FCC TEST REPORT PART 2
(Test Under Dynamic Transmission Condition)

Application No.:	ZEWM2311001675RG
Applicant:	vivo Mobile Communication Co., Ltd.
Manufacturer:	vivo Mobile Communication Co., Ltd.
Product Name:	Mobile Phone
Model No.(EUT):	V2318
Trade Mark:	vivo
FCC ID:	2AUCY-V2318
Date of Receipt:	2023/11/08
Date of Test:	2023/11/16 to 2023/12/02
Date of Issue:	2023/12/07
Test conclusion:	**PASS**

REVISION HISTORY

Report Number	Revision	Description	Issue Date
ZEWM2311001675RG03	01	Original	2023/12/07

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Checked By	Roman Pan **Roman Pan**

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1 Introduction

The equipment under test (EUT) is a portable handset that supports the 2G/3G/4G/5G NR/BT/WLAN/NFC frequency band.It contains embedded file system (EFS) version 20 configured for Smart Tx 1st generation (GEN1), but only 2G/3G/4G/5G NR are enabled with Qualcomm Smart Transmit feature to control and manage transmitting power in real time and to ensure at all times the time-averaged RF exposure is in compliance with the FCC requirement. GSM/WCDMA/LTE Standalone/NR SA are configured for peak exposure mode, and NSA and Inter band UL CA are enabled the dynamic mode, we verification the applicable cases in part2.

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

1.1 Details of Client

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1.2 Test Lab Information

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1.3 Bibliography

Report Type	Report No.
ZEWM2311001675RG02_FCC_SAR report_part0	ZEWM2311001675RG02
ZEWM2311001675RG01_FCC SAR Report_part1	ZEWM2311001675RG01

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 DSI (Device State Index) change: To prove that the Smart Transmit feature functions correctly during transition from one device state (DSI) to another.
4. During antenna switch: To prove that the Smart Transmit feature functions correctly during transitions in antenna (such as AsDiv scenario).
5. During time window switch: To prove that the Smart Transmit feature correctly handles the transition from one time window to another specified by FCC and maintains the normalized time-averaged RF exposure to be less than FCC limit of 1.0 at all times.
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 0 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 (for f < 6GHz) 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 5.

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Mathematical expression:

- For sub-6 transmission only:

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

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

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 or 10gSAR values at Plimit corresponding to sub-6 transmission. Plimit is the parameters pre-defined in Part 0 and loaded via Embedded File System (EFS) onto the EUT.

- Demonstrate the total RF exposure averaged over FCC defined time windows does not exceed FCC's SAR limit, through time-averaged SAR measurement. Note as mentioned earlier, this measurement is performed for transmission scenario 1 only.
  - For sub-6 transmission only, measure instantaneous SAR versus time; for LTE+5G NR transmission, request low power (or all-down bits) on LTE so that measured SAR predominantly corresponds to 5G NR.
  - Convert it into RF exposure and divide by respective FCC limits to obtain normalized exposure versus time.
  - Perform time averaging over FCC defined time window.
  - Demonstrate that the total normalized time-averaged RF exposure is less than 1 for transmission scenario 1 at all times.

    Mathematical expression:

    - For sub-6 transmission only:

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

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

where, $pointSAR(t)$, $pointSAR\_Plimit$, and $1g\_or\_10gSAR\_Plimit$ correspond to the measured instantaneous point SAR, measured point SAR at Plimit, and measured 1gSAR or 1gSAR values at Plimit corresponding to sub-6 transmission.

Note: cDASY6 or Cdasy8 measurement system by Schmid & Partner Engineering AG (SPEAG) of Zurich, Switzerland measures relative E-field and provides ratio of $\frac{[pointE(t)]^2}{[pointE\_input.power.limit]^2}$ versus time.

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:

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

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

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

3.2 Test configuration selection criteria for 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 P_{limit} values determined in Part 0 report. Select the band in each supported technology that corresponds to the P_{limit} value that is less than P_{max} for validating Smart Transmit.

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

3.2.2 Test configuration selection for change in call

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

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

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

3.2.3 Test configuration selection for change in antenna

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

- Whenever possible and supported by the DUT, first select antenna switch configuration within the same technology/band (i.e., same technology and band combination).
- Then, select any technology/band that supports multiple Tx antennas, and has the highest difference in Plimit among all supported antennas.
- In case of multiple bands having same difference in Plimit among supported antennas, then select the band having the highest measured 1gSAR at Plimit in Part 1 report.

This test is performed with the DUT's Tx power requested to be at maximum power in selected technology/band, and antenna change is conducted during Tx power enforcement duration (i.e., during the time when DUT is forced to have Tx power at 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 $P_{limit} < P_{max}$ within any technology and DSI group, and for the same technology/band having a different P_{limit} in any other DSI group. Note that the selected DSI transition need to be supported by the device.

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

3.2.5 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 at 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. 5G 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 + 5G NR transmission) is sufficient, where the SAR exposure varies among SAR_{radio1} only, SAR_{radio1} + SAR_{radio2}, and SAR_{radio2} only scenarios.

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

- Select any two < 6GHz technologies/bands that the EUT supports simultaneous transmission (for example, LTE+5G NR).
- Among all supported simultaneous transmission configurations, the selection order is

1. select one configuration where both P_{limit} of radio1 and radio2 is less than their corresponding P_{max}, preferably, with different P_{limits}. If this configuration is not available, then,
2. select one configuration that has P_{limit} less than its P_{max} for at least one radio. If this cannot be found, then,
3. select one configuration that has P_{limit} of radio1 and radio2 greater than P_{max} but with least (P_{limit} – P_{max}) delta.

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

3.2.6 Test configuration selection for change in time window

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

- Select any technology/band that has operation frequency classified in one time window defined by FCC (such as 100s time window), and its corresponding Plimit is less than Pmax if possible.
- Select the 2nd technology/band that has operation frequency classified in a different time window defined by FCC (such as 60s time window), and its corresponding Plimit is less than Pmax if possible.
- It is preferred both Plimit values of two selected technology/bands are less than corresponding Pmax, but if not possible or due to limitation of test setup, then at least one of technologies/bands has its Plimit less than Pmax.
- Else, if all Plimit > Pmax, then,

✓ First select both technologies/bands (one is in 100s time window, another is in 60s time window) having (Plimit – Pmax) < 2.2dB; if it is not available, then

✓ Select at least one technology/band in 60s time window having (Plimit – Pmax) < 2.2dB; if it it not available, then

✓ Test for change in time window is not required.

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

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

3.3 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 exceed the FCC limit at all times (see Eq. (1a) and (1b)).

Test procedure

1. Measure P_{max}, measure P_{limit} and calculate $P_{reserve}$ (= measured P_{limit} in dBm – *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 P_{max} and measured P_{limit} of the EUT. Test condition to measure P_{max} and P_{limit} is:
   - □ Measure P_{max} with Smart Transmit disabled and callbox set to request maximum power.
   - □ Measure P_{limit} with Smart Transmit enabled and *Reserve_power_margin* set to 0 dB, callbox set to request maximum power.
2. Set *Reserve_power_margin* to actual (intended) value (3dB for this EUT based on Part 1 report) and reset power on EUT to enable Smart Transmit, establish radio link in desired radio configuration, with callbox requesting the EUT's Tx power to be at

   pre-defined test sequence 1, measure and record Tx power versus time, and then convert the conducted Tx power into 1gSAR or 10gSAR value (see Eq. (1a)) using measured P_{limit} from above Step 1. Perform running time average to determine time-averaged power and 1gSAR or 10gSAR versus time as illustrated in Figure 3-1 where using 100-seconds time window as an example.

NOTE: In Eq.(1a), instantaneous Tx power is converted into instantaneous 1gSAR or 10gSAR value by applying the measured worst-case 1gSAR or

10gSAR value at P_{limit} for the corresponding technology/band/antenna/DSI reported in Part 1 report.

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

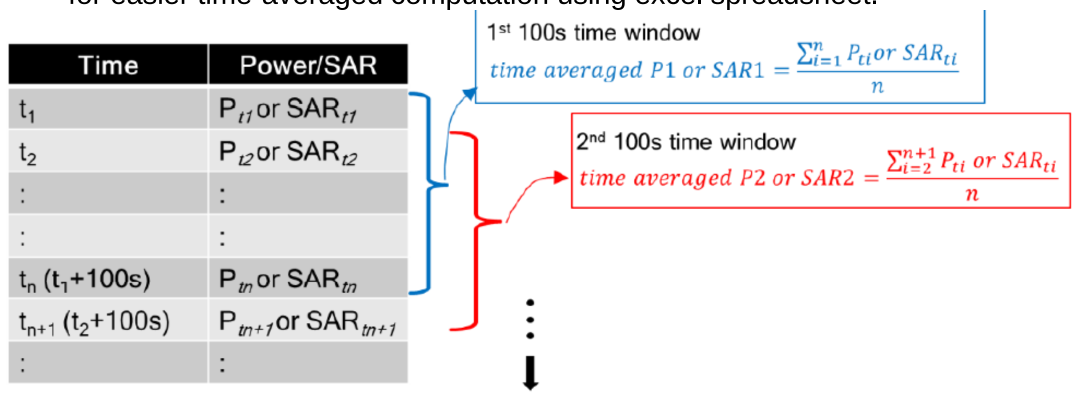

Figure 3-1 100s running average illustration

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 1gSAR or 4.0W/kg for 10gSAR) given by

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

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

4. Make another plot containing:
   a. Computed time-averaged 1gSAR or 10gSAR versus time determined in Step 2
   b. FCC $1gSAR_{limit}$ of 1.6W/kg or FCC $10gSAR_{limit}$ of 4.0W/kg.

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

The validation criteria are, at all times, the time-averaged power versus time shown in Step 3 plot shall not exceed the time-averaged power limit (defined in Eq. (5a)), in turn, the time-averaged 1gSAR or 10gSAR versus time shown in Step 4 plot shall not exceed the FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR (i.e., Eq. (1b)).

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 $P_{reserve}$ level, to demonstrate the continuity of RF exposure management and limiting in call change scenario. In other words, the RF exposure averaged over any FCC defined time window (including the time windows containing the call change) doesn't exceed FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

Test procedure

1. Measure P_{limit} for the technology/band selected in Section 3.2.2. Measure P_{limit} with Smart Transmit enabled and *Reserve_power_margin* set to 0 dB, callbox set to request maximum power.
2. Set *Reserve_power_margin* to actual (intended) value and reset power on EUT to enable Smart Transmit.
3. Establish radio link with callbox in the selected technology/band.
4. Request EUT's Tx power at 0 dBm for at least one time window specified for the selected technology/band, followed by requesting EUT's Tx power to be at maximum power for about ~60 seconds, and then drop the call for ~10 seconds. Afterwards, re-establish another call in the same radio configuration (i.e., same technology/band/channel) and continue callbox requesting EUT's Tx power to be at maximum power for the remaining time of at least another full duration of the specified time window. Measure and record Tx power versus time. Once the measurement is done, extract instantaneous Tx power versus time, convert the measured conducted Tx power into 1gSAR or 10gSAR value using Eq. (1a), and then perform the running time average to determine time-averaged power and 1gSAR or 10gSAR versus time.

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

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

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

3.3.3 Change in antenna

This test is to demonstrate the correct power control by Smart Transmit during antenna switches from one antenna to another. 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.

Similar to the change in call test in Section 3.3.2, to validate the continuity of RF exposure limiting during the transition, the antenna handover needs to be performed when EUT's Tx power is at $P_{reserve}$ level (i.e., during Tx power enforcement) to make sure that the EUT's Tx power from previous $P_{reserve}$ level to the new $P_{reserve}$ level (corresponding to new antenna). Since the P_{limit} could vary with antenna, Eq. (1a) can be written as follows to convert the instantaneous Tx power in 1gSAR or 10gSAR exposure for the two given radios, respectively:

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

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

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

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 antenna1; *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 antenna2. Transition from technology1/band1 to the technology2/band2 happens at time-instant 't_1'.

Test procedure

1. Measure P_{limit} for both the antennas selected in Section 3.2.3. Measure P_{limit} with Smart Transmit enabled and *Reserve_power_margin* set to 0 dB, callbox set to request maximum power.
2. Set *Reserve_power_margin* to actual (intended) value and reset power on EUT to enable Smart Transmit
3. Establish radio link with callbox in first antenna 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 P_{limit} values from Step 1 of this section. Perform the running time average to determine time-averaged power and 1gSAR or 10gSAR versus time.

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

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 using Eq.(5a).
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 (i.e., Eq. (6c)).

3.3.4 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 antenna 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.

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3.3.5 SAR exposure switching

This test is to demonstrate that Smart Transmit feature is accurately accounts for switching in exposures among SAR from radio1 only, SAR from both radio1 and radio2, and SAR from radio2 only scenarios, and ensures total time-averaged RF exposure complies with the FCC limit. Here, radio1 represents primary radio (for example, LTE anchor in a NR non-standalone mode call) and radio2 represents secondary radio (for example, 5G NR). The detailed test procedure for SAR exposure switching in the case of LTE+5G NR non-standalone mode transmission scenario is provided in Appendix B.

Test procedure:

1. Measure conducted Tx power corresponding to P_{limit} for radio1 and radio2 in selected band. Test condition to measure conducted P_{limit} is:
   - □ Establish device in call with the callbox for radio1 technology/band. Measure conducted Tx power corresponding to radio1 P_{limit} with Smart Transmit enabled and *Reserve_power_margin* set to 0 dB, callbox set to request maximum power.
   - □ Repeat above step to measure conducted Tx power corresponding to radio2 P_{limit}. If radio2 is dependent on radio1 (for example, non-standalone mode of 5G 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 5G NR, measured conducted Tx power corresponds to radio2 P_{limit} (as radio1 LTE is at all-down bits)
2. Set *Reserve_power_margin* to actual (intended) value, with EUT setup for radio1 + radio2 call. In this description, it is assumed that radio2 has lower priority than radio1. Establish device in radio1+radio2 call, and request all-down bits or low power on radio1, with callbox requesting EUT's Tx power to be at maximum power in radio2 for at least one time window. After one time window, set callbox to request EUT's Tx power to be at maximum power on radio1, i.e., all-up bits. Continue radio1+radio2 call with both radios at maximum power for at least one time window, and drop (or request all-down bits on) radio2. Continue radio1 at maximum power for at least one time window. Record the conducted Tx power for both radio1 and radio2 for the entire duration of this test.
3. Once the measurement is done, extract instantaneous Tx power versus time for both radio1 and radio2 links. Convert the conducted Tx power for both these radios into 1gSAR or 10gSAR value (see Eq. (6a) and (6b)) using corresponding technology/band P_{limit} measured in Step 1, and then perform the running time

average to determine time-averaged 1gSAR or 10gSAR versus time.

