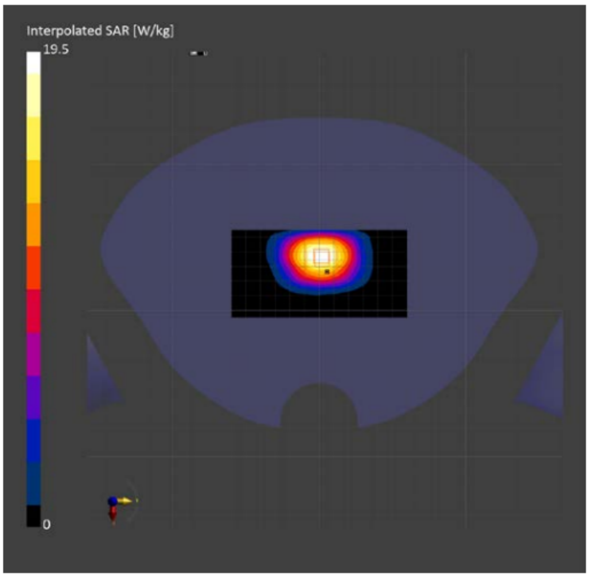
Phantom	TSL	Probe, Calibration Date	DAE, Calibration Date
Twin-SAM V8.0 (30deg probe tilt) - 2157	HSL1900 --	EX3DV4 - SN7846, 2023-10-03	DAE4 Sn1806, 2023-10-06

Scan Setup

	Area Scan	Zoom Scan
Grid Extents [mm]	60.0 x 120.0	30.0 x 30.0 x 30.0
Grid Steps [mm]	15.0 x 15.0	6.0 x 6.0 x 1.5
Sensor Surface [mm]	3.0	1.4
Graded Grid	N/A	Yes
Grading Ratio	N/A	1.5
MAIA	N/A	N/A
Surface Detection	VMS + 6p	VMS + 6p
Scan Method	Measured	Measured

Measurement Results

	Area Scan	Zoom Scan
Date	2024-03-06, 09:33	2024-03-06, 09:39
psSAR**1g** [W/kg]	8.94	**10.4**
psSAR**10g** [W/kg]	4.95	**5.41**
Power Drift [dB]	-0.01	-0.10
Power Scaling	Disabled	Disabled
Scaling Factor [dB]		
TSL Correction	No correction	No correction
M2/M1 [%]		81.6
Dist 3dB Peak [mm]		9.9



Test Laboratory: ADR TCC SAR LAB

System check_head_3500MHz

Device under Test Properties

Model	Dimensions [mm]	
D3500V2-SN：1143	40.0 x 30.0 x 8.0	Phone

Ambient Temperature: 22.7℃; Liquid Temperature: 22.1℃

Exposure Conditions

Phantom Section, TSL	Position, Test Distance [mm]	Band	Group, UID	Frequency [MHz], Channel Number	Conversion Factor	TSL Conductivity [S/m]	TSL Permittivity
Flat,	FRONT, 10.00	D3500	CW, 0--	3500.000, 50	6.88	2.81	39.4

Hardware Setup

Phantom	TSL	Probe, Calibration Date	DAE, Calibration Date
Twin-SAM V8.0 (30deg probe tilt) - 2098	HSL3500 --	EX3DV4 - SN7746, 2023-08-22	DAE4 Sn719, 2023-04-10

Scan Setup

	Area Scan	Zoom Scan
Grid Extents [mm]	60.0 x 80.0	28.0 x 28.0 x 28.0
Grid Steps [mm]	10.0 x 10.0	5.0 x 5.0 x 1.4
Sensor Surface [mm]	3.0	1.4
Graded Grid	N/A	Yes
Grading Ratio	N/A	1.5
MAIA	N/A	N/A
Surface Detection	VMS + 6p	VMS + 6p
Scan Method	Measured	Measured

Measurement Results

	Area Scan	Zoom Scan
Date	2024-03-09, 09:07	2024-03-09, 09:14
psSAR**1g** [W/kg]	6.38	**6.44**
psSAR**10g** [W/kg]	2.44	**2.47**
Power Drift [dB]	0.01	0.01
Power Scaling	Disabled	Disabled
Scaling Factor [dB]		
TSL Correction	No correction	No correction
M2/M1 [%]		75.9
Dist 3dB Peak [mm]		8.6