4. Make one plot containing: (a) instantaneous Tx power versus time measured in Step 2.
5. Make another plot containing: (a) instantaneous 1gSAR versus time determined in Step 3, (b) computed time-averaged 1gSAR versus time determined in Step 3, and (c) corresponding regulatory $1gSAR_{limit}$ of 1.6W/kg or $10gSAR_{limit}$ of 4.0W/kg.

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

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 Plimit, and compliance 1g_ or 10g_SAR values at P_{limit_1} of band1 with time-averaging window 'T1$_{SAR}$'; conducted_Tx_power$_{2}$(t), conducted_Tx_power_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 conducted Tx power corresponding to P_{limit} for radio1 and radio2 in selected band. Test condition to measure conducted P_{limit} is:
   - □ Establish device in call with the callbox for radio1 technology/band. Measure conducted Tx power corresponding to radio1 P_{limit} with Smart Transmit enabled and *Reserve_power_margin* set to 0 dB, callbox set to request maximum power.
   - □ Repeat above step to measure conducted Tx power corresponding to radio2 P_{limit}. If radio2 is dependent on radio1 (for example, non-standalone mode of 5G 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 5G NR, measured conducted Tx power corresponds to radio2 P_{limit} (as radio1 LTE is at all-down bits)
2. Set *Reserve_power_margin* to actual (intended) value, with EUT setup for radio1 + radio2 call. In this description, it is assumed that radio2 has lower priority than radio1. Establish device in radio1+radio2 call, and request all-down bits or low power on radio1, with callbox requesting EUT's Tx power to be at maximum power in radio2 for at least one time window. After one time window, set callbox to request EUT's Tx power to be at maximum power on radio1, i.e., all-up bits. Continue radio1+radio2 call with both radios at maximum power for at least one time window, and drop (or request all-down bits on) radio2. Continue radio1 at maximum power for at least one time window. Record the conducted Tx power for both radio1 and radio2 for the entire duration of this test.
3. Once the measurement is done, extract instantaneous Tx power versus time for both radio1 and radio2 links. Convert the conducted Tx power for both these radios into 1gSAR or 10gSAR value (see Eq. (6a) and (6b)) using corresponding technology/band P_{limit} measured in Step 1, and then perform the running time average to determine time-averaged 1gSAR or 10gSAR versus time.
4. Make one plot containing: (a) instantaneous Tx power versus time measured in Step 2.
5. Make another plot containing: (a) instantaneous 1gSAR versus time determined in Step 3, (b) computed time-averaged 1gSAR versus time determined in Step 3, and (c) corresponding regulatory $1gSAR_{limit}$ of 1.6W/kg or $10gSAR_{limit}$ of 4.0W/kg.

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

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 i n 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 (Over the Air) 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:
   - i For a 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*_P_{limit}, corresponds to point SAR at the measured P_{limit} (i.e., measured P_{limit} from the EUT in Step 1 of Section 3.3.1).
   - ii 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.i. Establish radio link in desired

radio configuration, with callbox requesting the EUT's Tx power at power levels described by test sequence 1 generated in Step 1 of Section 3.3.1, conduct point SAR measurement versus time at peak location of the area scan determined in Step 2.i of this section. Once the measurement is done, extract instantaneous point SAR vs time data, *pointSAR(t)*, and convert it into instantaneous 1gSAR or 10gSAR vs. time using Eq. (3a), re-written below:

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

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

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

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

v Repeat 2.ii ~ 2.iv for test sequence 2 generated in Step 1 of Section 3.3.1.

vi Repeat 2.i ~ 2.v 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 (i.e., Eq. (3b)).

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 0 report and summarized in Table 4-1.

Table 4-1: Plimit for supported technologies and bands (Plimit in EFS file)

Band	Mode	Antenna	P_{max*}	P_{limit} (average)			
				Head	Limbs	Hotspot	Body worn
				DSI 2	DSI 4	DSI 6	DSI 7
GSM 850	GPRS 2TS	11#	25.1	/	25.1	/	25.1
	GPRS 4TS		24.6	23.8	/	23.9	/
	GPRS 2TS	41#	25.0	25.0	25.0	/	25.0
	GPRS 4TS		24.5	/	/	24.2	/
GSM 1900	GPRS 2TS	14#	22.2	/	22.2	/	22.2
	GPRS 4TS		21.7	18.4	/	21.0	/
	GPRS 1TS	31#	21.0	/	/	20.1	/
	GPRS 2TS		22.0	22.0	22.0	/	22.0
WCDMA_B2	RMC	14#	23.1	17.1	20.6	19.1	23.1
	RMC	31#	23.0	23.0	20.5	19.0	20.5
WCDMA_B4	RMC	14#	24.3	17.3	20.3	19.3	23.8
	RMC	31#	24.0	24.0	20.0	18.5	20.0
WCDMA_B5	RMC	11#	24.2	22.7	24.2	22.7	24.2
	RMC	41#	24.0	24.0	24.0	23.0	24.0
LTE_B2	QPSK	14#	23.9	17.9	21.4	19.9	23.9
	QPSK	31#	23.6	23.6	21.1	19.6	21.1
LTE_B4	QPSK	12#	23.4	23.4	23.4	23.4	23.4

	QPSK	14#	24.5	17.5	21.0	19.5	24.5
	QPSK	31#	24.0	24.0	20.5	18.5	20.5
LTE_B5	QPSK	11#	24.1	23.1	24.1	23.1	24.1
	QPSK	41#	24.0	24.0	24.0	23.5	24.0
LTE_B7	QPSK	12#	24.1	20.6	21.6	19.6	24.1
	QPSK	14#	23.7	16.2	21.2	19.7	23.7
	QPSK	31#	23.6	23.6	21.1	19.6	21.1
LTE_B12	QPSK	11#	24.2	24.2	24.2	24.2	24.2
	QPSK	41#	24.0	24.0	24.0	24.0	24.0
LTE_B13	QPSK	11#	24	24.0	24.0	23.5	24.0
	QPSK	41#	24.0	24.0	24.0	24.0	24.0
LTE_B17	QPSK	11#	24.2	24.2	24.2	24.2	24.2
	QPSK	41#	24.0	24.0	24.0	24.0	24.0
LTE_B26	QPSK	11#	23.7	23.2	23.7	23.7	23.7
	QPSK	41#	23.5	23.5	23.5	23.0	23.5
LTE_B38	QPSK	14#	22.2	17.2	21.7	20.2	22.2
	QPSK	31#	22.2	22.2	21.7	20.2	21.7
LTE_B41	QPSK	14#	22.2	15.7	21.2	19.7	22.2
	QPSK	31#	22.2	22.2	20.7	19.2	20.7
LTE_B66	QPSK	14#	24.5	17.5	21.0	19.5	24.5
	QPSK	31#	24.2	24.2	20.7	18.7	20.7
NR5G_N2	QPSK	12#	23.0	20.5	21.5	20.0	23.0
	QPSK	14#	23.5	17.0	20.5	18.5	23.5
	QPSK	31#	23.5	23.5	20.5	19.0	20.5
NR5G_N5	QPSK	11#	24.4	21.9	24.4	23.4	24.4
	QPSK	41#	24.5	24.5	24.5	23.5	24.5
NR5G_N7	QPSK	12#	23.7	20.2	21.7	20.2	23.7
	QPSK	14#	23.3	15.3	19.8	18.3	22.8
	QPSK	31#	23.5	23.5	20.5	19.0	20.5

NR5G_N26	QPSK	11#	23.5	22.0	23.5	22.0	23.5
	QPSK	41#	24.0	24.0	24.0	23.5	24.0
NR5G_N38	QPSK	12#	24.5	20.5	20.5	19.0	24.5
	QPSK	14#	23.3	16.8	20.8	18.8	23.3
	QPSK	31#	24.0	24.0	21.0	19.5	21.0
NR5G_N41 PC2 100% Duty Cycle	QPSK	12#	24.5	20.5	21.0	19.0	24.5
	QPSK	14#	23.6	16.1	21.1	19.1	23.6
	QPSK	24#	23.3	16.3	20.3	18.8	20.3
	QPSK	31#	24.0	24.0	21.0	19.5	21.0
NR5G_N41 PC3 100% Duty Cycle	QPSK	12#	22.8	20.5	21.0	19.0	22.8
	QPSK	14#	22.8	16.1	21.1	19.1	23.6
	QPSK	24#	22.5	16.3	20.3	18.8	20.3
	QPSK	31#	23.0	23.0	21.0	19.5	21.0
NR5G_N66	QPSK	12#	23.1	23.1	23.1	23.1	23.1
	QPSK	14#	23.6	17.0	20.5	19.0	24.0
	QPSK	31#	24.5	24.5	20.5	19.0	20.5
NR5G_N77	QPSK	13#	23.5	18.0	17.5	16.0	21.5
	QPSK	23#	22.0	17.0	19.5	18.0	19.5
	QPSK	15#	22.9	16.6	20.6	18.6	22.9
	QPSK	21#	22.0	13.4	15.9	13.9	15.9
NR5G_N78 PC2 100% Duty Cycle	QPSK	13#	26.0	18.0	17.5	15.5	21.5
	QPSK	23#	23.8	16.8	19.3	17.8	19.3
	QPSK	15#	25.6	16.6	20.6	18.6	23.6
	QPSK	21#	22.9	13.4	15.9	13.9	15.9
NR5G_N78 PC3 100% Duty Cycle	QPSK	13#	23.0	18.0	17.5	15.5	21.5
	QPSK	23#	19.5	15.8	18.3	16.8	18.3
	QPSK	15#	23.2	16.6	20.6	18.6	23.2
	QPSK	21#	20.2	13.4	15.9	13.9	15.9

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

Uncertainty dB (k=2)	All Band
Total uncertainty	1.49

To account for total uncertainty, SAR_design_target should be determined as:

$$SAR\_design\_target < SARregulatory\_limit \times 10^{\frac{-\text{total uncertainty}}{10}}$$

Exposure position	**Frequency band**	**SAR_Regulatory_Limit W/kg(1g)**	**SAR_design_target W/kg(1g)**
Head	WWAN	1.6	0.60
Body worn	WWAN	1.6	0.75
Hotspot	WWAN	1.6	0.50
Exposure position	**Frequency band**	**SAR_Regulatory_Limit W/kg(10g)**	**SAR_design_target W/kg(10g)**
Product specific 10gSAR	WWAN	4.0	2.00

Table4-2: Radio configurations selected for Part 2 test

Part 2 test configurations											Part 1 worst-case ratio config 1g SAR measured at P_{limit}
Test case No.	Test scenario	Tech.	Band	Ant	DSI	RB Size	Channel/Freq (MHz)	mode	position	Distance (mm)	
1	time-varying Tx power transmission	DC_7A_n5A	N5	Ant41	DSI6	QPSK 50_28	167300/836.5	QPSK	Back side	10mm	0.244
		DC_2A_n78A	N78	Ant13	DSI6	QPSK 1_1	650000/3750	QPSK	Left side	10mm	0.483
2	change in call	DC_2A_n78A	N78	Ant13	DSI6	QPSK 1_1	650000/3750	QPSK	Left side	10mm	0.483
3	Antenna Switch	DC_2A_n7A	N7	Ant12	DSI6	QPSK 1_108	504000/2520	QPSK	Back side	10mm	0.264
			N7	Ant14	DSI6	QPSK 108_54	507000/2535	QPSK	Top side	10mm	0.336
4	Change In DSI	DC_2A_n7A	N7	Ant14	DSI2	QPSK 1_214	504000/2520	QPSK	Right tilted	0mm	0.613
			N7	Ant14	DSI6	QPSK 108_54	507000/2535	QPSK	Top side	10mm	0.336
5	Time Windows Switch (100-60-100)	SA	N41	Ant31	DSI6	QPSK 135_69	513900/2569.5	QPSK	Back side	10mm	0.319
		SA	N78	Ant13	DSI6	QPSK 1_1	650000/3750	QPSK	Left side	10mm	0.483
	Time Windows Switch （60-100-60）	SA	N78	Ant13	DSI6	QPSK 1_1	650000/3750	QPSK	Left side	10mm	0.483
		SA	N41	Ant31	DSI6	QPSK 135_69	513900/2569.5	QPSK	Back side	10mm	0.319
6	SAR1 vs SAR2	DC_2A_n78A	LTE Band 2	Ant14	DSI6	QPSK 1_50	18700/1860	QPSK	Top side	10mm	0.364
			N78	Ant13	DSI6	QPSK 1_1	650000/3750	QPSK	Left side	10mm	0.483
7	SAR1 vs SAR2	CA_2A_7A	LTE Band 2	Ant31	DSI6	QPSK 1_0	18700/1860	QPSK	Bottom side	10mm	0.408
			LTE Band 7	Ant14	DSI6	QPSK 50_50	21350/2560	QPSK	Top side	10mm	0.393

The radio configurations used in Part 2 test for selected technologies, bands, DSIs and antennas are listed in Table 4-2. The corresponding worst-case radio configuration 1gSAR or 10gSAR values for selected technology/band/DSI are extracted from Part 1 report and are listed in the last column of Table 4-2.

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

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

1. Technologies and bands for time-varying Tx power transmission: The test case 1 listed in Table 4-2 are selected to test with the test sequences defined in Section 3.1 in both time-varying conducted power measurement and time-varying SAR measurement.
2. Technology and band for change in call test: The test case 2 listed in Table 4-2 are selected for performing the call drop test in conducted power setup. NSA N78 having the lowest P_{limit} among all technologies and bands.
3. Antenna switch: The test case 3 listed in Table 4-2 is selected for antenna switch

from NSA N7 Antenna 12 to NSA N7 Antenna 14, in conducted power setup.

4. Technologies and bands for change in DSI: The test case 4 listed in Table 4-2 is selected for DSI switch test by establishing a call in NSA N7 in DSI=2, and then handing over to DSI = 6 exposure scenario in conducted power setup.
5. Technologies and bands for change in time-window: The test case 5 listed in Table 4-2 is selected for time window switch between 60s window (NR N78) and 100s window (NR N41) in conducted power setup. NR N41 is using different antenna from NR N78, so this test also address the antenna change.
6. Technologies and bands for switch in SAR exposure: The test case 6-7 listed in Table 4-2 are selected for SAR exposure switching test in one of the supported simultaneous WWAN transmission scenario, i.e., LTE + 5G NR active or LTE Inter-Band Uplink CA active, in conducted power setup.

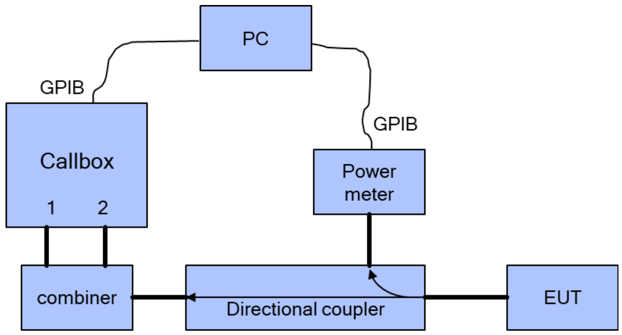
5 Conducted Power Test Results for Sub-6 Smart Transmit Feature Validation

5.1 Measurement setup

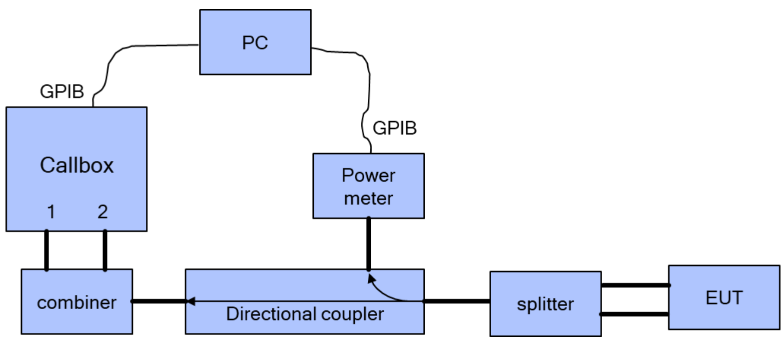
The Rohde & Schwarz callbox is used in this test. The test setup schematic are shown in Figures 6-1. For single antenna measurement, one port (RF1 COM) of the callbox is connected to the RF port of the EUT using a directional coupler. For antenna & technology switch measurement, two ports (RF1 COM and 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 Keysight UXME7515B callbox is used in this test. The test setup schematic are shown in Figures 6-1. For single antenna measurement, one port (RF1 COM) of the callbox is connected to the RF port of the EUT using a directional coupler.

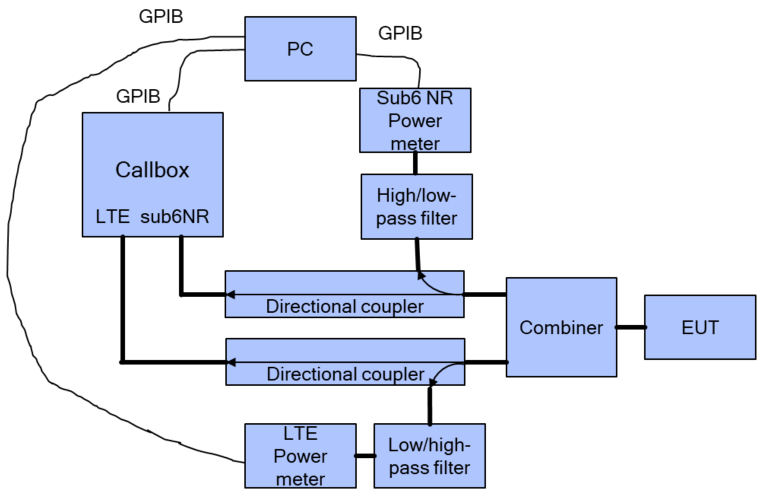
LTE+5G NR test setup:
The Keysight UXME7515B callbox is used in this test. If LTE conducted port and 5G NR conducted port are same on this EUT (i.e., they share the same antenna), therefore, low-/high-pass filter are used to separate LTE and 5G NR signals for power meter measurement via directional couplers, as shown in below Figure 6-1 C (Appendix F – Test Setup Photo).
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.


PC
GPIB
GPIB
Callbox
1
2
Power
meter
combiner
Directional coupler
EUT

(a)


PC
GPIB
GPIB
Callbox
1
2
Power
meter
combiner
Directional coupler
splitter
EUT

(b)



(c)

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 $P_{reserve}$ 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 P_{limit} for all the selected radio configurations given in Table 4-2 are listed in below Table. P_{max} was also measured for radio configurations selected for testing time-varying Tx power transmission scenarios in order to generate test sequences following the test procedures in Section 3.

Table5-1: Measured Plimit and Pmax of selected radio configurations

Part 2 test configurations														
Test case No.	Test scenario	Tech.	Band	Ant	DSI	RB Size	Channel/Freq (MHz)	mode	position	Distance (mm)	Pmax EFS setting(dBm)	Plimit EFS setting(dBm)	Measured Pmax (dBm)	Measured Plimit (dBm)
1	time-varying Tx power transmission	DC_7A_n5A	N5	Ant41	DSI6	QPSK 50_28	167300/836.5	QPSK	Back side	10mm	24.5	23.5	24.94	23.69
		DC_2A_n78A	N78	Ant13	DSI6	QPSK 1_1	650000/3750	QPSK	Left side	10mm	26.0	15.5	26.02	15.54
2	change in call	DC_2A_n78A	N78	Ant13	DSI6	QPSK 1_1	650000/3750	QPSK	Left side	10mm	26.0	15.5	26.02	15.54
3	Antenna Switch	DC_2A_n7A	N7	Ant12	DSI6	QPSK 1_108	504000/2520	QPSK	Back side	10mm	23.7	19.7	23.72	20.21
			N7	Ant14	DSI6	QPSK 108_54	507000/2535	QPSK	Top side	10mm	23.3	18.3	22.83	18.31
4	Change In DSI	DC_2A_n7A	N7	Ant14	DSI2	QPSK 1_214	504000/2520	QPSK	Right tilted	0mm	23.3	15.3	22.85	15.33
			N7	Ant14	DSI6	QPSK 108_54	507000/2535	QPSK	Top side	10mm	23.3	18.3	22.83	18.31
5	Time Windows Switch (100-60-100)	SA	N41	Ant31	DSI6	QPSK 135_69	513900/2569.5	QPSK	Back side	10mm	24.0	19.5	24.02	19.65
		SA	N78	Ant13	DSI6	QPSK 1_1	650000/3750	QPSK	Left side	10mm	26.0	15.5	26.02	15.54
	Time Windows Switch （60-100-60）	SA	N78	Ant13	DSI6	QPSK 1_1	650000/3750	QPSK	Left side	10mm	26.0	15.5	26.02	15.54
		SA	N41	Ant31	DSI6	QPSK 135_69	513900/2569.5	QPSK	Back side	10mm	24.0	19.5	24.02	19.65
6	SAR1 vs SAR2	DC_2A_n78A	LTE Band 2	Ant14	DSI6	QPSK 1_50	18700/1860	QPSK	Top side	10mm	23.9	19.9	23.88	19.89
			N78	Ant13	DSI6	QPSK 1_1	650000/3750	QPSK	Left side	10mm	26.0	15.5	26.02	15.54
7	SAR1 vs SAR2	CA_2A_7A	LTE Band 2	Ant31	DSI6	QPSK 1_0	18700/1860	QPSK	Bottom side	10mm	23.6	19.6	23.89	19.69
			LTE Band 7	Ant14	DSI6	QPSK 50_50	21350/2560	QPSK	Top side	10mm	23.7	19.7	23.26	19.13

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

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

(1a)

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

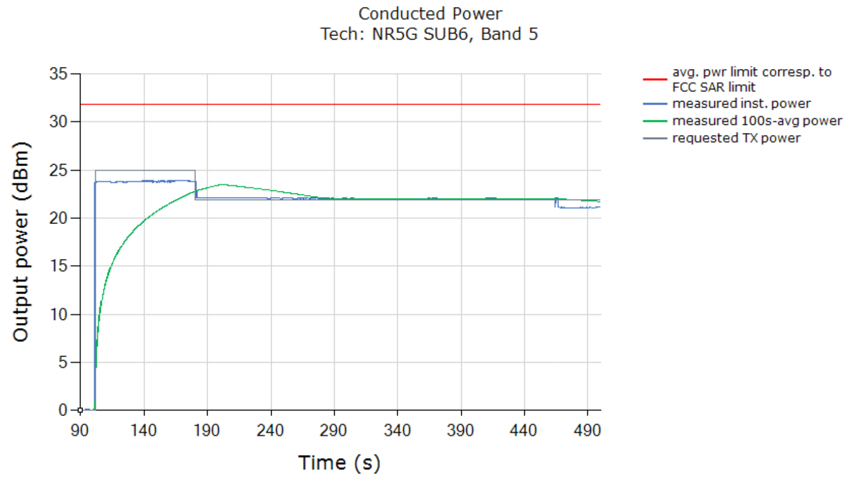
where, $conducted\_Tx\_power(t)$, $conducted\_Tx\_power\_Plimit$, and $1g\_or\_10gSAR\_Plimit$ correspond to the measured instantaneous conducted Tx power, measured conducted Tx power at P_{limit}, and measured *1gSAR* and *10gSAR* values at P_{limit} reported in Part 1 test (listed in Table 4-2 of this 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.

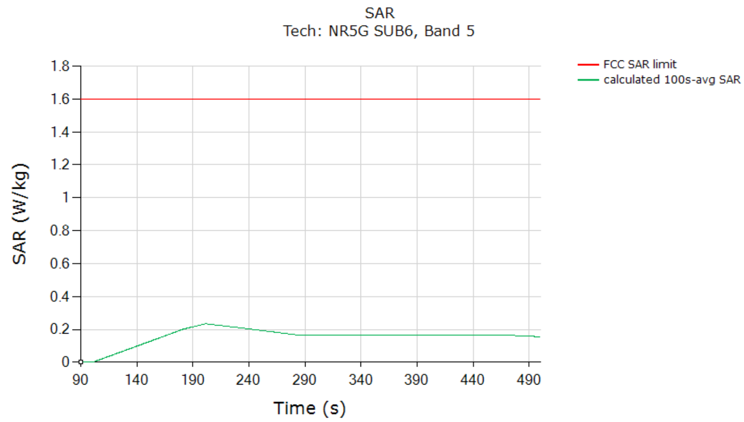
Similarly, in all the 1g or 10gSAR plots (when converted using Eq. (1a)), the green curve represents the 100s/60s-time averaged 1gSAR or 10gSAR value calculated based on instantaneous 1gSAR or 10gSAR; and the red line limit represents the FCC limit of 1.6 W/kg for 1gSAR or 4.0 W/kg for 10gSAR.

5.3.1 **ENDC 7A_n5A**

Test result for test sequence 1:

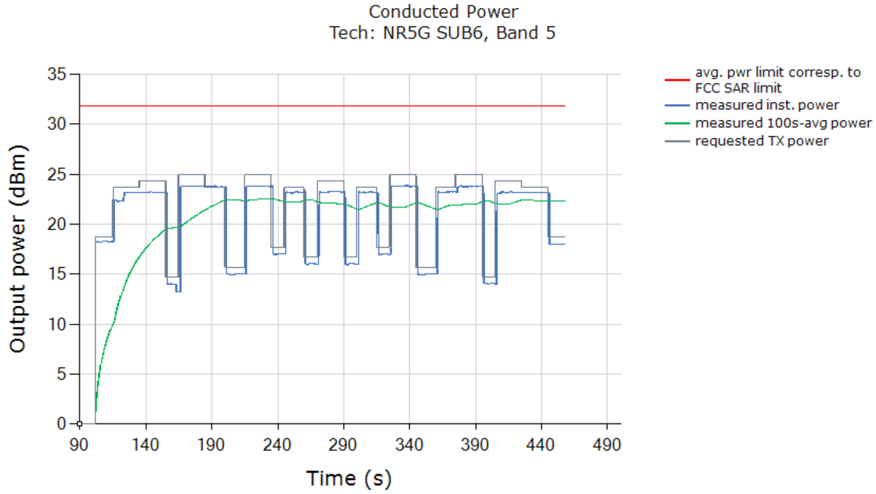


Above time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:

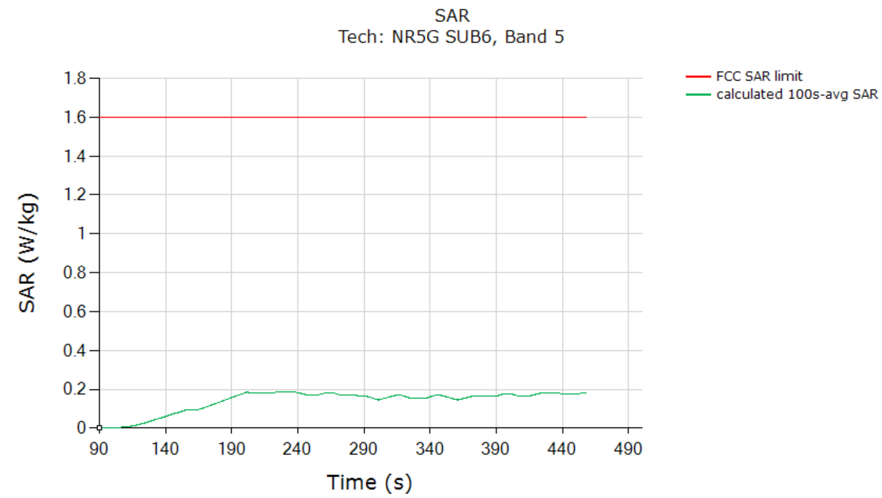


	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.234
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit + device uncertainty	

Test result for test sequence 2:



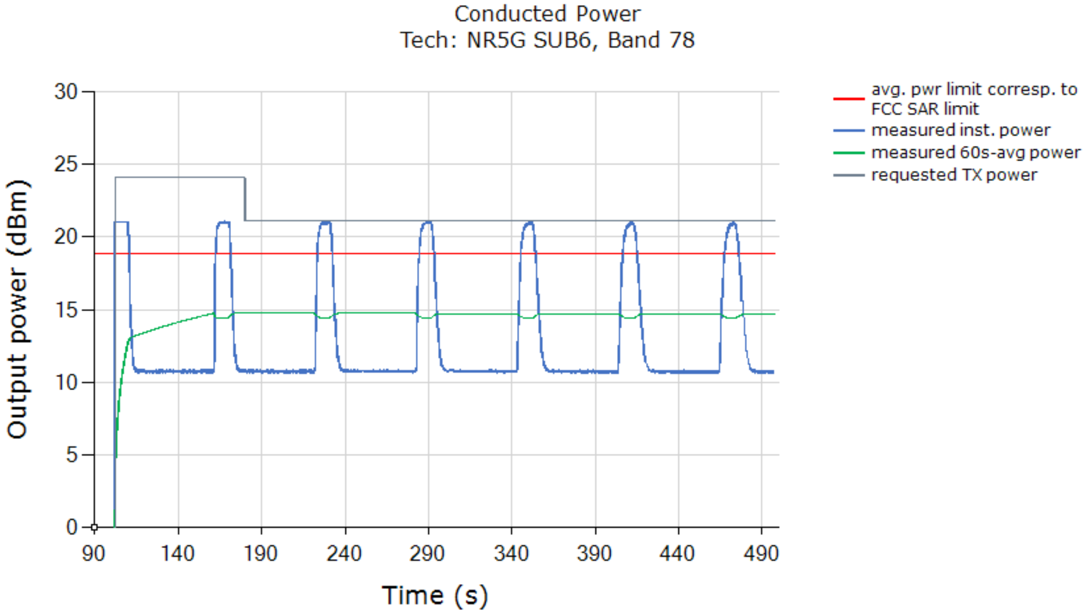
Above time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:



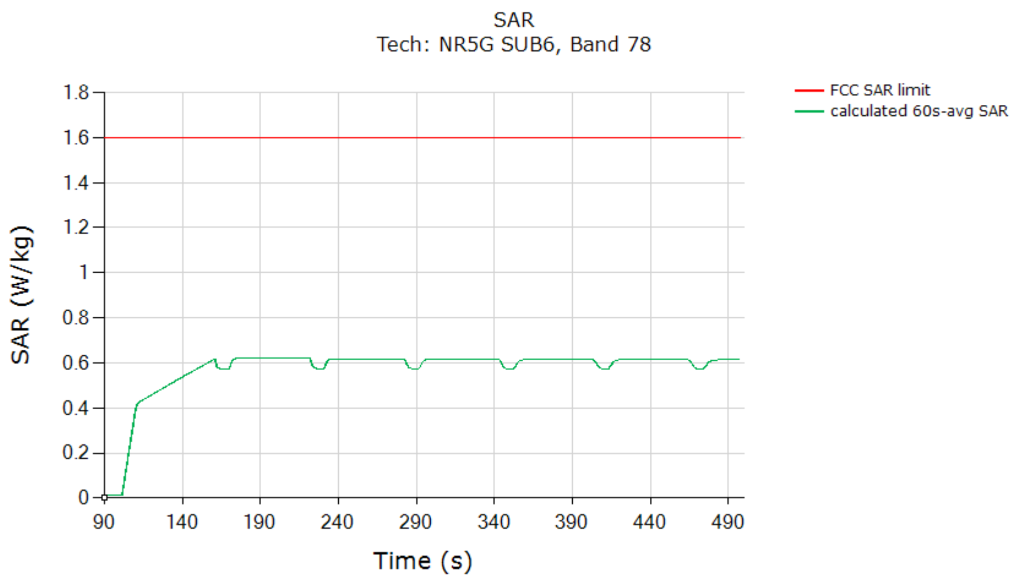
	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.188
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit + device uncertainty	

5.3.2 ENDC 2A_n78A

Test result for test sequence 1:

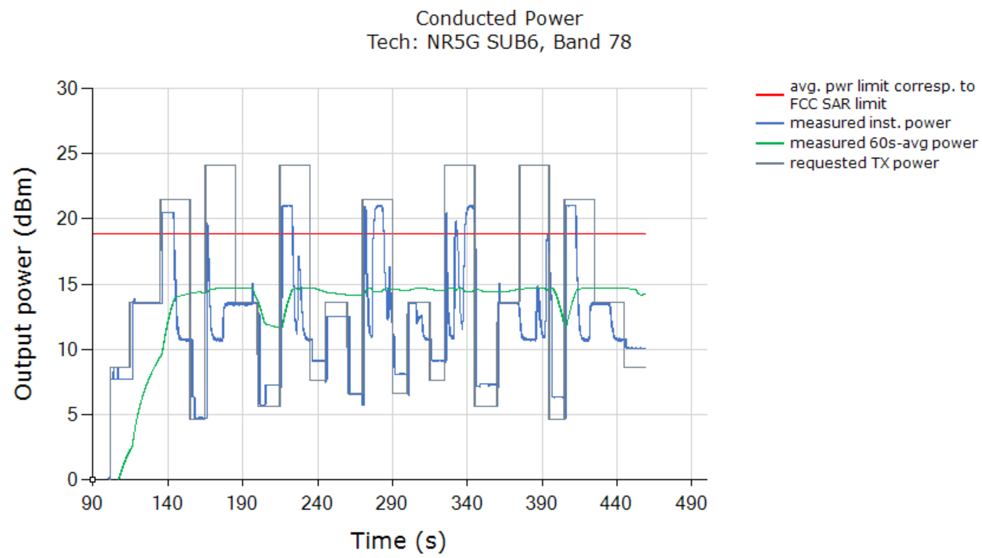


Above time-averaged conducted Tx power is converted/calculated into time-averaged 1gSAR using Equation (1a) and plotted below to demonstrate that the time-averaged 1gSAR versus time does not exceed the FCC limit of 1.6 W/kg for 1gSAR:

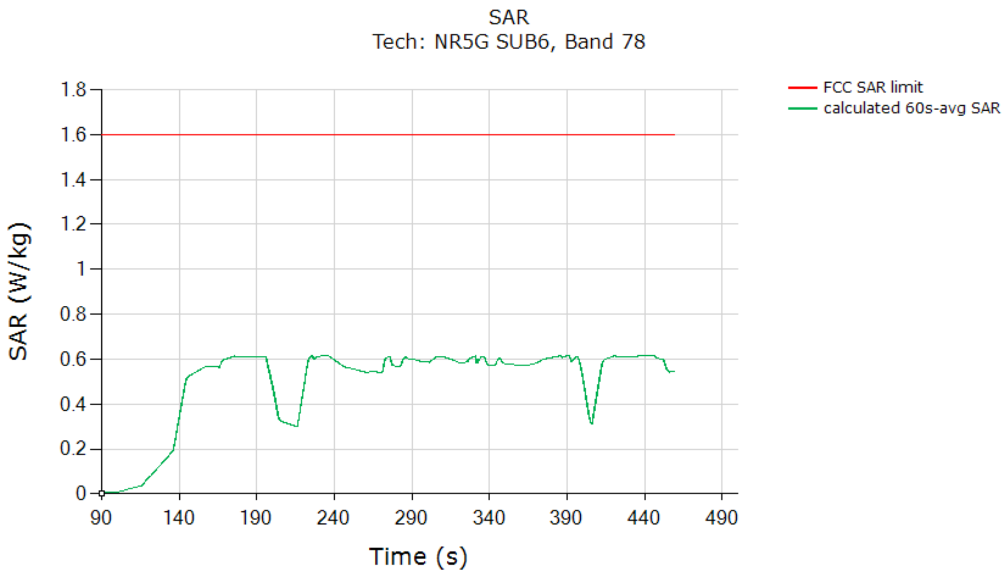


	(W/kg)
FCC 1gSAR limit	1.6
Max 60s-time averaged 1gSAR (green curve)	0.619
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit + device uncertainty	

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)	0.615
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit + device uncertainty	

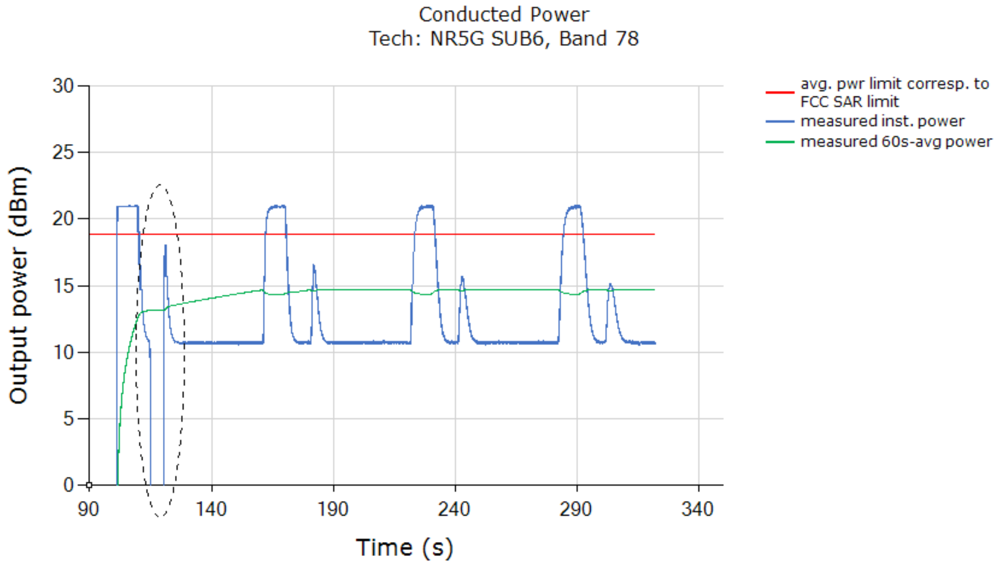
5.4 Change in Call Test Results

This test was measured with ENDC 2A_n78A, DSI=6, and with callbox requesting maximum power. The call drop was manually performed when the EUT is transmitting at $P_{reserve}$ level as shown in the plot below (dotted black region). The measurement setup is shown in Figure 6

1. The detailed test procedure is described in Section 3.3.2.

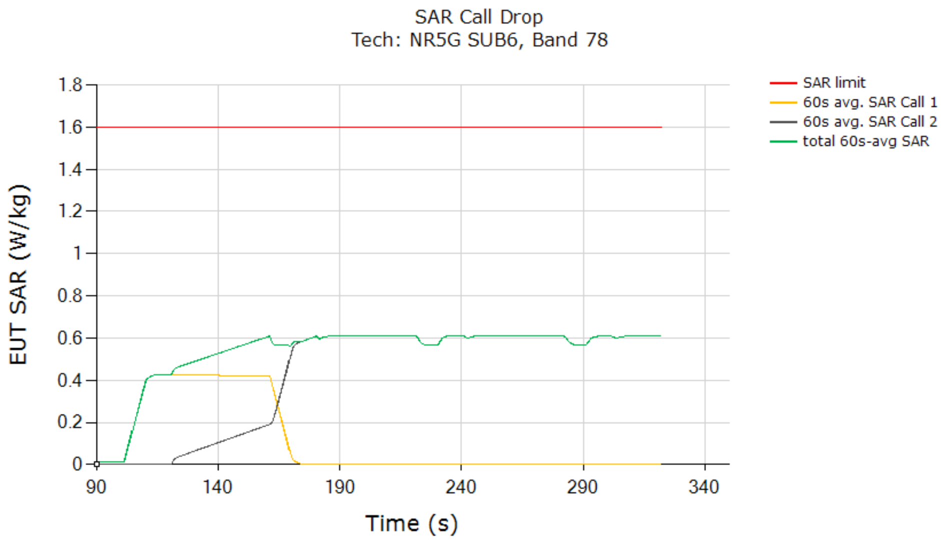
Call drop test result:

Plot 1: Measured Tx power (dBm) versus time shows that the transmitting power kept the same $P_{reserve}$ level of ENDC 2A_n78A after the call was re-established:



Plot Notes: The conducted power plot shows expected Tx transition.

Plot 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)	0.610
Validated	

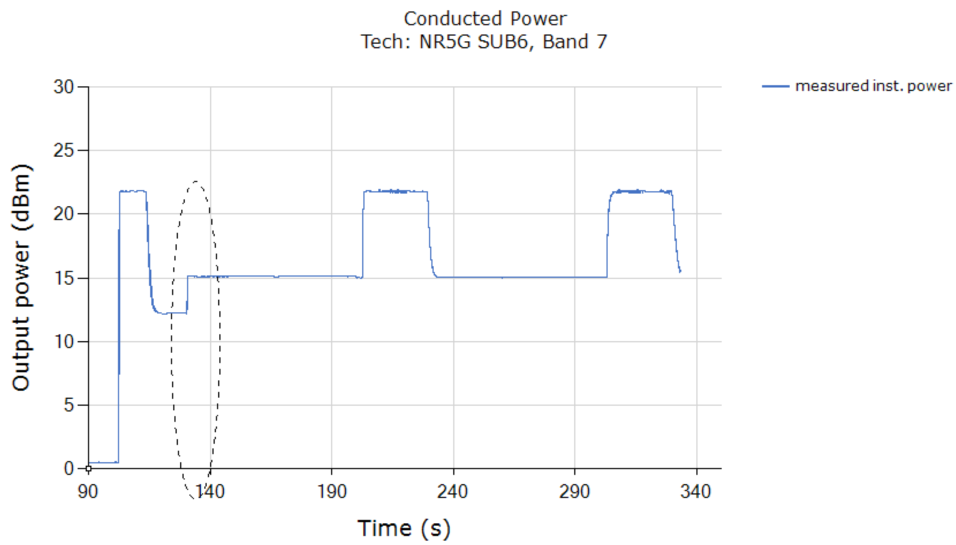
The test result validated the continuity of power limiting in change in call scenario.

5.5 Change in DSI test results

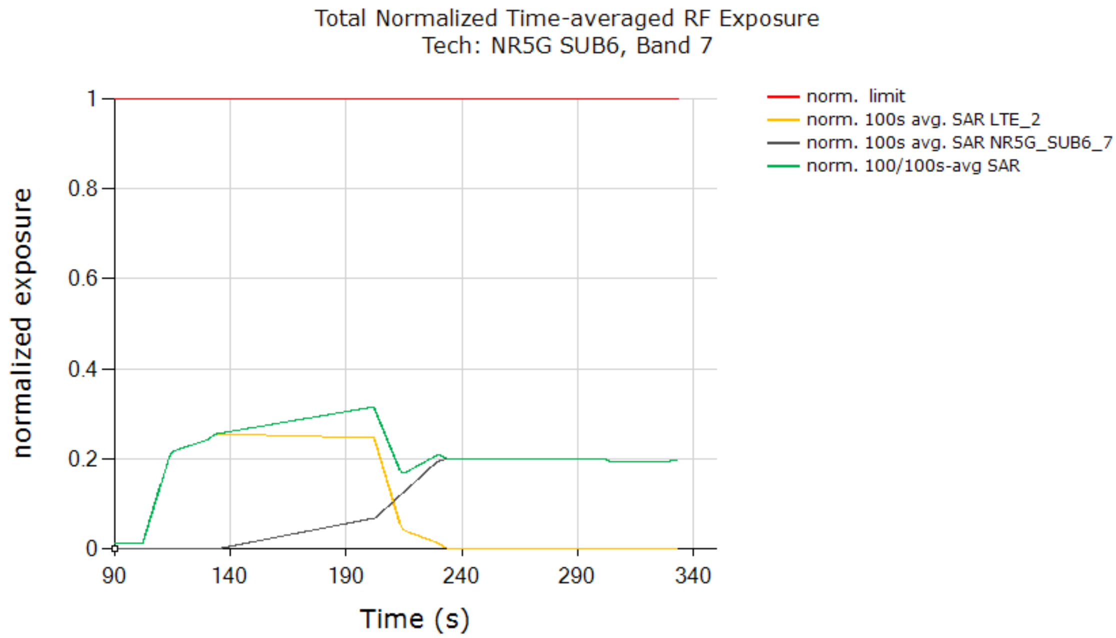
This test was conducted with callbox requesting maximum power, and with DSI switch from ENDC 2A_n7A DSI=2 to DSI = 6. Following procedure detailed in Section 3.3.4 using the measurement setup shown in Figure 5-1(a) and (c), the DSI switch was performed when the EUT is transmitting at $P_{reserve}$ level as shown in the plot below (dotted black circle).

Test result for change in DSI:

Plot 1: Measured Tx power (dBm) versus time shows that the transmitting power changed when DSI=2 to DSI = 6.



Plot 2: All the time-averaged conducted Tx power measurement results were converted into time-averaged normalized SAR values using Equation (6a), (6b) and (6c), and plotted below to demonstrate that the time-averaged normalized Exposure versus time does not exceed the FCC limit of 1 unit.



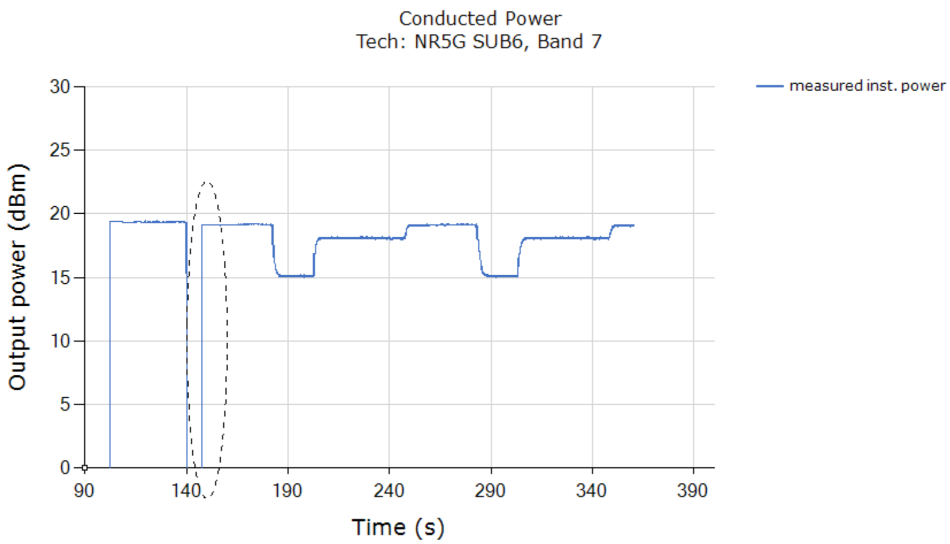
	Exposure Ratio
FCC normalized Exposure Ratio limit	1.0
Max 100s-time averaged normalized Exposure Ratio (green curve)	0.316
Validated	

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

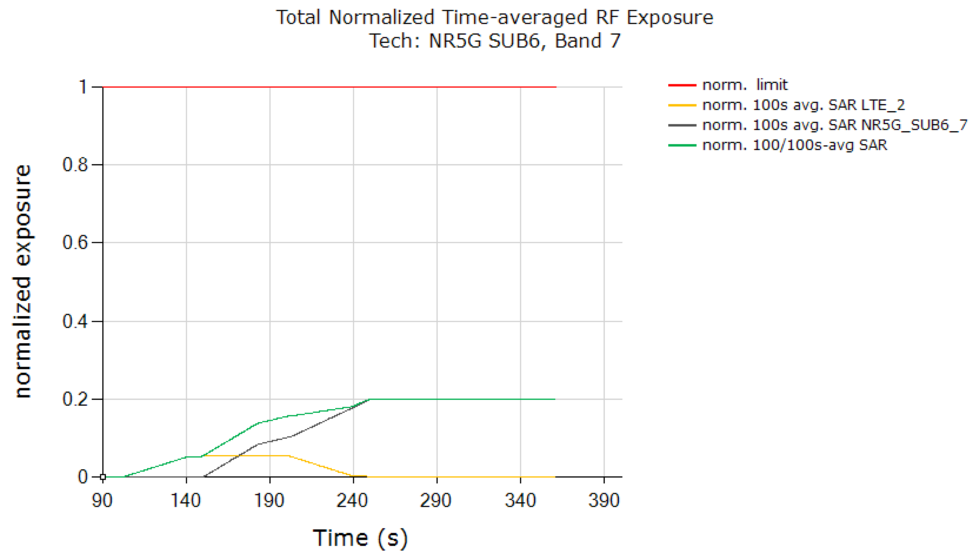
5.6 Change in antenna switch test results

This test was conducted with callbox requesting maximum power, and with Antenna switch from ENDC 2A_n7A Ant 12 to Ant 14. Following procedure detailed before using the measurement setup shown in Figure 5-1(a), the Antenna switch was performed when the EUT is transmitting at Preserve level as shown in the plot below (dotted black circle).

Plot 1: Measured Tx power (dBm) versus time shows that the transmitting power changed when Ant 12 switches to Ant 14.



Plot 2: All the time-averaged conducted Tx power measurement results were converted into time-averaged normalized SAR values and plotted below to demonstrate that the time-averaged normalized Exposure versus time does not exceed the limit of 1 unit.



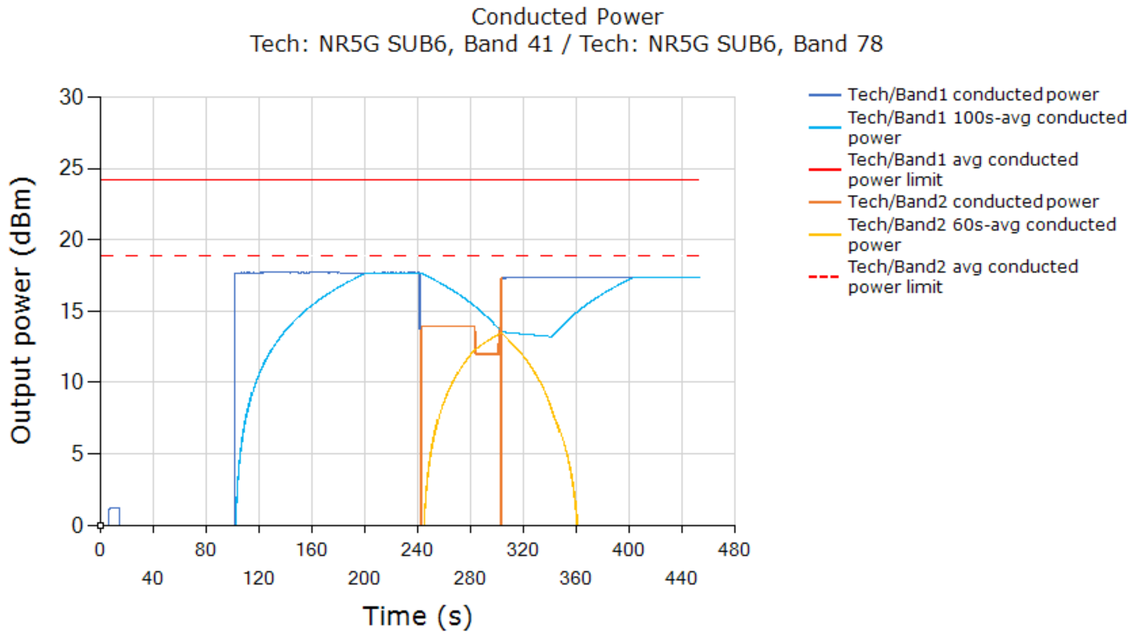
	Exposure Ratio
FCC normalized Exposure Ratio	1.0
Max time averaged normalized Exposure Ratio (green curve)	0.201
Validated	

5.7 Change in Time window

5.7.1 Test case 1: transition from NR N41 to NR N78 (i.e., 100s to 60s), then back to NR N41

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

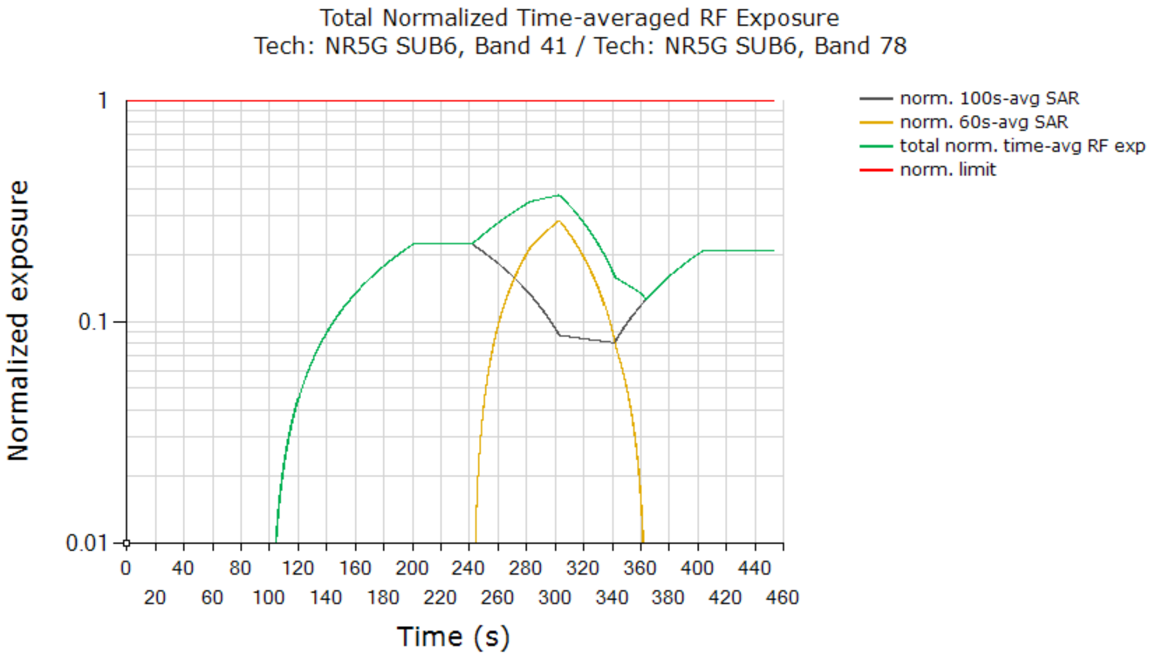
Plot 1: Measured Tx power (dBm) versus time shows that the transmitting power changed when NR N41 switches to NR N78 (~245 seconds timestamp) and switches back to NR N41 (~310 seconds timestamp): switch measurement is performed with the EUT in various SAR exposure scenarios.



Plot Notes: The conducted power plot shows expected transitions in Tx power at ~245 seconds (100s-to-60s transition) and at ~310 seconds (60s-to-100s transition) in order to maintain total time-averaged RF exposure compliance across time windows, as show in next

Plot 2: All the conducted Tx power measurement results were converted into time-averaged normalized SAR values using Equation (7a), (7b) and (7c), and plotted below to demonstrate that the time-averaged normalized SAR versus time does not exceed the FCC limit of 1 unit. Equation (7a) is used to convert the Tx power of device to obtain 100saveragednormalized SAR in NR N41 as shown in black curve. Similarly, equation (7b) isused to obtain 60s-averaged normalized SAR in NR N78 as shown in orange curve.

Equation (7c) is used to obtain total time-averaged normalized SAR as shown in green curve (i.e., sum of black and orange curves)



	Exposure Ratio
FCC normalized Exposure Ratio limit	1.0
Max time averaged normalized Exposure Ratio (green curve)	0.374
Validated	

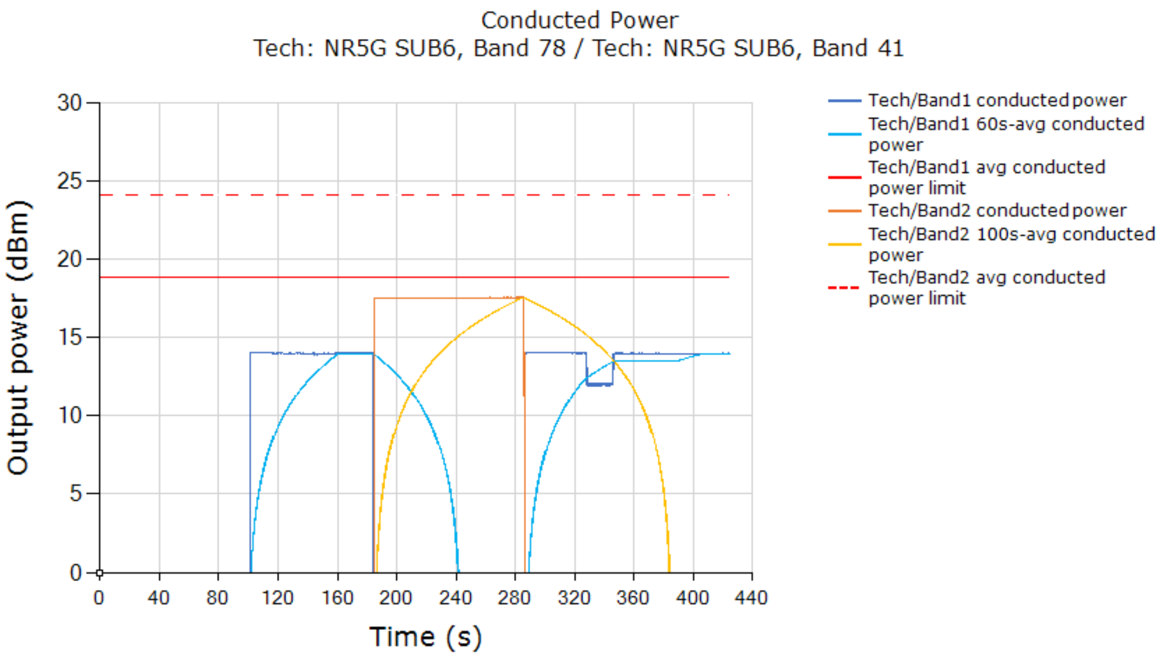
Plot Notes:

Maximum power is requested by callbox for the entire duration of the test, with tech/band switches from 100s-to-60s window at ~245s time stamp, and from 60s-to-100s window at ~310s time stamp. Smart Transmit controls the Tx power during these time window switches to ensure total time-averaged RF exposure, i.e., sum of black and orange curves given by equation (7c), is always compliant. In time-window switch test, at all times the total time averaged normalized RF exposure (green curve) should not exceed normalized SAR_design_target +1.49dB device uncertainty. In this test, with a maximum normalized SAR of 0.374 being ≤ 0.440 (=0.5/1.6 +1.49dB device uncertainty), the above test result validated the continuity of power limiting in time-window switch scenario.

5.7.2 Test case 1: transition from NR N78 to NR N41 (i.e., 60s to 100s), then back to NR N78

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

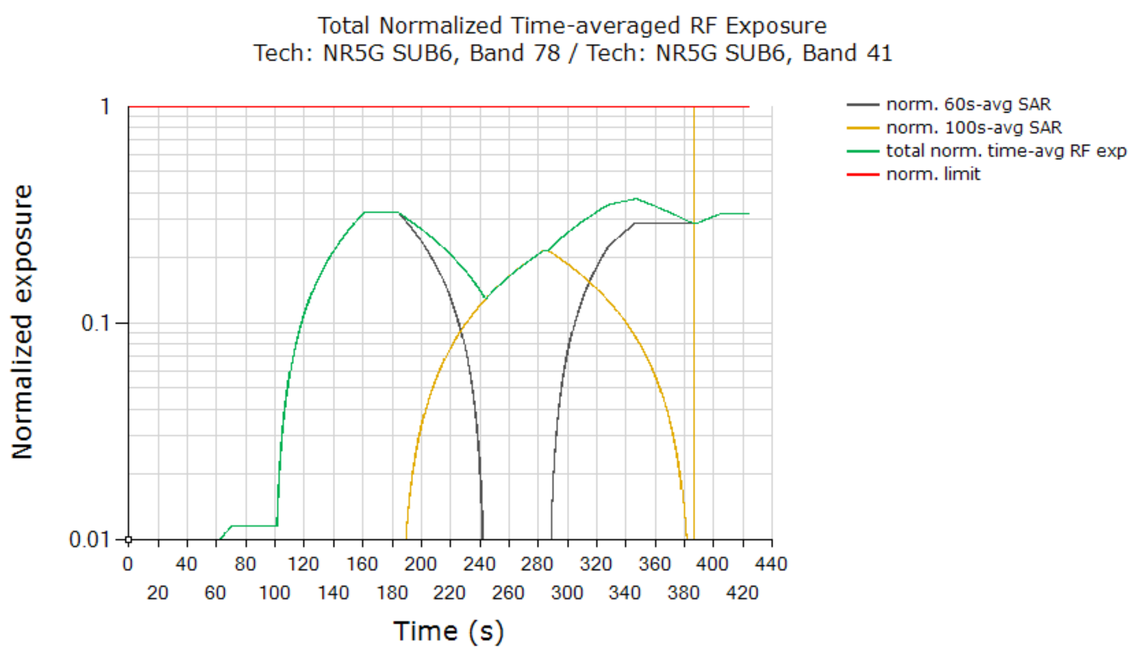
Plot 1: Measured Tx power (dBm) versus time shows that the transmitting power changed when NR N78 switches to NR N41 ((~185 seconds timestamp) and switches back to NR N78 (~290 seconds timestamp): switch measurement is performed with the EUT in various SAR exposure scenarios.



Plot Notes: The conducted power plot shows expected transitions in Tx power at ~245 seconds (60s-to-100s transition) and at ~290 seconds (100s-to-60s transition) in order to maintain total time-averaged RF exposure compliance across time windows, as show in next

Plot 2: All the conducted Tx power measurement results were converted into time-averaged normalized SAR values using Equation (7a), (7b) and (7c), and plotted below to demonstrate that the time-averaged normalized SAR versus time does not exceed the FCC limit of 1 unit. Equation (7a) is used to convert the Tx power of device to obtain 100saveragednormalized SAR in NR N41 as shown in black curve. Similarly, equation (7b) isused to obtain 60s-averaged normalized SAR in NR N78 as shown in orange curve.

Equation (7c) is used to obtain total time-averaged normalized SAR as shown in green curve (i.e., sum of black and orange curves)



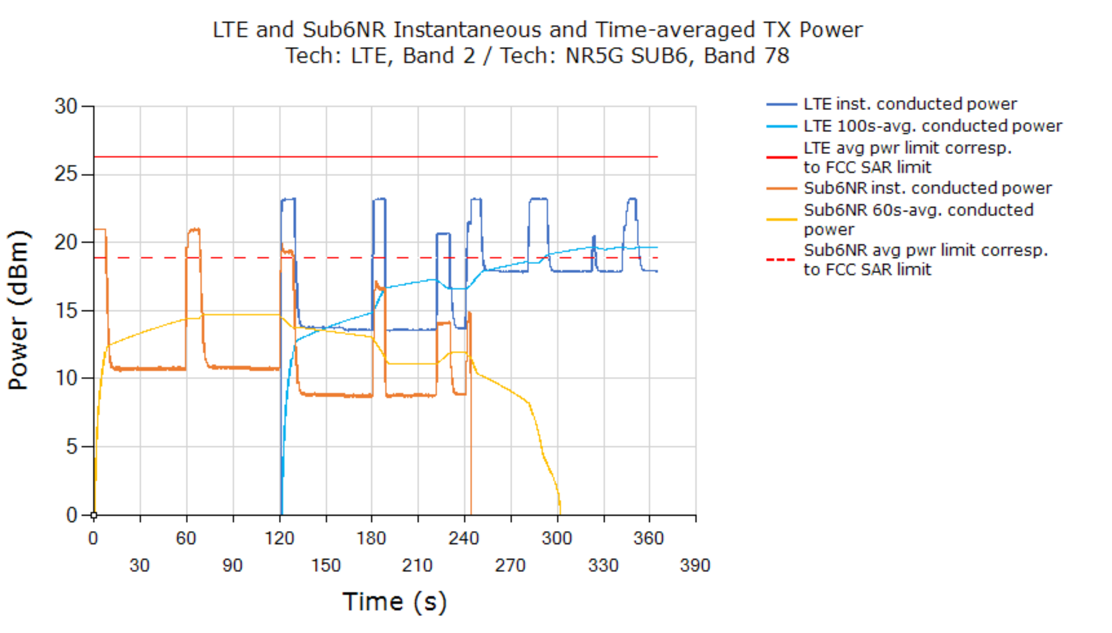
	Exposure Ratio
FCC normalized Exposure Ratio limit	1.0
Max time averaged normalized Exposure Ratio (green curve)	0.376
Validated	

Plot Notes:

Maximum power is requested by callbox for the entire duration of the test, with tech/band switches from 1 60s-to-100s window at ~185s time stamp, and from 100s-to-60s window at ~290s time stamp. Smart Transmit controls the Tx power during these time-window switches to ensure total time-averaged RF exposure, i.e., sum of black and orange curves given by equation (7c), is always compliant. In time-window switch test, at all times the total time averaged normalized RF exposure (green curve) should not exceed normalized SAR_design_target +1.49dB device uncertainty. In this test, with a maximum normalized SAR of 0.376 being ⩽ 0.440 (=0.5/1.6 +1.49dB 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)

This test was conducted with callbox requesting maximum power, and with the EUT in LTE Band 2 + Sub6 NR Band 78 call. The SAR exposure switch measurement is performed with the EUT in various SAR exposure scenarios.



Plot 2: All the conducted Tx power measurement results were converted into time-averaged normalized SAR values and plotted below to demonstrate that the time-averaged normalized SAR versus time does not exceed the limit of 1 unit. Equation is used to convert the LTE Tx power of device to obtain 100s-averaged normalized SAR in LTE B2 as shown in black curve. Similarly, equation is used to obtain 60s-averaged normalized SAR in Sub6 NR n78 as shown in orange curve. Equation is used to obtain total time-averaged normalized SAR as shown in green curve (i.e., sum of black and orange curves).

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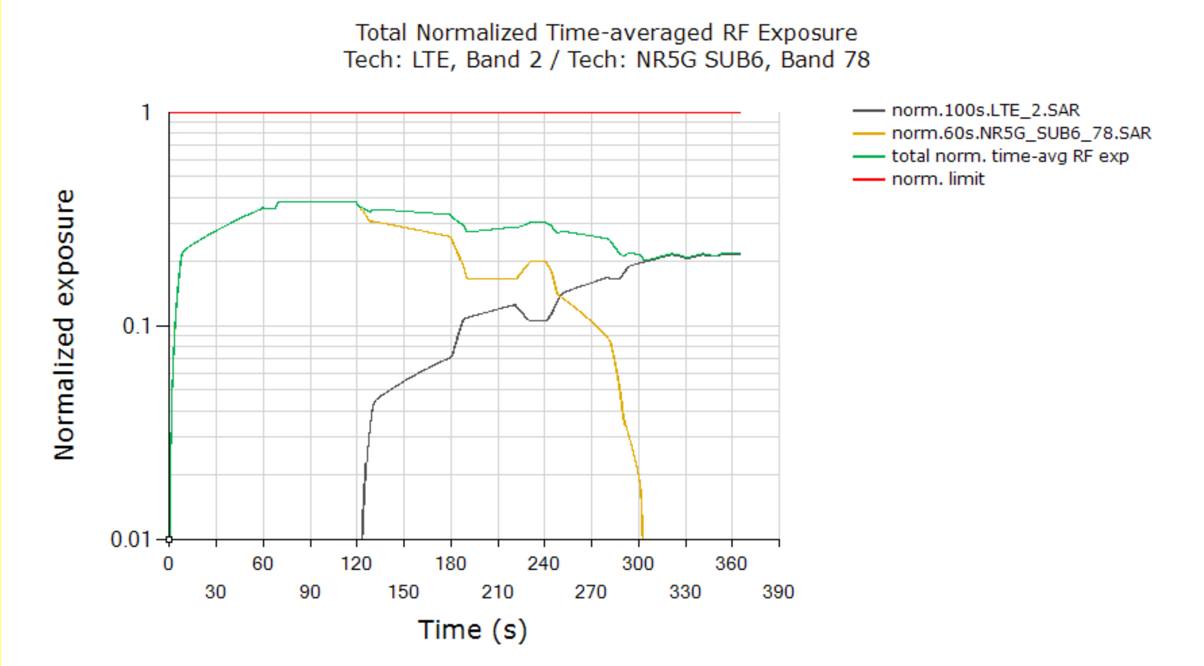


	Exposure Ratio
FCC normalized Exposure Ratio limit	1.0
Max time averaged normalized Exposure Ratio (green curve)	0.384
Validated	

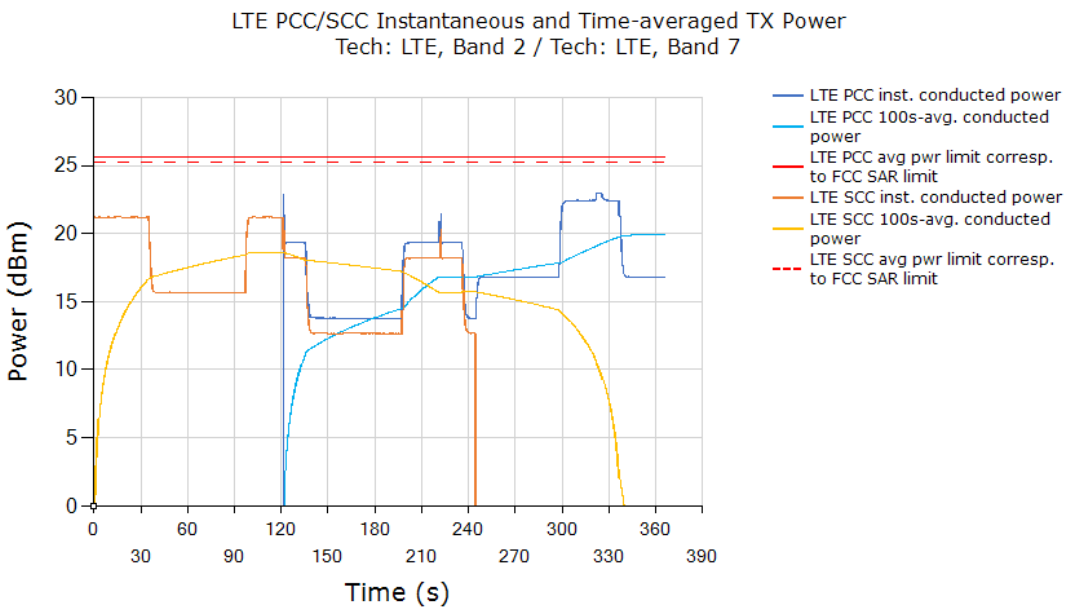
The above test result validated the continuity of power limiting in SAR exposure switch scenario.

Plot Notes:

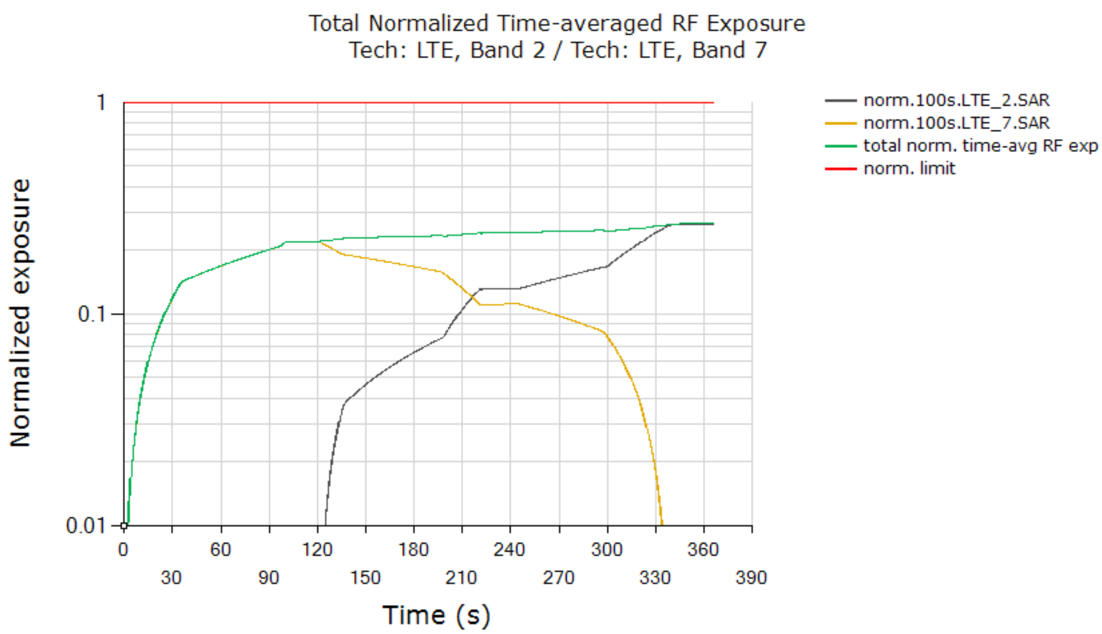
Device starts predominantly in 5G NR SAR exposure scenario between 0s and 120s, and in LTE SAR + 5G NR SAR exposure scenario between 120s and 240s, and in predominantly in LTE SAR exposure scenario after t=240s. Here, Smart Transmit allocates a maximum of 100% of exposure margin (based on reserve margin setting) for 5G NR. This corresponds to a normalized 1gSAR exposure value = 0.215 W/kg measured SAR at 5G NR Plimit / 1.6W/kg limit = 0.228+ “+1.49dB~ -1.49dB” device related uncertainty (see orange curve between 0s~120s). For predominantly LTE SAR exposure scenario, maximum normalized 1gSAR exposure should correspond to 100% exposure margin = 0.384W/kg measured SAR at LTE Plimit /1.6W/kg limit = 0.240+ “+1.49dB~ -1.49dB” device related uncertainty (see black curve after t = 240s). Additionally, in SAR exposure switch test, at all times the total time-averaged normalized RF exposure (green curve) should not exceed normalized SAR_design_target +1.49dB device uncertainty. In this test, with a maximum normalized SAR of 0.384 being ≤ 0.440 (=0.5/1.6 +1.49dB device uncertainty), the above test result validated the continuity of power limiting in SAR exposure switch scenario.

5.9 Switch in SAR exposure test results (LTE Inter-Band Uplink CA)

This test was conducted with callbox requesting maximum power, and with the EUT in LTE UL CA B2 + LTE UL CA B7 call. Following procedure detailed in Section 3.3.5 and Appendix C, and using the measurement setup shown in Figure 5-1, the SAR exposure switch measurement is performed with the EUT in various SAR exposure scenarios.



Plot 2: All the conducted Tx power measurement results were converted into time-averaged normalized SAR values using Equation (6a), (6b) and (6c), and plotted below to demonstrate that the time-averaged normalized SAR versus time does not exceed the FCC limit of 1 unit. Equation (6a) is used to convert the LTE Tx power of device to obtain 100s-averaged normalized SAR in LTE UL CA B2 PCC as shown in black curve. Similarly, equation (6b) is used to obtain 100s-averaged normalized SAR in LTE UL CA B7 SCC as shown in orange curve. Equation (6c) is used to obtain total time-averaged normalized SAR as shown in green curve (i.e., sum of black and orange curves).



	Exposure Ratio
FCC normalized Exposure Ratio limit	1.0
Max time averaged normalized Exposure Ratio (green curve)	0.267
Validated	

Plot Notes:

Device starts predominantly in SCC SAR exposure scenario between 0s and 120s, and in PCC SAR + SCC SAR exposure scenario between 120s and 240s, and in predominantly in PCC SAR exposure scenario after t=240s. Between 0s and 120s, PCC is at low power, however, SCC Tx power leakage (~30dB lower) due to filter/directional coupler characteristics in the measurement setup is shown as PCC power in the plot. Similarly, PCC leakage is shown as SCC power after t=240s. For predominantly PCC SAR exposure scenario, maximum normalized 1gSAR exposure should correspond to 100% exposure margin = 0.267 W/kg measured SAR at LTE Plimit / 1.6W/kg limit = 0.255 +1.49dB 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 + device uncertainty. In this test, with a maximum normalized SAR of 0.267 being ≤ 0.440 (=0.5/1.6 +1.49dB device uncertainty), the above test result validated the continuity of power limiting in SAR exposure switch scenario.

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

6.1 Measurement setup

The measurement setup in Figure 5-1 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 or cDASY8 system verification for SAR measurement is provided in Appendix D, and the associated SPEAG certificates are attached in Appendix E.

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 cDASY6/8 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 cDASY6/8 time-average pointSAR measurement by (100s or 60s / cDASY6/8_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 (listed in Table 5-2):

7. With *Reserve_power_margin* set to 0 dB, area scan is performed at P_{limit}, and time-averaged pointSAR measurements are conducted to determine the pointSAR at P_{limit} at peak location, denoted as *point*SAR$_{Plimit}$.
8. 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.

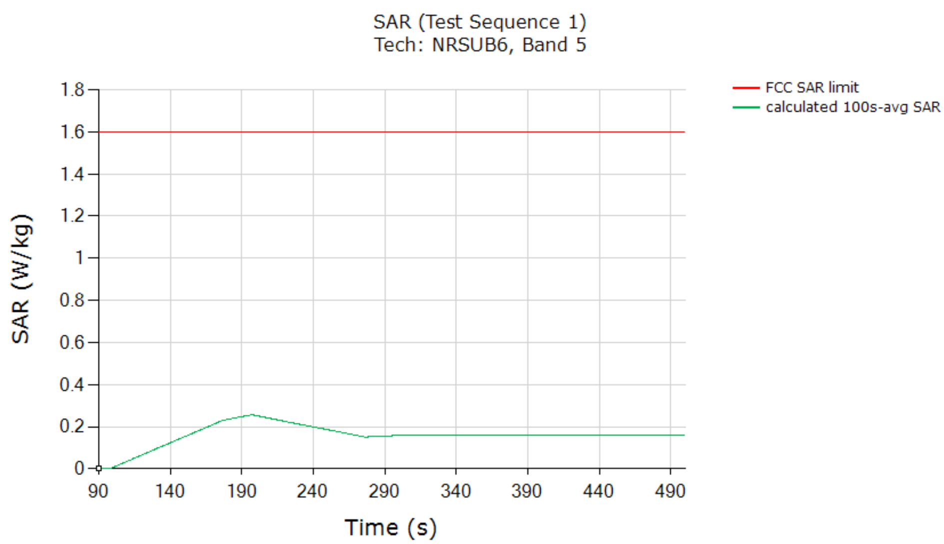
To demonstrate compliance, all the pointSAR measurement results were converted into 1gSAR or 10gSAR values by using Equation (3a), rewritten below:

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

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 measured 1gSAR or 10gSAR values at P_{limit} obtained from Part 1 report and listed in Table 4-2 in Section 4.1 of this report.

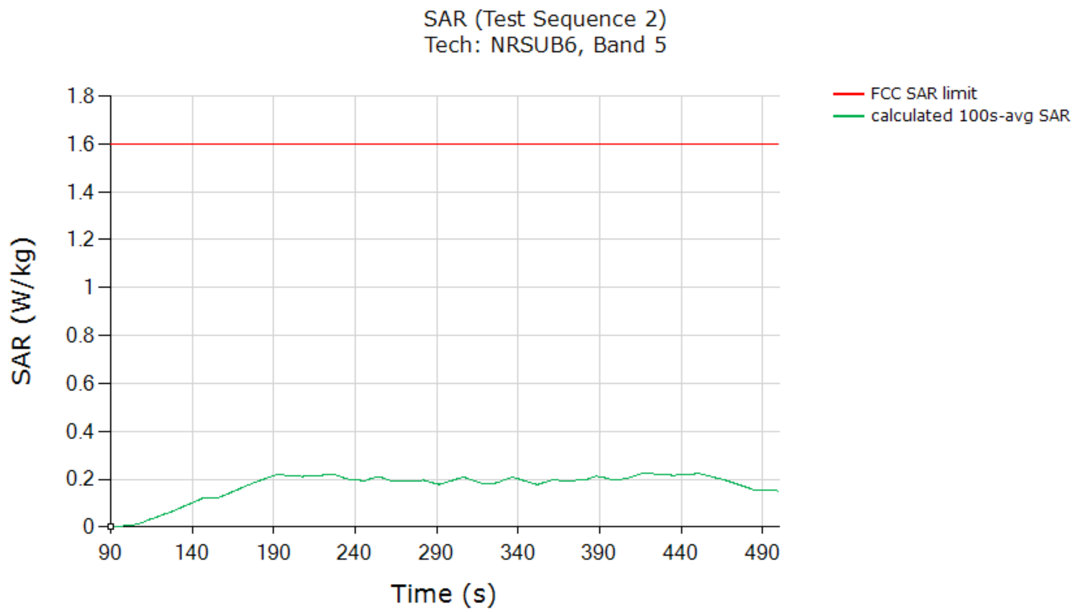
6.2.1 5G NR Band 5 NSA SAR test results

SAR test results for test sequence 1:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.256
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit + device uncertainty	

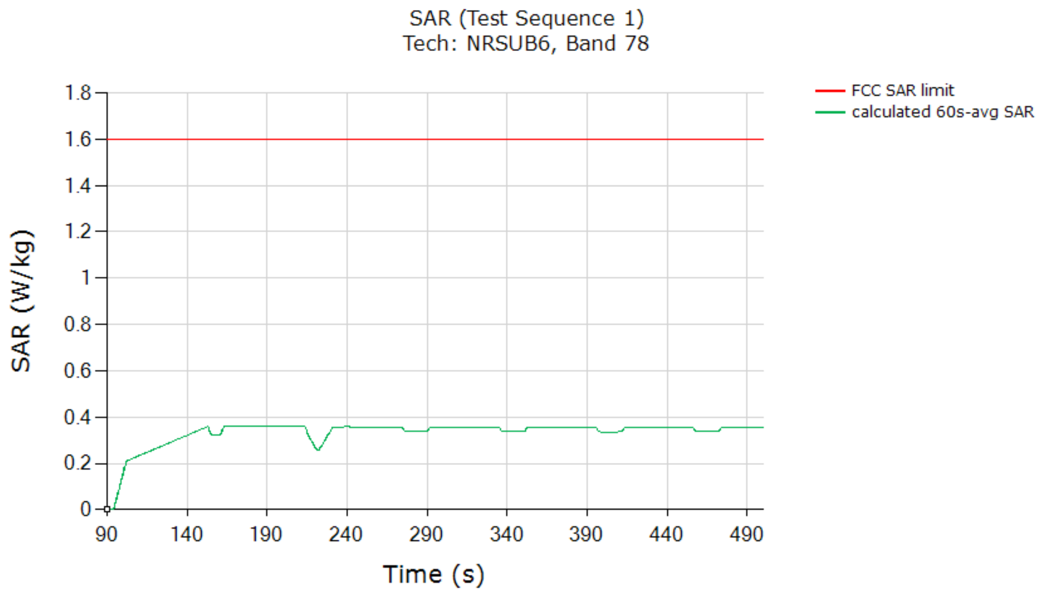
SAR test results for test sequence 2:



	(W/kg)
FCC 1gSAR limit	1.6
Max 100s-time averaged 1gSAR (green curve)	0.225
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit + device uncertainty	

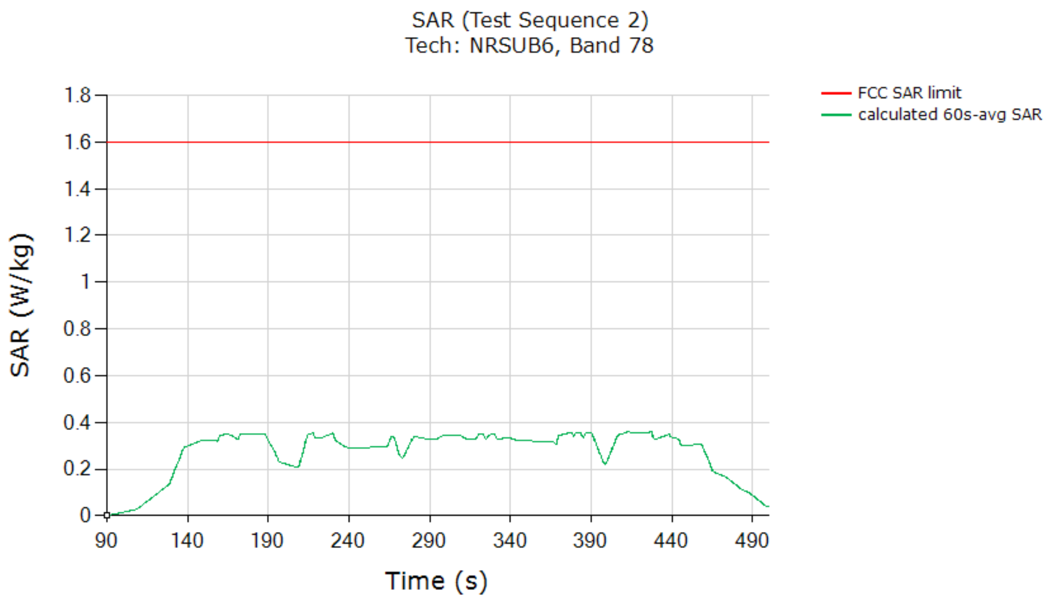
6.2.1 5G NR Band 78 NSA SAR test results

SAR test results for test sequence 1:



	(W/kg)
FCC 1gSAR limit	1.6
Max 60s-time averaged 1gSAR (green curve)	0.360
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit + device uncertainty	

SAR test results for test sequence 2:



	(W/kg)
FCC 1gSAR limit	1.6
Max 60s-time averaged 1gSAR (green curve)	0.360
Validated: Max time averaged SAR (green curve) does not exceed measured SAR at Plimit + 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. Test Sequences

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

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

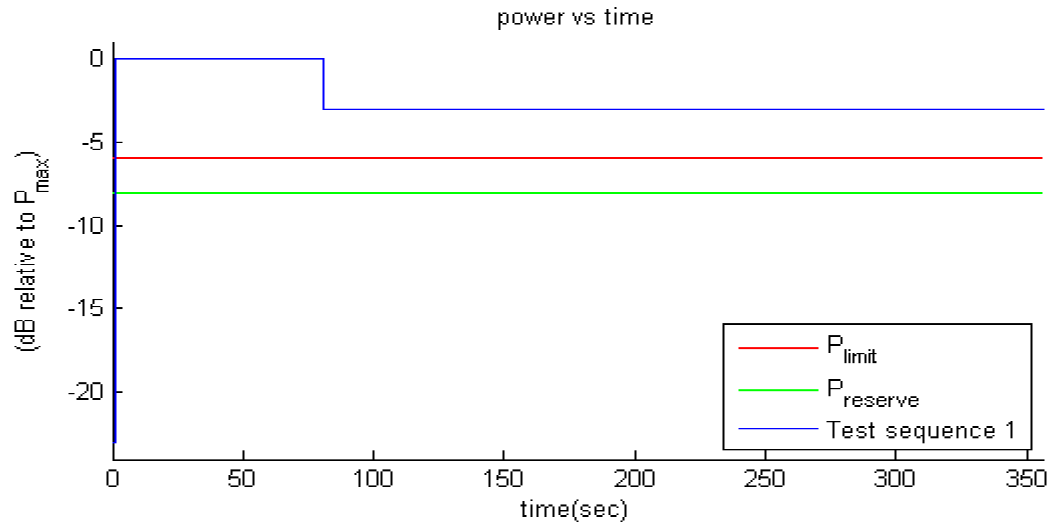


Figure 0-1 Test sequence 1 waveform

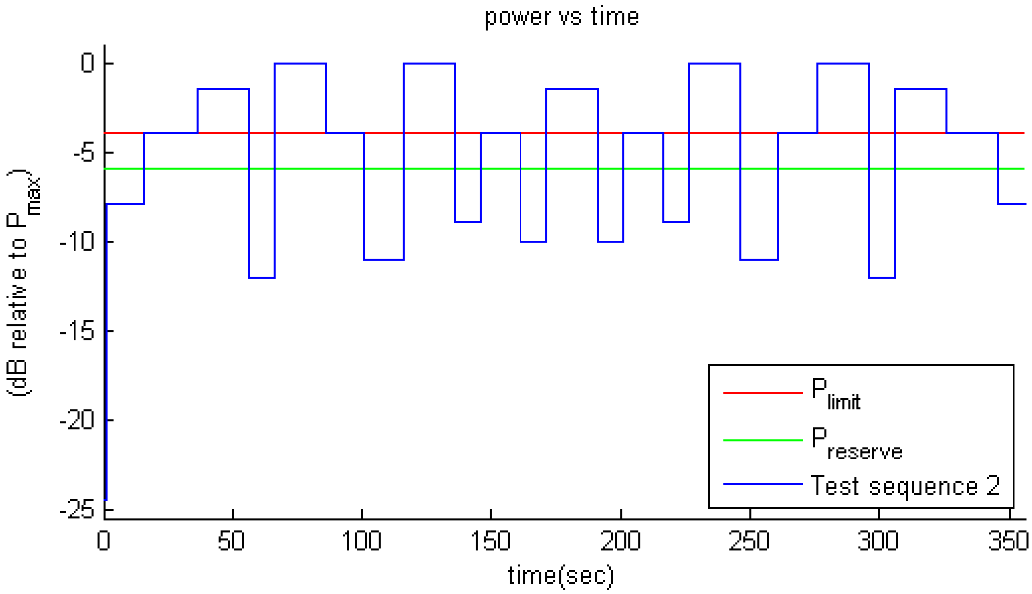
3. Test Sequence 2 Waveform:

Based on the parameters in A-1, the Test Sequence 2 is generated as described in Table 10-1, which contains two 170 second-long sequences (yellow and green highlighted rows) that are mirrored around the center row of 20s, resulting in a total duration of 360 seconds:

Table 0-1 Test Sequence 2

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

The Test Sequence 2 waveform is shown as below.



Appendix B. Test Procedures for 5G NR + LTE Radio

Appendix B provides the test procedures for validating Qualcomm Smart Transmit feature for LTE + 5G NR non-standalone (NSA) mode transmission scenario, where sub-6GHz LTE link acts as an anchor.

Time-varying Tx power test for 5G NR in NSA mode

Follows Section 3.2.1 to select test configurations for time-varying test. This test is performed with two pre-defined test sequences (described in Section 3.1) applied to 5G NR (with LTE on all-down bits or low power for the entire test after establishing the LTE+5G NR call with the callbox). Follow the test procedures described in Section 3.3.1 to demonstrate the effectiveness of power limiting enforcement and that the time averaged Tx power of 5G NR when converted into 1gSAR values does not exceed the regulatory limit at all times (see Eq. (1a) and (1b)). 5G NR response to test sequence1 and test sequence2 will be similar to other technologies (say, LTE), and are shown in Sections 6.3.7 and 6.3.8.

Switch in SAR exposure between LTE vs. 5G NR during transmission

This test is to demonstrate that Smart Transmit feature accurately accounts for switching in exposures among SAR for LTE radio only, SAR from both LTE radio and 5G NR, and SAR from 5G NR only scenarios, and ensures total time-averaged RF exposure compliance with FCC limit.

Test procedure:

1. Measure conducted Tx power corresponding to P_{limit} for LTE and 5G NR in selected band. Test condition to measure conducted P_{limit} is:
   - Establish device in call with the callbox for LTE in desired band. Measure conducted Tx power corresponding to LTE P_{limit} with Smart Transmit enabled and *Reserve_power_margin* set to 0 dB, callbox set to request maximum power.
   - Repeat above step to measure conducted Tx power corresponding to 5G NR P_{limit}. If testing LTE+5G NR in non-standalone mode, then establish LTE+5G NR call with callbox and request all down bits for radio1 LTE. In this scenario, with callbox requesting maximum power from 5G NR, measured conducted Tx power corresponds to radio2 P_{limit} (as radio1 LTE is at all-down bits)

2. Set *Reserve_power_margin* to actual (intended) value with EUT setup for LTE + 5G NR call. First, establish LTE connection in all-up bits with the callbox, and then 5G NR connection is added with callbox requesting UE to transmit at maximum power in 5G NR. As soon as the 5G NR connection is established, request all-down bits on LTE link (otherwise, 5G NR will not have sufficient RF exposure margin to sustain the call with LTE in all-up bits). Continue LTE (all-down bits)+5G NR transmission for more than one time-window duration to test predominantly 5G NR SAR exposure scenario (as SAR exposure is negligible from all-down bits in LTE). After at least one time-window, request LTE to go all-up bits to test LTE SAR and 5G NR SAR exposure scenario. After at least one more time-window, drop (or request all-down bits) 5G NR transmission to test predominantly LTE SAR exposure scenario. Continue the test for at least one more time-window. Record the conducted Tx powers for both LTE and 5G NR for the entire duration of this test.
3. Once the measurement is done, extract instantaneous Tx power versus time for both LTE and 5G NR links. Similar to technology/band switch test in Section 3.3.3, convert the conducted Tx power for both these radios into 1gSAR value (see Eq. (6a) and (6b)) using corresponding technology/band P_{limit} measured in Step 1, and then perform 100s running average to determine time-averaged 1gSAR versus time as illustrated in Figure 3-1.
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 (b) corresponding regulatory $1gSAR_{limit}$ of 1.6W/kg.

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

Appendix C. Test Procedures for inter-band UL CA

Appendix C provides the test procedures for validating Qualcomm Smart Transmit feature for Switch in SAR exposure between PCC vs. SCC during inter-band ULCA transmission mode transmission scenario.

Switch in SAR exposure between PCC vs. SCC during inter-band ULCA transmission

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

Test procedure:

1. Measure *Plimit* for PCC and SCC in selected band. Test condition to measure conducted *Plimit* is:
   □ Establish a LTE call with single active Tx in desired PCC band. Measure conducted Tx power corresponding to LTE *Plimit* with Smart Transmit enabled and *Reserve_power_margin* set to 0 dB, callbox set to request maximum power.
   □ Repeat above step to measure *Plimit* corresponding to LTE SCC band under single active Tx scenario.

2. Set Reserve_power_margin to actual (intended) value, with EUT setup for interband ULCA call. First, establish interband ULCA connection with the callbox, and as soon as the connection is established, request all-down bits (or low power) on PCC link and then request UE to transmit at maximum power in SCC link. Continue PCC (all-down bits)+SCC transmission for more than one time-window duration to test predominantly SCC SAR exposure scenario (as SAR exposure from PCC is negligible from all-down bits). After at least one time-window, request PCC to go all-up bits to test PCC SAR and SCC SAR exposure scenario. After at least one more time-window, drop (or request all-down bits) SCC transmission to test predominantly PCC SAR exposure scenario. Continue the test for at least one more time-window. Record the conducted Tx powers for both PCC and SCC for the entire duration of this test.

3. Once the measurement is done, extract instantaneous Tx power versus time for both PCC and SCC links. Similar to technology/band switch test in Section 3.3.3, convert the conducted Tx power for both these radios into 1g_or_10gSAR value (see Eq. (6a) and (6b)) using corresponding technology/band *Plimit* measured in Step 1, and then perform 100s running average to determine time-averaged 1g_or_10gSAR versus time as illustrated in Figure 5-1. Note that here it is assumed both radios have Tx frequencies < 3GHz, otherwise, 60s running average should be performed for radios having Tx frequency between 3GHz and 6GHz.

4. Make one plot containing: (a) instantaneous 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 1g_or_10gSARlimit limit.
   The validation criteria is, at all times, the time-averaged 1g_or_10gSAR versus time shall not exceed the regulatory 1g_or_10gSARlimit limit.

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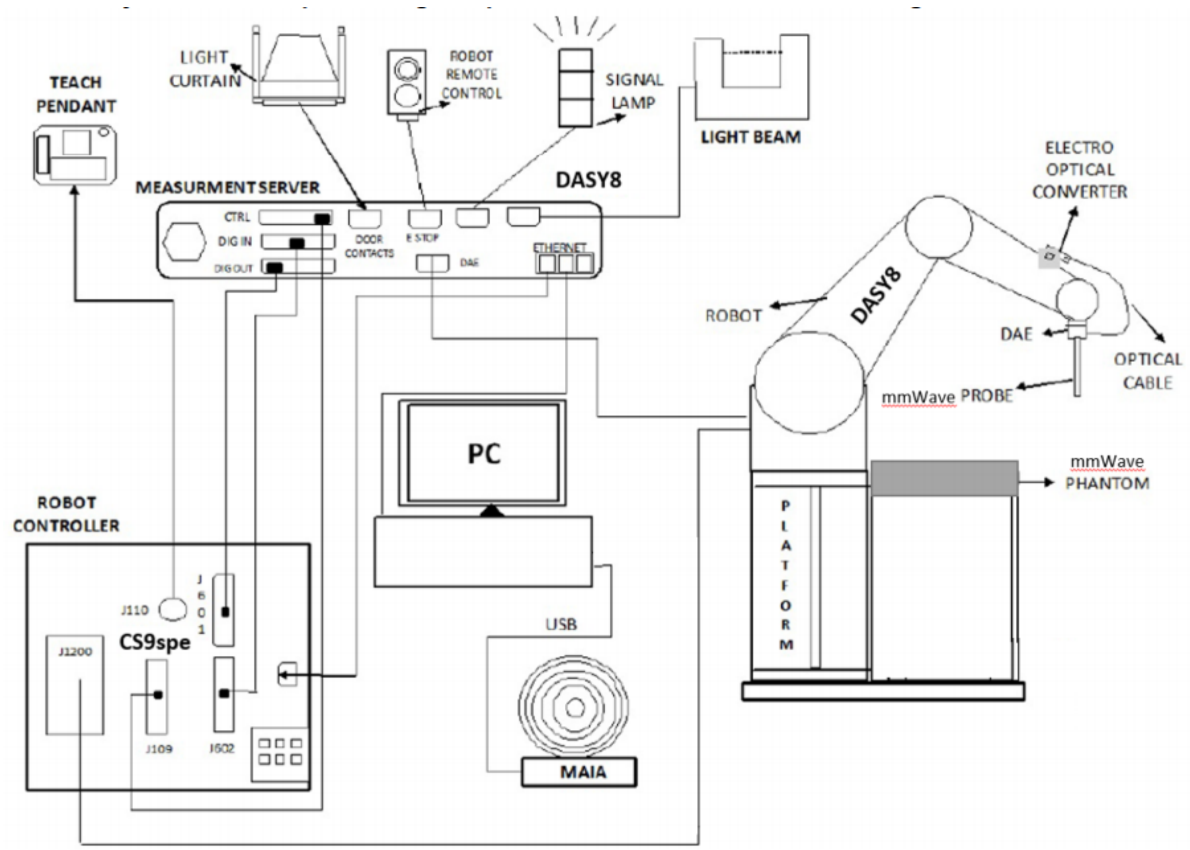
Appendix D. cDASY8 System Verification

1 The system to be used for SAR measurement

- SPEAG DASY8 system



2 Test Equipment List

Test Platform		SPEAG DASY Professional				
Description		SAR Test System				
Software Reference		cDASY8 V16.2.4.2524				
Hardware Reference						
Equipment		Manufacturer	Model	Serial Number	Calibration Date	Due date of calibration
☒	Twin Phantom	SPEAG	SAM V8.0	2256	NCR	NCR
☒	DAE	SPEAG	DAE4ip	1830	2023/09/12	2024/09/11
☒	E-Field Probe	SPEAG	EX3DV4	7838	2023/09/11	2024/09/10
☒	Validation Kits	SPEAG	D835V2	4d105	2022/11/02	2025/11/01
☒	Validation Kits	SPEAG	D3700V2	1046	2022/09/15	2025/09/14
☒	Dielectric parameter probes	SPEAG	DAKS-3.5	0005	2023/06/15	2024/06/14
☒	Vector Network Analyzer and Vector Reflectometer	SPEAG	DAKS_VNA R140	0140913	2023/06/07	2024/06/06
☒	Universal Radio Communication Tester	R&S	CMW500	171428	2023/05/11	2024/05/10
☒	UXM Wireless Test Platform	Keysight	E7515B	MY59150869	2023/09/14	2024/09/13
☒	Power Sensor	R&S	NRP8S	104926	2022/12/22	2023/12/21
☒	Power Sensor	R&S	NRP8S	105296	2022/12/22	2023/12/21
☒	RF Coupler	Narda	4216-10	01703	NCR	NCR
☒	RF Coupler	Narda	4216-10	01442	NCR	NCR
☒	RF Bi-Directional Coupler	Agilent	86205-60001	MY31400031	NCR	NCR
☒	Signal Generator	Agilent	N5171B	MY53050736	2023/02/16	2024/02/15
☒	Preamplifier	Mini-Circuits	ZHL-42W	15542	NCR	NCR
☒	Preamplifier	Compliance Directions Systems Inc.	AMP28-3W	073501433	NCR	NCR
☒	Power Meter	Agilent	E4416A	GB41292095	2023/02/16	2024/02/15
☒	Power Sensor	Agilent	8481H	MY41091234	2023/02/16	2024/02/15
☒	Power Sensor	R&S	NRP-Z92	100025	2023/02/16	2024/02/15
☒	Attenuator	SHX	TS2-3dB	30704	NCR	NCR
☒	Speed reading thermometer	MingGao	T809	NA	2022/06/07	2023/06/06
☒	Humidity and Temperature Indicator	CHIGAO	HTC-1	ZGL2020120550471	2022/07/06	2023/07/05
☒	Humidity and Temperature Indicator	CHIGAO	HTC-1	ZGL2020120550472	2022/07/06	2023/07/05

Note: All the equipment are within the valid period when the tests are performed.

3 SAR system verification and validation

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.

The composition of the brain tissue simulating liquid is:

Broad-band head tissue simulating liquids	SPEAG Product	Frequency range (MHz)	Main Ingredients
	HBBL600-10000V6	600 - 10000	Water, Oil

<Tissue Check Results>

Measurement for Tissue Simulate Liquid									
Tissue Type	Measured Frequency （MHz）	Target Tissue (±5%)		Measured Tissue		Deviation (Within ±5%)		Liquid Temp. (℃)	Test Date
		ε_r	σ(S/m)	ε_r	σ(S/m)	ε_r	σ(S/m)		
835 Head	835	42.310	0.936	41.50	0.90	1.95%	4.00%	22.1	2023/11/29
3700 Head	3700	38.900	2.98	37.70	3.12	3.18%	-4.49%	22.3	2023/12/1

System Verification

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 Part2 Appendix D.

<System Verification Results>

Validation Kit		Measured SAR 250mW	Measured SAR 250mW	Measured SAR (normalized to 1W)	Measured SAR (normalized to 1W)	Target SAR (normalized to 1W)	Target SAR (normalized to 1W)	Deviation (Within ±10%)		Liquid Temp. (℃)	Test Date
		1g (W/kg)	10g (W/kg)	1g (W/kg)	10g (W/kg)	1-g(W/kg)	10-g(W/kg)	1-g(W/kg)	10-g(W/kg)		
D835V2	Head	2.50	1.66	10.00	6.64	9.53	6.29	4.93%	5.56%	22.1	2023/11/29
Validation Kit		Measured SAR 100mW	Measured SAR 100mW	Measured SAR (normalized to 1W)	Measured SAR (normalized to 1W)	Target SAR (normalized to 1W)	Target SAR (normalized to 1W)	Deviation (Within ±10%)		Liquid Temp. (℃)	Test Date
		1g (W/kg)	10g (W/kg)	1g (W/kg)	10g (W/kg)	1-g(W/kg)	10-g(W/kg)	1-g(W/kg)	10-g(W/kg)		
D3700V2	Head(3.7GHz)	6.12	2.29	61.20	22.90	66.10	24.70	-7.41%	-7.29%	22.3	2023/12/1

Appendix E. Calibration certificate

Please see the Part2 Appendix E.

---END---